MANUAL FOR INTEGRATED PROJECTS FOR RURAL GROUNDWATER SUPPLIES

LOW-COST GROUNDWATER DEVELOPMENT

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This Manual has been prepared so that Malawian professional staff can effectively and economically provide domestic water supplies to the large number of Malawi rural villages that depend on groundwater. This Manual is distributed at the seminar so that other countries may benefit from significant advances in rural groundwater development which have taken place in Malawi over the past two years with the assistance of the United Kingdom Government and United Nations Development Programme. The Manual is based on work carried out by staff of the Department of Lands, Valuation and Water in co-operation with staff of the UKODA and UNDTCD and the participation of Malawi's industrial sector.

This Manual will be updated as the procedures and designs are further refined by technical improvements which will reduce the overall costs of groundwater supply systems for rural villages. These updatings will be made available on request to all interested African Governments.

A MALAWIAN PROGRAMME TO PROMOTE THE OBJECTIVES OF THE
INTERNATIONAL DRINKINGWATER SUPPLY AND SANITATION DECADE

1981-1990

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FOREWORD

"Pure drinking water is the greatest gift that man can give to man". This old saying is as relevant today as it was a thousand years ago. In fact, well over half the world's population still does not have access to pure drinking water. The United Nations, in one of its most human decisions, established the International Drinking Water Supply and Sanitation Decade in which nations have agreed to initiate programmes and co-operate with other nations during the 1980s to bring pure drinking water within reach of all the people of our world.

Malawi has, for the past fifteen years, been active in providing pure drinking water to its rural people through its internationally known gravity fed piped-water schemes which utilize the water flowing all the year round from its mountains. Her latest programme in developing low-cost boreholes and wells for obtaining drinking water from groundwater is another noteworthy effort. By learning from past experience with about 5,000 installed bore-holes, by introducing improvements and new ideas and making local approaches to village communities a number of significant breakthroughs have been achieved and a new system of groundwater supplies has been developed for Malawi. This Manual outlines this system in all its stages of implementation and operation.

This Manual and the system it describes has only been possible through the dedication of the Malawi Government and its officials in the Department of Lands, Valuation and Water and the motivated co-operation of many expatriates supported by the Overseas Development Administration of the United Kingdom and by the United Nations Development System. The authors of this Manual, David Grey, John Chilton and Amanda Smith-Carington deserve special mention for their tremendous effort in preparing such a comprehensive Manual in so short a time. Many others, too numerous to mention in this foreword, have given valuable assistance. The work of all these people has clearly been a

labour of love as they see the future implications and long term rewards of carefully planned projects to abstract water from the land on which they live. The Maoris of New Zealand have a saying which describes the land as a mother that never dies. The land provides us with life by her resources of food and water and materials for shelter, but like all mothers, the land must be respected. We must protect her soils and conserve her water resources and use them wisely if we are to have these gifts available for our children and for all future children.

This Malawi Manual will assist in the planning, construction, operation and long term maintenance of groundwater drinking water supplies in any country where groundwater can be obtained by handpumps. This document joins many other valuable contributions to the drinking water Decade activities and if it assists in promoting the accelerated development of groundwater for community water supplies during the remainder of the Decade, as we anticipate that it will, then Malawi's contribution will not have been a small one.

R.A. Borthwick
RESIDENT REPRESENTATIVE

29.11.82

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Danish International Development Agency

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United Nations Children's Fund

COMMONLY USED ABBREVIATIONS

ADD	Agricultural Development Division
CA	Consumer Association
CADO	Chief Agricultural Development Officer
CATR	Consumer Association Testing and Research
CSCU	Central Services Construction Unit
CTO	Chief Technical Officer
DANIDA	Danish International Development Agency
DC	District Commissioner
DDC	District Development Committee
DHI	District Health Inspector
DLVW	Department of Lands, Valuation and Water
DO	Development Officer
DRIMP	District Roads Improvement Project
EA	Enumeration Area
EC	Electrical Conductivity
EPA	Extension Planning Area
EPD	Economic Planning Division
HQ	Headquarters
HPWL	Handpumping water level
IDWSSD	International Drinking Water Supply and Sanitation Decade
IFAD	International Fund for Agricultural Development
ID	Internal diameter
KADD	Kasungu Agricultural Development Division
LADD	Lilongwe Agricultural Development Division
MANR	Ministry of Agriculture and Natural Resources
MCP	Malawi Congress Party
MP	Member of Parliament
NRDP	National Rural Development Project
NSO	National Statistical Office
NWRMP	National Water Resources Master Plan
OD	Outside diameter
ODA	Overseas Development Administration
OPC	Office of the President and Cabinet
PO	Professional Officer
PWL	Pumping Water Level

RDP	Rural Development Project
S	Storage Coefficient
Se	Elastic Storage coefficient
Sr	Specific retention
STA	Senior Technical Assistant
STO	Senior Technical Officer
Sy	Specific yield
TA	Technical Assistant
TO	Technical Officer
UN	United Nations
UNDP	United Nations Development Programme
UNDTCD	United Nations Department of Technical Cooperation for Development
UNICEF	United Nations Childrens Fund
UNV	United Nations Volunteer
WB	World Bank

A MANUAL FOR INTEGRATED PROJECTS FOR RURAL GROUNDWATER SUPPLIES

CHAPTERS

CHAPTER A

INTRODUCTION

CHAPTER A

INTRODUCTION

CONTENTS

1. BACKGROUND

1.1. There are more than 1,500 million people in developing countries who do not have access to adequate water supply and sanitation facilities; 80% of these people are living in rural areas. The incidence of illness and death due to water-related diseases is commonly much higher in rural than urban areas, and a major contributory factor to this is unprotected drinking water supplies. Access to potable water is one of the basic needs which is important for health, productivity and quality of life. Recognising the importance of providing safe drinking water and improved sanitation, the 1980s have been declared by the United Nations Assembly to be the International Drinking Water Supply and Sanitation Decade (IDWSSD), with an ambitious target of providing adequate domestic water and basic sanitation facilities to the population of the world.

1.2. The Malawi Government has adopted the goal of the IDWSSD. The 1977 census showed a population of 5.5 million of whom 5 million were living in rural areas. Of these, 1.26 million professed to have access to protected water supplies although there may be long walking distances involved. These protected sources were predominantly either boreholes (0.82 million served) or gravity-fed piped-water (0.44 million served); the number of protected dug wells was small in 1977 although the programme has since expanded considerably. The remaining 76% of the rural population (3.8 million) used "other sources" (unprotected wells and streams).

1.3. The probable 1990 population of Malawi is likely to exceed eight million people with over seven million living in rural areas. The existing protected rural water supplies (1982) are estimated as follows:

a) 5,000 boreholes serving approximately 1,250,000 people

b) 2,000 protected dug wells serving approximately 250,000 people

c) piped-water schemes serving approximately 700,000 people.

1.4. Malawi is widely reported to have made exceptional progress in the provision of safe water supplies, largely as a result of the successful programme of run-of-river piped-water schemes. At present, additional schemes are planned bringing the design capacity to about one million people; this is based on the estimated 1990 population or the "agricultural carrying capacity of the land" whichever is the greater. The schemes are designed to abstract the five year low-flows from the river intakes at maximum. Schemes used to full capacity cannot be augmented without the addition of further pipe network and possibly the identification of a new source. Any further piped-water schemes are likely to require the construction of dams (to ensure dry season supplies) and/or treatment works (because of the danger of source pollution), which will greatly increase both capital and recurrent costs. It is unlikely that piped-water schemes can serve more than 25% of the rural population.

1.5. There are no other cost-comparable rural water supply options except for groundwater in most other areas. It is clear, therefore, that groundwater supplies (boreholes, dug wells and protected springs) are required to serve about 75% of the rural population of Malawi (an estimated 5.5 million people in 1990). If rural water supply targets are to be met there is a need for intensive and greatly accelerated use of groundwater resources. Adequate yields of suitable quality for domestic supplies are available over large areas of Malawi [see Section 2] and much effort has been devoted to a careful review of groundwater development techniques [see Section 4].

1.6. Those relatively small areas which cannot be served either by run-of-river piped-water, or groundwater (perhaps because of unsuitable water quality or unreliable yield) will need to be served by other surface-water options which are likely to require expensive treatment works and/or other surface works.

2. GROUNDWATER IN MALAWI

2.1. The importance of groundwater is clear from the preceding section; it is therefore necessary to have an understanding of the occurence of groundwater and its development potential for rural domestic supplies. This section gives a summary of hydrogeological conditions in Malawi; for a fuller discussion the hydrogeological maps and report for the National Water Resources Master Plan and the Geological Survey Department Bulletins should be consulted.

2.2. PHYSIOGRAPHY

2.2.1. The occurence of groundwater in Malawi is controlled largely by topography, thus a brief description of the major physiographic divisions is given. Figure A.1.1 shows the four main zones:

a) plateau areas

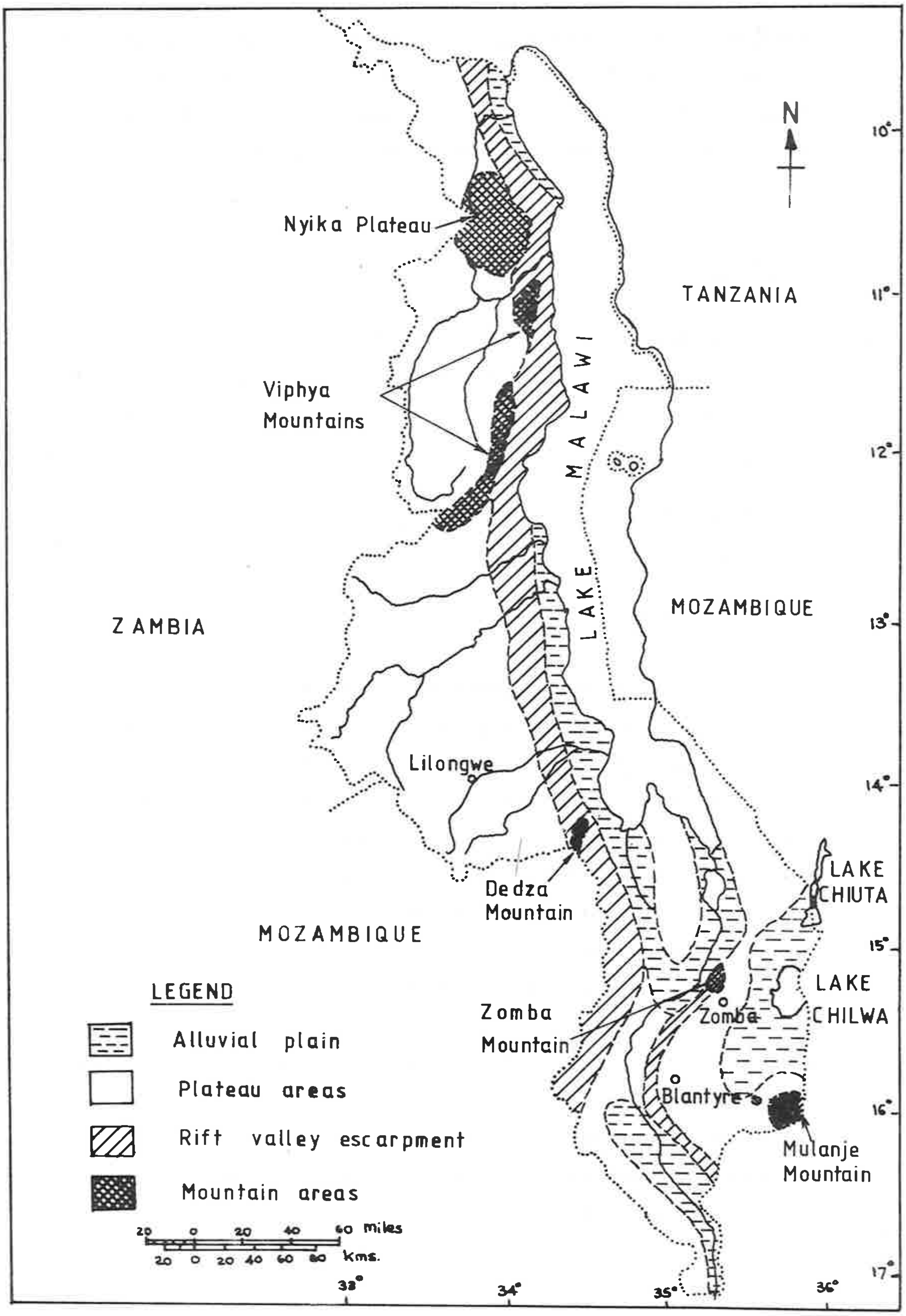
b) upland areas

c) Rift Valley escarpment

d) alluvial plains

2.2.2. *The plateau areas* are extensively peneplained gently undulating surfaces with broad valleys and large level areas on the interfluves. They are ancient erosion surfaces (the African Surface) of late Cretaceous to Miocene age , which slope away from the escarpment zones as a result of uplift along the Rift Valley System, but the drainage systems have kept pace with these earth movements and largely drain towards the Rift Valley. As a consequence the valleys become more incised towards the escarpment. The plateau areas are drained largely by "dambos" which are broad, grass-covered swampy valleys that are liable to flooding and commonly have no well-defined channels. The plateau areas are largely covered by a thick mantle of saprolite derived by prolonged in-situ weathering of the underlying strata; it is this which forms an extensive and important aquifer which is low-yielding but generally adequate for domestic water supplies.

Figure: A.1.1. MAJOR PHYSICAL FEATURES OF MALAWI



2.2.3. There are several *mountain areas and smaller uplands* rising abruptly from the plateau where the underlying strata are more resistant to erosion. These represent remnants of the post-Gondwana erosion surface of Jurassic-Cretaceous age. Slopes are steep and often very disected and there is little potential for groundwater supplies, except very locally.

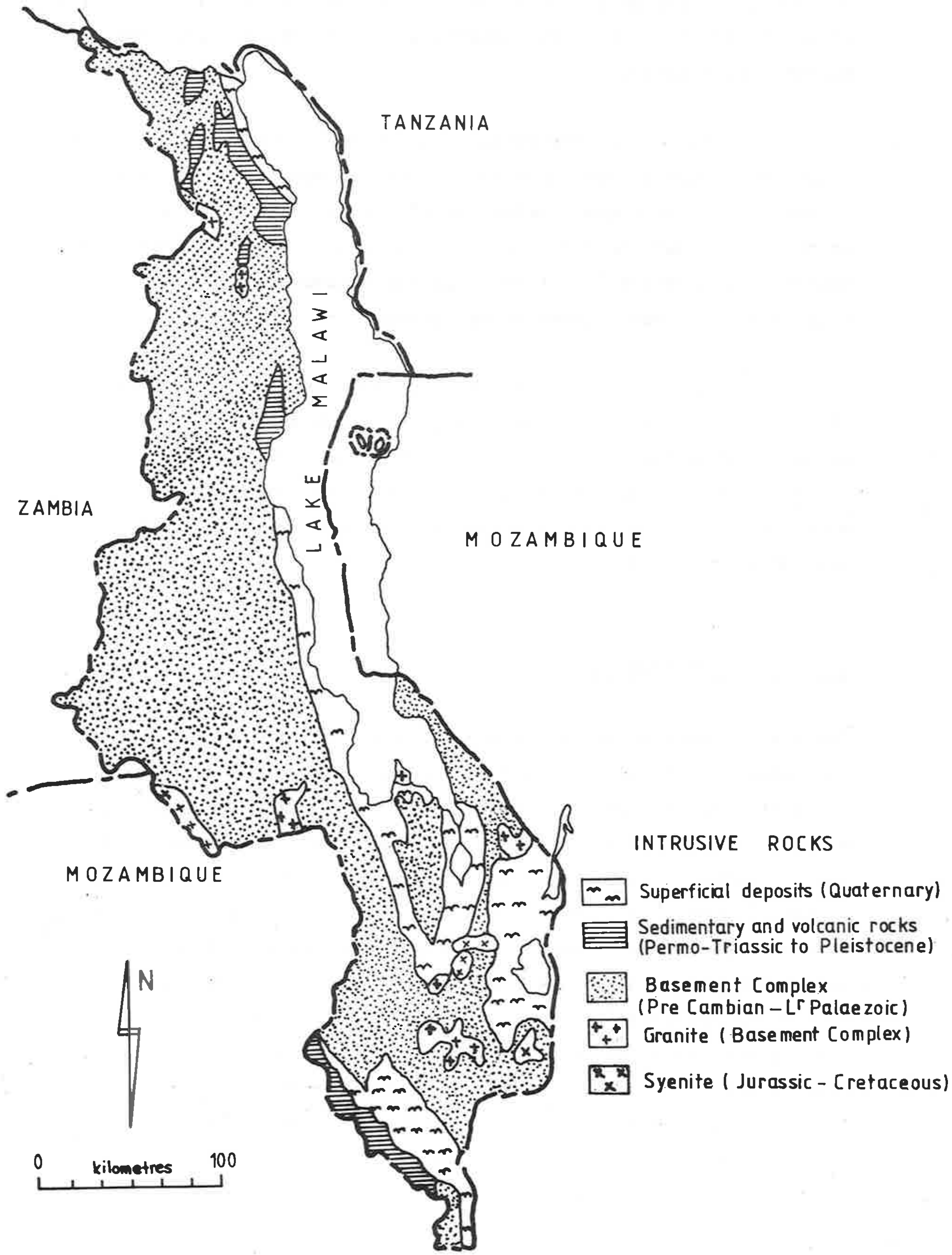
2.2.4. *The Rift Valley escarpment* falls steeply from the plateau areas and slopes are commonly very disected. There is considerable faulting in association with the development of the Malawi Rift Valley system which is the southern end of one limb of the East Africa Rift Valley system. Again there is little scope for groundwater development in these areas of steep slopes except perhaps very locally.

2.2.5. *The alluvial plains* of the Rift Valley floor are gently sloping and of very low relief. They extend along the lakeshores around Lakes Malawi, Chilwa and Chiuta, and along the Shire River Valley which is the only outlet from Lake Malawi. These areas have considerable potential for groundwater development wherever suitable sedimentary sequences are found.

2.3. GEOLOGY AND HYDROGEOLOGY

2.3.1. The greater part of Malawi is underlain by crystalline metamorphic and igneous rocks of Pre-Cambrian to Lower Palaeozoic age referred to as the Malawi Basement Complex [Figure A.1.2]. These consist of varying types of schist, gneiss and granulite, which have in parts been intruded by syenite and granite, and in addition (particularly in southern Malawi) disected by dolerite dykes. Over most of the plateau areas, except towards the escarpment edges, the bedrock is deeply weathered, and it is this saprolitic material (commonly 15 - 30 m thick but locally over 30 m) which forms the principle aquifer. Towards the crests of the escarpment the uplift associated with the development of the Rift Valley has resulted in rejuvenation of the rivers and increased erosion, and thus the thickness of the weathered rock is reduced.

Figure: A. 1.1.2. GEOLOGY



2.3.2. In detail the character of the weathered zone varies with parent rock type and texture, fracture patterns and topography; there can be considerable spatial heterogeneity even over short distances and the more permeable horizons may have only limited lateral extent. The coarser grained parent materials give rise to the best aquifers as they decompose to a more sandy texture. Considering a generalised weathered rock profile, the degree of alteration and unconsolidation progressively increases from the fresh unweathered bedrock upwards. Above the hard bedrock there is a zone of broken and hydrated rock where the surfaces are chemically weathered but the centres of the blocks remain fresh and unweathered. This grades into a zone of crumbling decomposed bedrock often of sandy or gravelly texture which retains the original structure; these lower layers usually have the highest permeability and effective porosity. Above there are pale brown or buff sandy clays or clayey sands often with small quartz fragments. This whole sequence makes up the aquifer and is commonly 10 - 25 m thick. The aquifer is then semi-confined by an overlying thickness of compacted clays and latosols at the surface (generally 15 - 20 m thick). Groundwater is struck at the base of the clays and usually rises (sometimes by several metres) before its rest water level is found. Rest water levels vary from surface to 30 m or more below ground level, but are most commonly in the range of 5 - 15 m. The yields required for rural domestic water supplies are low (0.25 - 0.5 l/sec) and it is thought that these can be sustained over most of the plateau area from the relatively thin but extensive aquifer.

2.3.3. The fresh bedrock underlying the weathered zone is rarely a significant aquifer, even where fractured, as the available storage is negligible in the rock matrix and very low in the fractures. Although there are many old boreholes which have been drilled to considerable depths into fresh bedrock (often reaching 50 - 70 m) these will rely on storage in the overlying weathered zone.

2.3.4. Where the rocks are more resistant to erosion they remain as uplands or inselbergs. The weathered zone is thin, and there is little potential for groundwater except very locally where boreholes intersect a well-connected fracture system, however yields are likely to be unreliable because of the low storage.

2.3.5. On the escarpment areas the weathering products have been largely stripped away by erosion and, as in the uplands described above the bedrock is close to the surface. Aquifers are poor and discontinuous.

2.3.6. In relatively small areas of the north and south of the country, the Basement Complex rocks are overlain unconformably by isolated tracts of sedimentary and volcanic rocks of Permo-Trassic age (Karoo series). The sedimentary succession comprises a variable sequence of basal conglomerates overlain by sandstones, grits, siltstones and mudstones interbedded with coal seams in places. They are mostly well cemented resulting in relatively low porosities, but there may be locally some scope for groundwater development particularly where the rocks are well fractured. There are also isolated outcrops of Cretaceous - Pleistocene sediments which are of very limited area.

2.3.7. In the Rift Valley large parts of the lakeshore areas and Shire River Valley are covered by Quaternary alluvial deposits comprising an unconsolidated and variable sequence of sands, silts and clays. The thickness of these deposits is defined largely by the undulations of the unconformity surface beneath. In general they appear to thicken towards the centre of the Rift Valley. Along the lakeshore itself, the alluvium comprises lacustrine sands and/or clays interbedded with fluvial deposits. The alluvial deposits form very important aquifers wherever a sufficient thickness of sands is found in the sequence (although these appear to be limited in both lateral and vertical extent) and adequate yields for irrigation have been produced from boreholes. However a yield of only 0.5 l/sec is required for rural domestic water supplies, and this is likely to be sustained over most of the alluvial plains even where there are only relatively fine-grained horizons. Rest water levels are commonly relatively close to the surface (less than 20 m).

2.3.8. It is clear from the preceding discussions that the principle aquifers most likely to be developed for domestic rural water supplies are those of the weathered basement of the plateau areas and the alluvial deposits of the Rift Valley plains, which potentially will have adequate yields over wide areas. In both cases the abstraction required for rural domestic supplies are likely to be a small

fraction of the annual recharge to groundwater and thus there is no danger of depletion of replenishable resources.

2.4. GROUNDWATER QUALITY

The quality of groundwater on a national scale is generally acceptable for drinking and domestic use [see Chapter D], but with some problem areas. The plateau areas are typified by usually low mineralisation but with locally high concentrations of sulphate (related to reactions with certain minerals derived from the bedrock) and occassionally high nitrate levels (most likely caused by pollution from the surface). There is also a widespread problem of high iron concentrations which is not harmful but gives an unpalatable taste to the water and causes brown staining, which may result in rejection of the water by the users. There are some plateau areas where there may be severe water quality problems but these are hard to quantify, with the available data. In the alluvial plains there are sizeable areas with unsuitable water quality,for example in the East Bwanje Valley where the groundwater is highly mineralised; this is thought to derive from mixing with magmatic waters moving along fault zones in the Rift Valley and/or from dissolution of evaporite deposits in the alluvial sequence. Problem areas can be located on the hydrogeological maps held by the Groundwater Section of the Department of Lands, Valuation and Water (DLVW).

3. GROUNDWATER DEVELOPMENT IN MALAWI

3.1. INTRODUCTION

3.1.1. Groundwater resources in Malawi have always been developed predominantly for domestic supplies. With Malawi's agricultural base, much of her population lives and works in rural areas and so the provision of domestic supplies to small settlements across the country is of special importance.

3.1.2. Historically, as in may developing countries, the responsibility for borehole construction lay with the Geological Survey Department. Partly in response to the challenge of the IDWSSD, the Government of Malawi wished to bring all the agencies responsible for its water development into one organisation, and the Department of Lands, Valuation and Water (DLVW) was formed in April, 1980.

3.2. THE BOREHOLE PROGRAMME

3.2.1. The first boreholes were drilled in Malawi in the 1930s. Between 1947 and 1969 about 100 boreholes were constructed each year, and in the early 1970s the figure rose to nearly 500 per year. This expansion resulted from the demands for improved village water supplies within three large agricultural development projects (in the Lower Shire Valley, Salima Lakeshore and the Lilongwe area). In the late 1970s the construction rate declined again, to about 150 boreholes each year by 1980. There are now (November, 1982) just over 5,000 boreholes in the country, the vast majority being equipped with handpumps [see Chapter D].

3.2.2. When the Groundwater Section moved from Geological Survey to DLVW it brought with it a long-established administrative and financial mode of operation, the Borehole Fund. This is a revolving Treasury fund, by which the Groundwater Section obtains a loan from Treasury's Development Account each financial year to cover all its operations. This must be balanced at the end of the financial year by income from "clients" for completed boreholes. There are no other sources of Government funds (from Revenue Account, for example). All the efforts of the very small number of geologists in the Groundwater Section at that time were directed towards the siting of boreholes

and the administration of the programme. There was little opportunity to carry out any detailed hydrogeological investigations, evaluation of groundwater resources, or other acitivities that could not be directly attributed to individual boreholes and covered by income from them.

3.2.3. Each annual borehole programme was carried out in response to requests, usually for individual boreholes, from the Agricultural Development Projects [now ADDs, see Chapter B], the District Development Committees (DDCs), other Government Departments, and privately owned and parastatal agricultural enterprises. The first two were the main means of providing boreholes (funded by external donors) for the rural population. The DDC programme aims to provide five boreholes to villages, clinics or schools in each district every year. It has seen a massive investment in rural groundwater supplies in the last twelve years, and has been the source of the main work for the borehole programme for much of that time. It is this commitment to constructing five boreholes in every district each year that has given the borehole programme its "dispersed" nature and accentuated many of the problems outlined below.

3.2.4. Throughout most of this time the Groundwater Section has been staffed by one geologist with overall responsibility for the operation of the programme and two or sometimes three geologists engaged full-time on choosing sites for the boreholes. Borehole siting has traditionally been carried out by geologists rather than hydrogeologists and is based almost entirely on the routine use of geophysics in a very standardised way, using resistivity profiling and depth probes according to a version of the Wenner configuration - "the Cooper-array" - first proposed in 1950 [see Bibliography]. The approach was much the same, whether the borehole was to be fitted with a handpump for a village supply (low to moderate yield requirement) or for a motorised urban supply (a high yield requirement). There was little appreciation of the general occurence of groundwater and hardly any reference was made to existing geophysical or construction data [see also Siting Section in Chapter D].

3.2.5. Borehole construction was carried out by the Groundwater Section using seven percussion drilling rigs [Chapter D], augmented by sub-contracting part of the programme to local drilling contractors. At the peak level of borehole construction in the early 1970s the seven Government rigs and 12 contractor's rigs were fully occupied but more recently the services of the contractor have only been required intermittently. The borehole construction practice (as in the case of siting) has been absolutely standardised in Malawi for many years. The borehole design was the same whatever the eventual use and yield requirement of the borehole. Boreholes were drilled to 45 - 60 m and lined with 168 mm OD mild steel casing, or left as "open-hole" in consolidated formations. To allow water to enter, the steel casing was perforated with torch-cut or hacksaw-cut slots, giving large slot widths but a very low overall open area. Slotted casing(commonly two 6 m lengths) was generally set at the bottom of the hole, regardless of the geological section. The annular space between the 168 mm steel casing and the borehole wall was filled with 6 - 12 mm crushed roadstone as a"stone grout" or gravel pack. This material is much too coarse [Chapter D] to prevent the inflow of fine material into the borehole. Little effort was made to develop the boreholes properly and a short (usually five hour) test pump was carried out on completion. This highly standardised borehole construction was used irrespective of geological conditions and the required yield or eventual use of the borehole.

3.2.6. The Groundwater Section also has responsibility for the maintenance of handpumps on rural supply boreholes, again through the operation of the Borehole Fund. The Fund is reimbersed for maintenance of the pumps by the District Councils for the DDC boreholes and by the Ministry of Agriculture for the Agricultural Project (ADD) boreholes [see 3.2.3 above]. A maintenance system has grown with the borehole programme and consists of units (based at the District Centres) with 5/7 ton trucks. These units repair borehole handpumps in response to reported breakdowns. There are now 20 such units and this will soon be increased to 24. There is little scope within the present system for the preventive maintenance so essential to prolonging the life of the pumps, even though the maintenance organisation is large and has an annual budget of approaching K1 million.

3.3. THE DUG-WELL PROGRAMME

People in Malawi have been digging shallow, unprotected wells in dambo margins for many hundreds of years. The first organised programme of protected dug wells was carried out by Colonial Development during the 1930s [Chapter D]. Between then and 1975 there was relatively little organised well digging activity. In 1975 a programme of protected dug-well construction was initiated in the Ministry of Community Development. This programme started as an off-shoot of the rural piped-water programme but quickly captured the imagination of both donors and local communities. By the time the dug-well programme came into the Groundwater Section of DLVW it was already constructing several hundred protected wells each year and it has continued to grow since 1980, supported by funds from UNICEF for vehicles and construction materials.

3.4. PROBLEMS OF THE EXISTING PROGRAMMES

Several problems with the existing borehole and dug-well programmes have been briefly referred to in the preceding paragraphs. The solutions to many of these problems are found in the new approach to the development of groundwater for rural domestic supplies that has been adopted in Malawi and these solutions are recurring themes throughout the Manual. Before discussing the solutions, it is worth summarising the problems:

a) The borehole and dug-well programmes have grown up independently. These two large, widely dispersed and costly activities have been implemented separately, without co-ordination and without due consideration for the most appropriate abstraction method for local conditions. Boreholes were sometimes drilled where water levels were within 2 - 3 m of the ground and dug wells were dug where water levels were deep.

b) The construction costs (K5,000 to K6,000 with handpump) and maintenance costs (about K200 per year) of boreholes had risen so much that it had become widely accepted that boreholes must inevitably be more expensive than the piped-water option.

c) Within the borehole programme both siting and construction were carried out with little understanding of the occurrence of groundwater.

d) The poorly designed boreholes were themselves a major contribution to the very high cost of handpump maintenance.

e) The widely dispersed activities of both borehole and dug-well programmes were difficult to manage and supervise. High costs and low technical standards were the result. In the borehole programme the geologists were fully involved in siting, and there was hardly any professional supervision of the construction of boreholes. There was no professional geological input to the dug-well programme.

f) The widely dispersed programmes resulted in inefficient use of vehicles. Transport costs of construction and maintenance were thus very high.

g) There was no maintenance stucture for the dug-well programme.

h) There was no involvement of the community at any stage of the borehole programme.

4. A NEW APPROACH TO GROUNDWATER DEVELOPMENT

4.1. THE LOW-COST BOREHOLE

4.1.1. *Introduction*

The idea of "low-cost boreholes" originated early in 1980, soon after the commencement of the ODA-supported Groundwater Project. A discussion document was prepared in May, 1980 for UNDP and was followed by a request for funds for equipment and materials to assist in the investigations to be carried out in a sub-Project entitled "Design of low-cost boreholes for rural water supply". The objective was stated as follows:

> *"Using basic, internationally-accepted design criteria, with modifications and simplifications where necessary and acceptable, it is hoped to design boreholes which*
> *a) can be rapidly and easily constructed at low cost*
> *b) utilise low-cost casing and screen which is chemically and bacteriologically inert*
> *c) have a relatively high hydraulic efficiency*
> *d) have reduced and simplified maintenance requirements.*
>
> *It is hoped that the cost can be reduced to at least half, and very possibly 25% or less of the present cost of borehole construction, together with the likely provision of more water for less pumping lift."*

The funding request was evaluated and approved by UNDTCD and the programme of investigations commenced in mid-May, 1980. The major improvements were envisaged to take place as a result of:

a) a better understanding of the hydrogeology of Malawi

b) selection of an improved casing and screen

c) improvements to gravel pack design.

4.1.2. *The Early Investigations*

a) A detailed evaluation of existing hydrogeological data suggested the existence of an extensive, shallow, weathered rock aquifer throughout much of the "plateau" areas of Malawi [see Section 2]. The importance of this aquifer had largely been ignored in the past, both in Malawi and elsewhere in Africa where similar

4.1.2. (2) terrain occurs. In Malawi several thousand rural water supply boreholes have been drilled deep into fresh rock in the search for water. A consequence of the recognition of the importance of this shallow aquifer is the general principle that boreholes should be drilled no deeper than necessary. A borehole to supply a handpump can be completed in the weathered zone aquifer and need be perhaps only 20 m deep, rather than 45 or 50 m as was commonly thought in the past [see Section 3]. This permits the use of lightweight and inexpensive drilling rigs which can be towed by a small vehicle. A further consequence is the greatly reduced need for sophisticated siting procedures [Chapter D]. Adequate yields for handpump supplies can be obtained wherever the weathered profile is adequately developed, as it is in many areas of Malawi. It is likely that adequate yields could also be obtained from most of the alluvial areas of Malawi [see Section 2].

b) The important components of the borehole, screen and gravel pack were subjected to careful hydraulic design work. At the same time, a search was made for locally-available materials to replace imported items. Firstly, imported mild steel casing was replaced by locally extruded and locally slotted PVC casing, with a hundredfold increase in open area [Chapter D], resulting in a considerable improvement in yields. The use of PVC should also increase the life of the boreholes because of its resistance to chemical attack from corrosive groundwater. Secondly, a national survey was carried out for correctly-graded gravel pack material which would prevent the movement of fine sand and silt into the boreholes (one of the major causes of the high frequency and cost of handpump maintenance). The survey located several sites along the shores of Lake Malawi where the beach sand has the characteristics of a perfect gravel filter.

c) The new borehole designs were tested in 1980 with the assistance of the UNDP "Design of low-cost boreholes" sub-project. Eight boreholes, between 15 and 30 m deep, were constructed at several sites near Lilongwe and completed with the local PVC casing and screen and lakeshore beach sand. Lightweight site investigation rigs (Pilcon Wayfarers) were used for the drilling. The boreholes were carefully developed and tested and all had specific capacities several times greater than nearby, deeper, steel-lined boreholes.

Thus the indications were that the combination of PVC screen and the gravel pack of lakeshore beach sand, correctly set against the more productive weathered zone aquifer, could produce efficient boreholes at a considerable reduction in cost. Two of the boreholes have been equipped with electric submersible pumps and have been supplying water to the Agricultural Research Station at Chitedze ever since.

d) It is clear even from a superficial examination that a large proportion of the cost of the dispersed borehole programme is vehicle spares, repairs, replacements and fuel [Chapter D]. Each drilling rig in the dispersed programme is serviced by its own 7 ton truck. Therefore, two new ideas were examined. Firstly, if drilling rigs could be kept close together, then perhaps four rigs could be serviced by one truck. Secondly if the drilling programme could be organised so that a large number of boreholes are constructed in one area at the same time, then the distances between sites would be reduced, allowing use of a tractor and trailer.

4.2. THE "INTEGRATED PROJECT" APPROACH

4.2.1. The proposal for "Integrated Projects for Rural Groundwater Supplies" followed naturally. This approach involves the complete provision of groundwater supplies in one area at a time by a project team which would:

- protect suitable existing dug wells
- rehabilitate existing boreholes where feasible
- construct new protected dug wells
- construct new low-cost boreholes
- establish a maintenance structure for all waterpoints.

4.2.2. These five components are incorporated into a project which would provide clean water to the entire population of a defined area to meet Malawi's targets within the IDWSSD. Thus, having defined an area and target population [see Chapter B] a project is planned to provide 27 litres per head per day of clean water within a one way walking distance of 500 m. Initial planning would be based on a dug well serving 125 people or a borehole serving 250 people.

The design principles for the Integrated Projects are discussed in detail in Chapter B. Where new waterpoints are required their general distribution would be planned using aerial photographs and population census maps. The choice between dug well and borehole would be made by the Project hydrogeologist from local groundwater conditions at each site. Detailed planning and site management would be carried out by a hydrogeologist. Construction would be carried out by up to four drilling rigs and two or three well-digging teams, serviced by one vehicle.

4.3. THE UPPER LIVULEZI TECHNICAL FEASIBILITY STUDY

4.3.1. The approach outlined above was tested from March to July, 1981 in a full-scale technical feasibility study in the Upper Livulezi Valley (the area had been taken out of the rural piped-water programme in January, 1981 because settler encroachment into the catchment had resulted in pollution of the proposed source river). Twenty-four low-cost boreholes ranging in depth from 17 to 22 m were constructed by two site investigation rigs and one standard percussion rig. No geophysical surveying was employed and all except one of the boreholes gave the design yield of 0.5 l/sec. In addition 10 dug wells were constructed. The Project was supervised by one hydrogeologist and was a success in every way, demonstrating the technical and economic feasibility of the new approach. Seven thousand people were supplied by the new waterpoints at a cost of less than K40,000, ie a per capita cost of about K6. This is considerably less [see Chapter B] than the current cost of other rural water supply options.

4.3.2. In summary, cost savings were made in the following ways:

a) the use of lightweight rigs drilling to one third of the previous depths in one third of the time

b) minimal expenses on site selection - the sites were chosen by each village community

c) the use of small diameter (90, 100 and 125 mm) PVC casing and screen in place of 168 mm steel

d) a massive reduction in vehicle running expenses

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c) the use of small diameter (90, 100 and 125 mm) PVC casing and screen in place of 168 mm steel

d) a massive reduction in vehicle running expenses

e) greater management and technical supervision, producing increased operating efficiency and a high borehole success rate

f) provision of labour and materials by the community.

It was demonstrated that the cost of borehole construction could be brought down to between K1,000 and K1,2000 (without handpumps), less than one third of the cost of rural supply boreholes in the concurrent dispersed programme.

4.4. HANDPUMPS AND HANDPUMP MAINTENANCE

4.4.1. The Upper Livulezi study successfully tested the technical and economic feasibility of the Integrated Project approach to waterpoint construction. Two major and interdependent elements of the Project remained to be proved by extensive field trials. These were:

a) the design and construction of a handpump that could be manufactured locally and would permit a major contribution to maintenance to be made by the user community,

b) the establishment of a largely community-based maintenance organisation for all waterpoints to replace the inefficient and costly system currently operating.

4.4.2. The successful establishment of a new maintenance system depends on the development of a new pump. The heavy, imported pumps have to be lifted by a truck-mounted winch in order to effect even the most basic repairs, such as the replacement of cup leathers. Thus, a specialist team in an expensive vehicle is called from the district centre to undertake a repair in which the parts to be replaced cost only a few kwacha. The most important feature of the new pump [described in detail in Chapter D] is the facility to remove the connecting rods, plunger, footvalve, cylinder and rising main by hand, through the pumphead, which remains in place over the borehole. This eliminates the need to use a winch, and for the first time makes it possible for the community to play a part in handpump caretaking and maintenance and thus to increase a sense of village ownership of the waterpoints.

4.5. PROJECT EXPERIENCE TO DATE

4.5.1. The system of Integrated Projects is clearly attractive to donors. Funds have been obtained to extend the work in the Upper Livulezi Valley to provide waterpoints for the whole of the projected 1990 population (60,000 people). Additional funding is either committed or under discussion for several major Integrated Projects [see Chapter B]. The Dowa West Project began in August, 1982 and construction of two more Projects could commence in 1983.

4.5.2. After a year of implementation of the Upper Livulezi Project and several months of construction activities in Dowa West, what have we learnt? How can our experience be fed back into the planning and implementation of future Projects? Above all, we have learnt that the Integrated Projects can be successfully implemented as envisaged at the outset, and that the design targets in terms of service and cost can be met. The potential for community involvement which is so successfully incorporated in the piped-water programme, can be similarly brought into the groundwater programme. Other activities can be given added impetus by being incorporated into the Integrated Projects. These include health education, sanitation promotion, horticulture and low-cost building, all of which are described in appropriate Sections of this Manual. Lastly, but perhaps most important of all, the systematic approach incorporating all these aspects has shown itself to be workable, and capable of full implementation by local staff within the existing Government organisations.

CHAPTER B

PROJECT PLANNING

CHAPTER B

PROJECT PLANNING

CONTENTS

PREFACE

A properly conducted planning phase is essential to the success of any project. However, before planning begins the design principles on which the Integrated Project is to be based must be clearly established by the Groundwater Section. At the start of this Chapter, the design principles that have so far been used for current projects are given. These underly the whole progress of the Integrated Project through the successive phases described in the Manual.

The period before an Integrated Project actually begins to construct waterpoints is best divided into planning and preparation phases. The principle aim of the planning phase is to see a potential project through from initial request and identification of an area to agreement to fund the Project by an external donor. The preparation phase takes up the process after funding has been agreed and a target date established. The hydrogeologist will contribute to much of the decision-making in the planning process, along with other members of staff, other Government agencies and the donor. It will, however, be the sole and very important responsibility of the hydrogeologist to ensure by his preliminary survey and cost estimates that the Integrated Project which reaches the preparation stage is hydrogeologically feasible and adequately funded.

1. DESIGN PRINCIPLES

1.1. AIMS

1.1.1. Every properly planned and implemented programme to improve rural water supplies must have its targets defined from the beginning. A number of fundamental questions must be answered whatever the proposed water supply source:

a) How many people will be served? What is the planning horizon?

b) What should be the per capita water consumption? What is it now? How will it change?

c) How many people will be served by each waterpoint?

d) What should be the maximum walking distance for water collection? What is it now?

For rural water supplies in which groundwater is to be the source there are some further equally fundamental questions to be answered:

a) What type of water abstraction method should be used?

b) What type of pumping method should be used?

c) How will a) and b) be designed for easy maintenance to ensure a long operating life for the project?

d) Who will carry out the operation and maintenance of the project?

1.1.2. The declaration by the United Nations of the International Drinking Water Supply and Sanitation Decade (IDWSSD) with its target of water for all by 1990 has focussed the attention of water supply planners on these questions. The Government of Malawi has adopted the Decade targets but the success with which they are likely to be met depends on many factors. Designing a rural water supply programme with sensible targets and one that will not subsequently break down is clearly one of these factors. The discussion in this Section of the Manual records the outcome of answering the questions by establishing general design criteria on which Integrated Projects should be based. The aim has been to relate the Decade targets to Malawi and set a level of service with improved water supplies that is realistic and achievable. The outcome is the following series of design principles for Integrated Projects; they do not apply to the rural piped-water projects.

1.2. METHOD OF ABSTRACTION

1.2.1. Although the "general" water project questions in 1.1.1 are listed before those for the specific "groundwater" project, the latter had a more fundamental role in the gradual evolution of the Integrated Project approach. The first question is answered by incorporating wells and boreholes together in the same project; getting away from the widely held, and we believe mistaken, attitude of"dug wells versus boreholes" which leads to projects based solely on one or the other.

1.2.2. Dug wells and boreholes do have distinctive features which can be summarised as follows:

a) Wells are generally shallow, cheap, require less sophisticated construction techniques and have much greater opportunity for community participation. The shallow water levels mean, however, that they may be more susceptible to pollution and the small penetration of the aquifer may provide poor drought protection.

b) Boreholes are deeper, more expensive, may require sophisticated construction techniques and have relatively little opportunity for community participation. Being deeper and with greater aquifer penetration, they offer much greater pollution protection and reliability in times of drought.

1.2.3. It will be seen from the summary of hydrogeology in Chapter A. that most of the areas of Malawi that will depend on groundwater for rural supplies can be served by a combination of wells and boreholes. Using the two together enables us to complement their respective advantages and offset their disadvantages rather than opting for one or the other. There may be areas where the overall depth to water is too deep for easy well digging and this should be the only criterion on which wells are ruled out altogether.

1.3. METHOD OF PUMPING

1.3.1. In rural water supply projects in Malawi, should groundwater be drawn using motorised or manually-operated pumps? It is our view that the combination of:

a) the present level of per capita water consumption

b) the need to provide at least a basic service to most of the rural population as soon as possible

c) the low level of rural incomes

d) the shallow but often poorly permeable aquifer

means that the handpump is at present the only logical pumping method. The Integrated Project is thus a "primary water supply", replacing the traditional unprotected source with a protected but still relatively simple supply. In the future water demand may increase with people's aspirations. Small motorised pumps could be installed in many of the previously handpumped boreholes, supplying storage tanks feeding individual connections. However, for the time being it is clear that priority should be be given to handpumped supplies.

1.3.2. Establishing a community-based maintenance system around handpumps that can be largely maintained at village level is the main way in which the life of the supplies is assured. The combination of correctly-designed boreholes and wells with handpumps that can be easily maintained at village level is thus a very important principle of the Integrated Project approach. The details of the way this is put into practice in project construction are set out in Chapter D and the proposed maintenance system to keep the supply operating is described in Chapter E.

1.4. POPULATION COVERAGE

The Integrated Projects are planned so as to give complete coverage at an acceptable service level to the whole population of an area at one time. This "concentrated" approach has the benefit of:

a) mobilising the community on a large scale through the Government, Party and traditional leaders,

b) low cost resulting from the concentration of effort of staff, rigs and vehicles,

c) the opportunity for proper management and close supervision.

The present planning horizon is 1990, the end of the IDWSSD, but this will have to be reviewed in due course. The way in which the target population is estimated is given in Sections 4 and 5.

1.5. WATER CONSUMPTION

1.5.1. The average amount of water used by each person daily is clearly an important design criteria. Present water use from existing supplies has to be taken into account and due allowance must be made for increases in water use that may result from an improved supply. This increase may be very considerable if the improved supply is nearer and more reliable, and if water use has been encouraged by the health education component of the Integrated Project. Patterns of water use are complex and an extensive literature [see Bibliography] has built up around the subject. The general consensus is that water use remains very low (less than 10 litres per day) unless there is a reliable source within a few hundred metres, remains moderate(10 - 25 litres per day) at these distances and only increases dramatically (> 50 litres per day) if there are individual house connections.

1.5.2. Within Malawi, a comprehensive evaluation of the piped-water projects and a much more rudimentary look at the first 34 waterpoints in the Upper Livulezi feasibility study both suggest that actual water consumption (about 12 l/head/day) is well below the design figures, which are 36 (upper limit) and 27 (lower limit) l/head/day for piped-water projects. An overall design figure of 27 litres per person per day has been chosen for the Integrated Projects, which is in line with Malawi's piped water projects and with similar handpump supplies in other parts of the world.

1.6. PUMP DISCHARGE AND PEOPLE SERVED

1.6.1. Integrated Project boreholes are designed to give a tested discharge of 30 l/min. Some give considerably more than this and a few are accepted with lower yields, down to 15 l/min. There are safeguards [Chapter D] to ensure that boreholes are not completed with yields less than this latter figure. The discharge of handpumps with 63 mm cylinders when pumped rapidly is up to 30 l/min which may

be higher than the borehole yield. However, because of the constant interruptions of pumping to clean collecting vessels and change operators, the actual sustained discharge is estimated to be about 20 l/min. Similarly, the shallow lift well handpump has a discharge of up to 60 l/min when pumped hard but the sustained yield is much lower. Taking into account also the limited storage in the well, the sustained discharge is estimated at about 10 l/min.

1.6.2. Taking these figures and the per capita water consumption, the next step is to calculate the number of people that can be served from each well and each borehole within a daily pumping regime which fits traditional practices of water collection and water use. Many researchers [see Bibliography] have demonstrated that there are peak times for water collection in the early morning and late afternoon; not a very surprising conclusion. It is therefore undesirable to have so many people dependent on one pump that they are obliged to queue for long periods at peak times or collect water in the middle of the day. If this were to happen use of the new protected supply will not be as much as it should be, people will use their traditional source instead and many of the health and amenity benefits of the project will be lost.

1.6.3. The equation relating the number of people served by the pump and the pumping period is as follows:

$$27 \times N = 20 \times 60 \times n \text{ (for boreholes)}$$
$$27 \times N = 10 \times 60 \times n \text{ (for wells)}$$

where: N is the number of people served
and n is the number of hours continuous pumping.

Successive iterations have resulted in the selection of figures of 250 people for a borehole and 125 for a dug well, giving daily discharges of 6,750 litres and 3,375 litres respectively for 5½ hours of continuous pumping per day. Taking a 12 hour day from 6 am to 6 pm, this is a theoretical design operating factor of 50%. In practice the operation of the pump would be spread through the day although concentrated in early morning and late afternoon. There is thus a built in allowance for:

a) deterioration in pump or borehole performance

b) an increased population service level due to further

population growth or temporary breakdown of a nearby pump

c) increased water consumption for domestic use or for garden watering and brickmaking.

As current water consumption is probably well below the design figure of 27 litres per person per day, this further increases the safety margin and the room for growth of the general level of service provided by Integrated Projects.

1.6.4. While the consumption figures and service levels appear to be more than adequate after nearly a year of operation of the Upper Livulezi Project, it should be emphasised that they were very much a first attempt to draw from experience in Malawi and from examples given in the literature, to establish design principles for Integrated Projects. There needs to be a programme of monitoring of pump performance [Chapter D] and evaluation of water-use patterns that feeds its results directly back into the design principles of the Integrated Projects.

1.7. <u>WALKING DISTANCE</u>

1.7.1. The chosen target is to site water points so that no one has to walk more than 500 m from house to pump. This implies a theoretical spacing of waterpoints at 1 km intervals, which may be greatly modified in practice. The Project hydrogeologist, in carrying out his village survey and siting programme [Chapter D] sets the number of waterpoints for each village on the basis of a maximum of 250 people per borehole and 125 people per dug well, taking the estimated 1990 population of the village. Most villages will have several waterpoints and keeping the walking distance below 500 m is usually easily achieved. Thus, where the population is clustered in well-defined villages there may be several waterpoints in or on the edge of the village, perhaps at much closer spacings than the theoretical 1 km, and then a larger distance with no people and no waterpoints between villages. This has been the case in the Upper Livulezi Integrated Project where nucleated settlement of high population density has resulted in very closely spaced waterpoints. In several cases there are examples of 4 or 5 pumps within one square kilometre.

1.7.2. Where there is scattered settlement the walking distance target may not be met. If settlement is very scattered indeed, extra waterpoints may be justified to cut out excessive collection times even though the number of people served by each pump will come down and the per capita cost will go up. Where there is a conflict between the "distance" and "people served" criteria the former will normally be given greater weight, but there is a need for flexibility and each case should be treated individually on its merits. It must always be remembered that when the traditional source of water is much nearer the home than the new pump it will not be easy to persuade people to change their habits. This further emphasises the importance of siting waterpoints as close as possible to people's houses (while avoiding the risk of pollution).

1.8. CONSTRUCTION COSTS

1.8.1. During the early stages of the evolution of the Integrated Project approach target costs were set at K1,500 per borehole and K750 per dug well, both average figures, and inclusive of the pumps. These ambitious targets were the result of a carefully considered appraisal of the existing mode of operation of the borehole and wells programmes and how it could be improved [Chapter A], and were to include full overheads for the operation of the Project. The cost analysis described in Chapter D shows that these construction cost targets are more or less being achieved in the Upper Livulezi Project.

1.8.2. Boreholes thus serve twice as many people as dug wells and cost twice as much. The per capita cost of construction is therefore K6 (1982 prices) irrespective of whether people are served by wells or boreholes. This has led to the adoption for planning purposes of the very useful concept of the "waterpoint unit". Thus <u>1</u> borehole represents <u>2</u> "waterpoint units", whilst <u>1</u> dug well represents <u>1</u> "waterpoint unit". The waterpoint unit serves 125 people. Projects can be costed at the planning stage [Section 5] in terms of waterpoint units at K750 each for the target population requiring new waterpoints, irrespective of the eventual proportions of wells and boreholes.

1.9. REHABILITATION

An important component of the overall philosophy of the Integrated Projects is rehabilitation of existing boreholes and protected dug wells. This might include cleaning out a borehole or deepening a well, the installation of a new pump and construction of surround, as detailed in Chapter D. The average cost allowed for rehabilitation is K750 per borehole and K375 per dug well, i.e. 50% of construction costs.

1.10. MAINTENANCE

The final important component of the overall Integrated Project philosophy is the establishment of a system for maintaining the waterpoints which is largely community-based. As a design principle, therefore, funds for the establishment of such a system and its operation for three years after construction are included in the costing of the Project [Section 5]. The funds required are calculated at 5% of capital costs per year, which, if the village-level maintenance is a success could come down towards a target of 2.5%. The way in which this might be achieved is outlined in Chapter E.

DESIGN PRINCIPLES AND CURRENT COSTS OF INTEGRATED PROJECTS

a) *Populations are projected at 1990 figures [Section 1.4].*

b) *Daily consumption of water is designed at 27 litres per person [1.5].*

c) *Sustained yield and pump discharge of project boreholes is planned at about 20 l/min and of project dug wells at about 10 l/min [1.6].*

d) *Each project borehole will serve a maximum of 250 people and each dug well a maximum of 125 people, the figures referring to the 1990 population [1.6].*

e) *Daily borehole discharge will therefore be approximately 6,750 litres and dug well discharge 3,375 litres. In each case this represents 5½ hours continuous pumping. With the normal pumping period of 12 hours from 6 am to 6 pm, all boreholes and dug wells have a design operating factor of approximately 50%, which allows generously for pump performance deterioration, further population growth and increased water consumption for domestic use or other activities [1.6].*

f) *Water points will be sited within 500 m one-way walking distance of the great majority of the population to be served, except in areas of very scattered settlement where walking distances may be greater [1.7].*

g) *The current (1982) cost for a shallow (less than 25 m) PVC lined borehole complete with pump and surround is approximately K1,500 each. The current cost for a dug well also with pump and surround is approximately K750 each. These costs include full overheads for the operation of the project but not contingencies. A contingency and inflation element of 15% of the total project cost is added. Actual current construction costs are therefore approximately K6 per capita excluding contingencies, irrespective of the relative proportions of boreholes or dug wells required. The selection of the type of waterpoint, i.e. borehole or dug well, will be the responsibility of the project hydrogeologist and will be a unique decision at each site after inspection [1.8].*

h) *Where rehabilitation of an existing borehole or dug well is appropriate, the cost is estimated to be 50% of the current construction cost - i.e. K750 per borehole, K375 per shallow well or K3 per head of population served. Rehabilitation will generally include installation of a new pump and construction of a surround.*

j) *The Integrated Project costs include a component for the establishment of a maintenance organisation for all waterpoints during the three years after project completion. This is calculated at 5% of the capital costs of construction per year (i.e. K75 per borehole per year, K37.50 per shallow well per year). During this period a predominantly village-based maintenance organisation will be established and costs brought down towards a target of 2½% of capital cost per year which will be borne by Malawi [1.10].*

2. SELECTION OF PROJECT LOCATION

2.1. The first major step to be taken in an Integrated Project is the selection of project location. This is an initial identification of a rural area of Malawi which is in need of improved water supplies. Work which is being carried out by the Groundwater Project for the National Water Master Plan will identify areas suitable for Integrated Projects. A phased programme for implementation will then be drawn up by DLVW and the National Action Committee for the IDWSSD. The basic criterion of poor existing water supplies is (at present) met by a very large proportion of the rural area of the country. What identifies a particular area for selection may be other "development" considerations, for example*:

a) Areas with high but largely undeveloped agricultural potential.

b) Areas where considerable initiative is being shown by farmers.

c) Areas of food deficit.

d) Areas of ready accessibility.

e) Maintaining an even balance in providing development assistance to all regions.

The selection is thus most likely to be made by Government agencies other than DLVW.

2.2. To illustrate this, let us examine the present situation in Malawi. The means of channelling rural development is the National Rural Development Programme (NRDP) which is co-ordinated by the Department of Agricultural Development under the Chief Agricultural Development Officer (CADO). In an economy as dominantly agrarian as Malawi's, rural development means agricultural development and all the supporting infrastructural development that goes with it. To facilitate this, the country is now divided into eight Agricultural Development Divisions (ADD's). Each of these has a phased programme of proposed development which is submitted to outside donors. When a funding proposal is being prepared for, say, a five year phase, respective Government departments are asked to prepare proposals within their own field, which are co-ordinated and put to a donor by the ADD. Thus, for example, in mid-1981 the Kasungu ADD was preparing a project for the Dowa West area for submission to the International Fund for

*taken from: *Ministry of Agriculture and Natural Resources (1980): NRDP*

Agricultural Development (IFAD) and asked DLVW to prepare a proposal for the water component. The eventual outcome, after completion of the series of steps described in this Chapter of the Manual, was the Dowa West Integrated Groundwater Project. This mode of initiation of the project planning phase has since been repeated for other areas, some of which will be quoted to illustrate specific points in this Chapter of the Manual.

2.3. While the NRDP has been, and is likely to remain in the near future, the main source of project area identification, other criteria can also apply. Our first Integrated Project, the Upper Livulezi, arose initially because the area was withdrawn from the rural piped-water programme. It had been identified previously as a potential piped-water project but in January, 1981 was removed from that programme because settler encroachment onto the catchment had resulted in pollution of the proposed source river. The Groundwater Project was then approached to see whether the area could be supplied from groundwater, thus initiating the whole planning procedure described below.

2.4. The size of the project may be determined by several factors. In the case of the Upper Livulezi the planning of the Integrated Project simply took account of the area that would have been covered by the piped water project and which was in any case a logical geographical entity. In the case of proposals for NRDP the size of the project has been determined by either:

a) A pre-determined desire to keep the water component below a certain percentage of the total project cost:- a cash limit, e.g. Dowa West.

b) A desire to provide a service to meet the design targets for the whole population of a defined agricultural planning unit:- an area limit, e.g. Lilongwe North East and Dedza Hills.

2.5. The setting of a cash limit introduces another factor into the process of project selection. For a certain sum of money two alternatives may be put forward:

a) Improved water supplies to all of an NRDP Project, but spread thinly and not meeting the design targets [Section 1] in terms of service, or waterpoint cost.

b) Service to meet the design targets giving proper coverage to all of the people, but within a smaller area.

The former may be advocated by agricultural planners, but the latter should be the basis of proposals put forward by DLVW. Where this problem has arisen it has been satisfactorily resolved by taking the latter alternative, planning accordingly and fitting water projects into the phased NRDP programme. Thus the present Dowa West Integrated Project covers only Extension Planning Area(EPA)1 [Section 4]; if funding is available, further Integrated Projects will be planned for the other Extension Planning Areas in subsequent phases of the NRDP Project.

2.6. The question of viable project size must also be considered. For a small population,and hence small number of water points, the initial expense of setting up a base camp with buildings, mobilisation of drilling rigs and staff and all the other preparations involved [Chapter C] is spread over very few water points. A substantial programme of work is required to justify the setting up of an Integrated Project, or many of the advantages of the approach would be lost and the waterpoint cost targets would not be met. For example, a preliminary cost estimate [Section 5] has been made for the part of the Karonga Lakeshore not already served by piped water projects. The 1990 population of the proposed project area was estimated to be 50,000 and the total cost of the Integrated Project was K316,000, including a significant component for rehabilitation of existing boreholes. This would have been about the minimum size of a viable project. As the funding of the current Phase III of the Karonga-Chitipa Rural Development Project had already been agreed with an insufficient and already committed component for water supplies, even this small project could not go ahead. It may be possible to re-submit it for the next phase of the Karonga-Chitipa Rural Development Project.

2.7. Where a much larger population is to be served, the preliminary estimate of costs may be higher than a donor is prepared to consider and phasing may be required. Where large Integrated Projects (Lilongwe North East, Dedza Hills) have been accepted for funding this is of great assistance in the medium term planning of a programme of Integrated Projects. These two projects will be carried out over several years, keeping the construction team to the conveniently managed size of unit that has been evolved in the Upper Livulezi Project [Chapter D].

3. AVAILABLE SUPPLY OPTIONS

3.1. AIM

Having identified an area for a rural water supply project, the next step is to examine alternative ways of supplying the water. The aim is to ensure that, taking all factors into account, a logical and sensible decision is made as to the type of supply. This may involve a comprehensive study of the technical and economic feasibility of several options:

a) surface water - run of the river

b) surface water - with impounding storage dam

c) groundwater

d) conjunctive use of surface water and groundwater

e) any of a) to d) above with the addition of some level of water treatment

leading to the"selection of option" decision described in Section 6. The purpose of this Section of the Manual is not to discuss these options in detail but to draw the attention of the project planner, by two specific examples, to the need to consider these options at this very early stage.

3.2. BACKGROUND

3.2.1. Until April 1979 the principal Government agencies constructing rural water supplies were in different Ministries. The rural piped-water and the dug-well programmes, were in the Ministry of Community Development and the borehole programme was in the Department of Geological Survey (MANR). There was no co-ordinated planning between them. Incorporation of the three into DLVW allows for the first time proper consideration of supply alternatives.

3.2.2. The rural piped-water programme has a successful history going back over the last 14 years. In this time most of the more obvious source rivers have been used to supply piped-water projects ranging in size from a few thousand to over 100,000 people. The Piped-Water Section has a prepared and funded programme up until 1986, by which

time about 25% of the 1990 rural population will have been served by piped water. Much of the remainder of the rural population can only be served from groundwater, the only available option as there are few suitable rivers unless extensive water storage and/or treatment is considered. There are, however, some important areas where both a surface water and a groundwater option exist and each must be considered on its merits. There are also likely to be areas where a groundwater option does not exist for reasons of quantity or quality.

3.2.3. Over the history of the piped-water projects the average per capita cost has gradually risen to its present figure of about K20. The borehole drilling programme throughout this time was slow and inefficient [Chapter A] and the effort was widely dispersed over the whole country at once. The boreholes were very expensive to construct and maintain and it was widely accepted at the time that the piped-water option was much less expensive than the borehole option both in capital and recurrent costs. With the evolution over the last two years of the Integrated Project approach to the development of groundwater for rural supplies the situation has changed. Piped water is no longer invariably the cheaper option. Two examples which are currently receiving extensive discussion within DLVW will help to illustrate the problem.

3.3. THE ZOMBA SOUTH AREA

3.3.1. One of the proposed piped-water projects in the already funded programme to 1986 would provide water to the Zomba South area (with a 1977 population of 87,560). This would complete piped water coverage to a very high proportion of the Phalombe Plain with several projects in all,using rivers from Mulanje Mountain and Zomba Plateau. The proposal is thus an attractive one but there are good reasons why other supply options should be examined.

3.3.2. Several possible source rivers for the piped-water project flow from Zomba Plateau but there are significant existing demands on most of them. The Domasi, Naisi and Likangala Rivers provide water to existing irrigation schemes and the dry season flows are particularly important for irrigating a winter wheat or maize crop on a proportion of the scheme area. Using one or more of these rivers for a piped-water project would reduce or even eliminate this possibility. The Mulunguzi River is fully committed to providing the

water supply to Zomba Municipality and there is also an existing water right (hardly ever exercised) for the Electricity Supply Company to use water to run the standby turbine generators at Zomba. There are thus conflicting demands on a limited surface water resource. The amenity value of the resource also becomes important in this case. It may be wiser to use a substantial dry season river flow (a concentrated resource) for irrigation, industrial or urban supply and groundwater (a dispersed resource,which in this case is nowhere available in large enough quantities for any other use) for rural water supplies.

3.3.3. The surface water resource could perhaps be augmented to meet these existing demands and leave enough for the rural supply project by either raising the existing Mulunguzi Dam or constructing a new dam at Mulunguzi Marsh. Both of these might require water treatment works. The additional cost of dam and treatment would be considerable. The piped-water project would have to bear a major proportion of these costs, adding significantly to the cost of the surface supply option for the Zomba South area.

3.3.4. A preliminary survey as outlined in Section 4 has been carried out for the Zomba South area. Records from the 109 existing boreholes in the area indicate that the alluvial and weathered bedrock aquifers can provide adequate yields for handpumps and water of acceptable chemical quality. Taking the 1977 base population, an annual growth rate of 3%, and taking into account the existing boreholes, a calculation can be carried out as in Section 5 of this Chapter of the Manual to give a preliminary cost estimate for an Integrated Groundwater Project. This is considerably cheaper than the equivalent piped-water supply project based on a run-of-the-river source and without treatment. The capital cost difference would be greater if a dam and treatment works were required.

3.3.5.. The operation and maintenance costs of each option must also be examined. In the design principles [Section 1] the cost of establishing a maintenance system for an Integrated Project is given as 5% of capital cost per year, which could subsequently drop to 2½% per year. Much depends on the performance of the handpumps and the exact level of maintenance service [Chapter E] that is required. At 5% of capital, annual maintenance costs for an Integrated Project may be three or four times those for the run-of-the river

piped-water project. However, their possible reduction to 2½%, together with an increase in maintenance costs for a piped-water project if a dam and treatment works were incorporated could make the recurrent costs of the two options more closely comparable.

3.3.6. The existing protected supplies in the area, the 109 boreholes, should be taken into account. Rehabilitated in an Integrated Project they represent a service to 20% of the 1990 population; a considerable existing investment that should not be ignored.

3.3.7. At the present time (November, 1982) the option decision is deferred while further work is carried out to investigate the feasibility of a second dam on the Mulunguzi River, large enough to serve both Zomba Municipality and the rural piped-water project.

3.4. THE MPIRA - BALAKA AREA

3.4.1. Mpira - Balaka is the most ambitious of the proposals for piped-water projects to date. It arose in the late 1970's as a means of supplying domestic water to an eventual target population of 235,000 in the relatively dry areas of the southern Bwanje Valley and Liwaladzi Valley. Because there were no adequate run-of-the-river sources a large storage dam was proposed; a radical departure in design concept for the piped-water programme. A feasibility study of the Mpira valley was made in 1980-81 by consultants and the optimum dam site recommended.

3.4.2. In the meantime the Integrated Project approach to groundwater development has been evolving and the groundwater option, as in Zomba South, has now been given serious consideration. A preliminary survey, much as outlined in Section 4, has been carried out and has produced two further proposals for consideration:

a) A small run-of-the-river piped-water project supplying the escarpment areas where groundwater potential is poor, together with an Integrated Project for the majority of the area (and population) on the valley floor.

b) A conjunctive-use supply using a smaller dam or run-of-the-river flow for most of the year with a few strategically placed high-

yielding boreholes pumping into the reticulation system to supplement the dry-season flow.

3.4.3. Both of the above are likely to be cheaper to construct than the original dam proposal, but as in the previous case, there are other considerations and the comparison is not made on a purely capital cost basis. The different options have varying components of operating and maintenance costs for items such as treatment and pumping which must be evaluated. In particular, motorised pumping at high discharge may imply a considerable level of operational sophistication and high pumping costs. The latter proposal also requires a further feasibility investigation by drilling a small number of test boreholes to confirm the yield potential of the area. On the other hand, a proposal involving a large dam has an additional requirement for conservation of the catchment, in this case involving resettlement of people which may be expensive and present social problems. These are some of the factors involved in the selection of option decision [Section 6] which in this example is currently (November, 1982) awaiting further feasibility studies of both groundwater options.

3.5. It may be worth concluding this section on a cautionary note: with up to 75% of the 1990 rural population needing to be served from groundwater in areas where there is no alternative, perhaps the sheer size of this task implies that the surface water option should be taken where it is available and where donor support is likely to be available.

4. PRELIMINARY SURVEY

4.1. Proper assessment of the available options requires a preliminary survey and report with cost estimates. This Section of the Manual describes how that is done for the groundwater option. If a "quick look" appraisal has suggested that there may also be a surface-water option, its feasibility may be the subject of a simultaneous study (not described here) by the Hydrology, Piped Water and Planning Sections of DLVW. These studies form the basis of the selection of option decision briefly described in Section 6.

4.2. HYDROGEOLOGICAL DATA SEARCH

4.2.1. The first and most fundamental step is an examination of existing data to see whether the proposed project is hydrogeologically feasible. For borehole construction in basement areas experience has shown that a weathered rock aquifer with a saturated thickness of at least 10 - 15 m containing good quality water and within easy reach of the majority of the people in the area is necessary. A secondary consideration of importance is the depth to groundwater, which will give a rough estimate of the prop rtion of wells to boreholes. A dry-season depth to water of 6 m is considered the maximum for dug-well construction.

4.2.2. One of the main reasons for the compilation of surface water and groundwater data for the National Water Resources Master Plan (NWRMP) is to facilitate the planning of all types of water development projects. For groundwater, this data will comprise:

a) A complete, metricated cardex system of all 5,000 plus existing boreholes filed by Water Resource Units [example in Figure B.4.1.].

b) A master set of hydrogeological maps at 1:100,000 scale.

c) A set of 8 hydrogeological maps at 1:250,000 scale with brief sheet descriptions.

d) A hydrogeological "planning" map of the whole country at 1:1,000,000 scale.

e) A report on the hydrogeology of Malawi.

f) The initial volumes in a series of hydrogeological bulletins for each Water Resource Unit.

Figure B.4.1. Cardex Record of Borehole Information

a) Front

BOREHOLE DATA FORM BDF1

DESCRIPTORS

Locality	Chisuzi Village
Grid Ref.	WIV 513 818
Map Sheet	1333 C2
Depth b.d. (m)	45.75
RWL (construction)(m)	9.15
Datum altitude AOD (m)	1128.5
RWL AOD (avg min)(m)	1119.5
RWL AOD (avg max)(m)	
District	Lilongwe
Client	LLDP

Detailed Geology

0-32.9 Colluvium

32.9-45.7 Basement gneiss

G.S Ref No	D P 1 1 1
Borehole No.	5 E 1 9 9

CONSTRUCTION

Driller / Contractor: WCL JOSIA

Drilling Method: Percussion

Start: 23 03 72 Drilling Finish: 05 04 72

Drilling	diam (mm)	from (m)	to (m)
1.	203	0.00	33.55
2.	152	33.55	45.75
3.			

Water Struck (m)		rising to	
1.	22.0	rising to	9.15
2.		rising to	
3.		rising to	

Casing		diam (mm)	from (m)	to (m)
Plain	1.	152	0.00	21.35
	2.			
Slotted	1.	152	21.35	33.55
	2.			

Casing Material: Plain	MS	Slotted	MS
Slot Size (mm)		Open Area %	
Pump: Type	Climax	Suction (m b.d)	37
Filter: quantity (m³)	1.5	d50 (mm)	9.5

Q	RWL bd	SC	EC		

PERFORMANCE

Driller's Pump Test

5 hour yield (l/min)	136.8
5 hour drawdown (m)	16.10
5 hour Spec. Cap (l/min/m)	22.4

Detailed pump test

Transmissivity (m^2/d)	
Storativity	x 10⁻
See file no.	N/A

SITING

Geologist: D Pascall

Date: 06 03 72

CST Spacing interval (m)	22.9
(10 Ωm) Point resistivity	10.2

DP:		
ρ1 (10 Ωm)	14.0	16.1 m
ρ2	12.5	m
ρ3		

Recommended: drill to (m) 61.0

Figure B.4.1. Cardex Record of Borehole Information

b) Reverse

5	E	1	9	9	c

PLUMBED DEPTH and WATER LEVEL 1

Date	Depth (m)	W.L. (m)
07 04 72	45.75	9.15
23 09 76	45.75	5.19
11 11 76	45.75	8.54
11 10 79	45.45	4.58
13 03 80	45.45	3.66
21 09 80	30.50?	4.88
09 11 80	30.50?	3.36
03 02 81	45.75	4.27
16 05 81	44.23	3.66
04 01 82	44.23	5.49

PLUMBED DEPTH and WATER LEVEL 2

Date	Depth (m)	W.L. (m)

CHEMISTRY

Date	10/72			Date	EC (μS)
Ion	mg/l	mg/l	mg/l		
Ca	30				
Mg	11				
Na	22				
K	3				
Fe	1.8				
HCO_3	152				
SO_4	70				
Cl	110				
NO_3	<1				
F					
TDS	268				
EC					
pH	6.00				
T°C	25.0				

NOTES

Checked. [signature]

4.2.3. The first aspect to be considered is the general topography and geology of the area. The areas of alluvium along the lakeshore, for example the Salima - Nkhotakota area or the Bwanje Valley will at first sight appear ideal for an Integrated Project. In contrast, a steeply dissected part of the plateau edge, for example Dedza Hills, may from this initial look appear much less favourable. This first impression is then refined by the cardex data, which gives existing borehole yields, depth to water and depth of weathering. The yield data may be of limited value in themselves as, for old boreholes, they are likely to be unreliable and may reflect poor borehole construction practices. Nevertheless, the occurrence of very low yielding or "dry" boreholes may be important in identifying topographically unpromising (steep ridges) or geologically difficult (outcrop or shallow bedrock) areas. The combination of depth of weathering and depth at which water was struck are the main criteria for assessing the hydrogeological feasibility of an Integrated Project

4.2.4. Looking at some actual examples, an alluvial area such as the part of the Bwanje Valley to be served by the proposed Mpira Project [Section 3] clearly has an adequate thickness of aquifer. The general depth to water is greater than 15 m, ranging up to 35 m, which would largely rule out wells and require deeper boreholes. The average cost of boreholes may then be greater than the K1,500 quoted in the design principles [Section 1]. In contrast, the steeply dissected Dedza Hills area referred to earlier, may have very poor aquifers on the mountain ridges and an Integrated Project for this area may depend disproportionately on dug wells along the broad drainage valleys (dambo). It will be seen from the discussion of design principles that the proportion of wells to boreholes does not affect the per capita cost of the project but a major bias one way or the other must be borne in mind at this stage for its effect on the detailed planning and preparation for the construction programme.

4.2.5. Consideration must also be given to the ability of the groundwater resource to sustain the demand to be placed on it by the proposed project. What is the relationship between abstraction from and annual replenishment to the resource? Assuming the water points to be pumping according to the design principles [Section 1], by

1990 the 160 boreholes and 100 dug wells in the Upper Livulezi Project will be drawing about 510,000 m^3 per year. This represents about 1 mm over the floor area of the valley (185 km^2). Estimates of the annual recharge by baseflow analysis range from 30 - 90 mm and there is clearly no risk of overabstraction even if much closer spacing of water points is required to keep pace with population growth. In the future, however, expectations and financial circumstances may change so that reticulation systems, house connections and small scale irrigation become commonplace. If, in these circumstances, the use of motor pumps leads to greatly increased water use, the relationship between groundwater abstraction and replenishment will need much more careful evaluation and perhaps a long-term monitoring programme.

4.2.6. The preliminary survey should also include an appraisal of the chemical quality of groundwater in the area. Existing hydrochemical data are recorded on the cardex[Figure B.4.1]. In most areas of Malawi groundwater is of good general quality for drinking. Where this existing data suggests a local quality problem, the Department's (DLVW) Water Quality Section should be consulted. If they consider it appropriate, a rapid reconnaissance survey should be carried out which should be extended to a full-scale survey if warranted [see 4.5.2]. Large areas, or even the whole Project area, may have to be ruled out if groundwater quality is unsuitable.

4.3. POPULATION

4.3.1. The population of the project area is obviously the most important factor in determining the number of water points required and hence the cost and duration of project construction. This forms the basis of the funding proposal in the project document and determines the funds required for the project. Time and effort researching to get the best estimates possible at this stage are well worthwhile to avoid any embarrassing shortfall in funds at a much later date.

4.3.2. The starting point is the 1977 population census of Malawi, published by the National Statistical Office. The detailed figures are given by Districts, Traditional Authorities and Enumeration Areas (EA's) in separate district booklets. The water

Table B.4.1. Estimate of Base Population, Mchinji RDP

EPA	Total 1977 Population by EPA (ADD data)	Total 1977 Population by Traditional Authority (Census data)	Approximate Percentage of Estates and Population therein	1977 Population served by Piped Water Projects	1977 Population in Urban Supplies	1977 Base Population for Project (Rounded) A - (C+D+E)
	A	B	C	D	E	
MC1 Mkanda	33,417	33,874	40 13,500	-	-	20,000
MC2 Dambe	18,680	17,475	40 7,000	-	-	11,000
MC3 Nduwa	22,946	25,725	-	16,370	-	6,600
MC4 Zulu	26,379	28,504	-	8,870	-	17,500
MC5 Mlonyeni	19,572	13,714	-	-	1,957	17,600
MC6 Mavwere	31,204	37,584	10 3,000	-	-	28,000
TOTAL	152,198	156,876	23,000	25,240	1,957	100,000

project boundary should be overlaid on enumeration Area maps, and the 1977 population summed for the project. In the case of the Upper Livulezi Project this was a logical geographical boundary determined by the Groundwater Section. In the case of the Mchinji Project [Table B.4.1] the population is summed by agricultural Extension Planning Areas (EPA's). Where there are slight discrepancies [Table B.4.1] because EPA boundaries do not coincide with Traditional Authorities, the former should normally be adopted. Where the Integrated Project proposal is being prepared as a component of an NRDP project the ADD will probably have already carried out its own population calculations. These may, however, have a different basis. For example, in a preliminary proposal made recently for the South Mzimba Project, the starting point adopted by the ADD (and followed by us) was an early 1982 household survey. In any case, the origin of the baseline population should always be given.

4.3.3. The next step is to eliminate any areas and population to be served by other means. In the Mchinji example [Table B.4.1] the population of Mchinji Urban [1977 census] is removed. Water Supplies Branch of DLVW should be consulted to ensure that this is a realistic figure for the population served by their supply. The population served by any existing or planned rural piped-water projects are also removed at this stage [Table B.4.1]. A rather more difficult problem arises in relation to private and estate lands. In the Mchinji proposal the base population was reduced proportionately by measuring the area covered by estates and assuming an even population density. It has then been assumed that this percentage of the population lives in the estates and is provided with domestic water by the estates. No provision is made for them in the Integrated Project proposal. This is unlikely to be a valid assumption and, even if it were, a decision to leave out these people is a major policy issue that requires further consultation with the ADDs.

4.3.4. Having established the correct baseline population the next planning step is to extrapolate to the chosen planning horizon. At the present time, near the beginning of the Water Decade, 1990 is taken as an appropriate horizon for Integrated Groundwater Projects. While this is currently valid, by 1985 it would be sensible to assume a 1995

horizon. The overall annual rate of population growth in Malawi is about 2.9% [NSO, 1980], but there are significant regional variations which may need to be considered. Taking 3% per annum provides a very simple multiplication of the 1977 figure by 1.5 to give that for 1990 [Table B.5.1]. This has been adopted as one of our design principles [Section 1] and is considered an adequate estimate at this early planning stage.

4.3.5. In actual practice, other considerations such as the agricultural carrying capacity of the land, population movement and estate development may come into play; the ADD's and their own agricultural planning and soils reports should be consulted at this stage. Work on population projections and population distributions is being carried out at present by the Department of Town and Country Planning within the National Physical Master Plan. This may have a bearing on water project planning in the future. In the meantime, the combination of the flexibility built into the design principles [Section 1] and the 15% contingency item added in project costing [Section 5] is adequate to cover any changes that might occur between initial planning and construction of the project. It is important to note also that the Integrated Groundwater Projects can easily be augmented at a later date by selectively increasing the water point density to meet changing circumstances such as unpredicted, rapid population growth. This can rarely be done in piped-water projects.

4.3.6. The final step in the population calculations is to find the numbers of existing boreholes and wells in the proposed project area. Each of these will be rehabilitated as necessary [Chapter D] during the project. For planning purposes each rehabilitated borehole is taken to serve 250 of the 1990 population and each dug well 125 [see design principles in Section 1] and these are subtracted [Table B.5.1] to give the 1990 population to be served by newly constructed water points. Preliminary cost estimates for the proposed project can now be prepared [Section 5].

4.4. FIELD FAMILIARISATION VISIT

4.4.1. It is very important for the hydrogeologist who is carrying out the planning stage to make a field visit to the proposed project to get a general "feel" for the area. This would include a rapid appraisal of the traditional pattern of population distribution - scattered or nucleated, its relation to topography, and its influence therefore on waterpoint locations and type (proportion of wells to boreholes). The hydrogeologist should also be looking at existing water sources, getting a general impression of dug well potential, any possibility of spring protection and an impression of the current state (and hence rehabilitation requirements) of the existing boreholes. This familiarisation visit may also identify new agricultural developments, for example estates which may post-date information available in reports and may have a bearing on the planning of the project.

4.4.2. The question of access for project plant and vehicles should also be considered on this visit. Roads, bridges and drifts which become impassable in the rainy season may seriously hamper the construction programme. In the project preparation stage [Chapter C] this is considered in more detail; access difficulties may lead to scheduling of the construction programme in dry and wet season areas. The field visit at the planning stage may reveal road building in progress that has a bearing on the water project. In the Upper Livulezi, for example, the Central Services Construction Unit (CSCU) of the Ministry of Agriculture was in the process of constructing a link road along the west side of the valley. Having picked this up in the planning field visit, it was possible to keep up the pressure so that the road was completed by the time the implementation phase began, and the road has had a significant impact by greatly easing access for the drilling rigs. Thus liaison with other organisations [described in detail in Chapter C] may need to be initiated at the planning stage, particularly with respect to access. Within NRDP projects, for example, it may be possible at the planning stage to ensure that the activities of the District Roads Improvement and Maintenance Project (DRIMP) can be co-ordinated with the phasing of the water project to obtain maximum benefit of improved access.

4.5. COLLECTION OF ADDITIONAL FIELD DATA

4.5.1. The familiarisation field visit need only be short, perhaps a single day for areas near Lilongwe and two to three days for more distant areas. It is essential that this visit be carried out by the hydrogeologist, if necessary accompanied by other relevant Department staff (hydrologist, planning engineer, piped-water engineer) or ADD staff. Any further collection of field data can subsequently be delegated to technical staff of the Groundwater Section. At this stage, field data collection should be kept to a minimum.

4.5.2. The most important case for the collection of additional field data is if water quality problems are identified from the cardex check. A field conductivity survey of all water sources should then be rapidly carried out by a technician on a motorcycle. Samples should be collected and analysed in the laboratory of all waters whose conductivity is over 1,500 μS/cm. Following this some or all of the project area may be ruled out.

4.6. SURVEY REPORT

4.6.1. The preliminary survey outlined above forms the basis of the planning stage of the project. It should be concluded by a brief survey report on the feasibility of the groundwater option, including the table of preliminary costs [Section 5]. This, along with similar reports on the surface water option, then forms the basis of the option decision discussed in Section 6. A suitable format for the report would be as follows:

a) introduction to Project area : topography, soils,climate, land-use, population, access

b) existing water sources

c) geology and hydrogeology

d) groundwater quality

e) feasibility of groundwater option

f) preliminary costs.

4.6.2. The time taken in the preliminary survey should be kept fairly short and in fact pressure from the ADD is likely to ensure that this is the case. Collecting and collating the data described above, the field visit and writing a short report may take place over a period of three to four weeks of which the actual time required by the hydrogeologist would be equivalent to four or five full working days. At this stage, no funds have been identified for the project and the small cost of the preliminary survey (less than K1,000) is borne by the Groundwater Section of DLVW.

5. PRELIMINARY COST ESTIMATE

5.1. An estimate of the cost of the proposed project should be included in the groundwater option report. Two examples are given here to illustrate how these are compiled by following a series of simple steps, starting from the estimate of 1977 base population obtained by the approach described in Section 4. The steps can be followed in Tables B.5.1. and B.5.2.

5.2. STEPS IN COST ESTIMATION

5.2.1. Estimate 1977 base population for each EPA excluding estates, urban areas and piped water projects [Column A, see also Table B.4.1.

5.2.2. Estimate the 1990 population in each EPA to be served at a 3% per annum growth rate by multiplying 1977 population by 1.5 [B].

5.2.3. Obtain from hydrogeological maps and cardex the number of existing boreholes and protected wells in each EPA [C].

5.2.4. Make allowance for the 1990 population that will be served by these wells and boreholes at 250 people per borehole and 125 per dug well [design principles, Section 1] [D].

5.2.5. Subtract [D] from [B] to leave the number of people requiring new waterpoints [E].

5.2.6. Divide the population remaining to be served [E] by 125 to give the number of new waterpoint units required [F].

Note: In the design principles [Section 1] the concept of a "waterpoint" unit as a planning unit is explained; the per capita cost is the same for people served by wells or boreholes. A dug well serving 125 people is one waterpoint unit and a borehole serving 250 people comprises two waterpoint units. Thus at this stage 993 waterpoint units [F in Table B.5.1] could be 993 dug wells or 497 boreholes or any combination in between; the proportions do not affect the costing of the project.

5.2.7. Cost the new waterpoint units [F] at K750 each [1982 prices - see Section 1] [G].

5.2.8. Calculate the rehabilitation costs at an average of K750 per existing borehole and K375 per existing well [Section 1] [H].

5.2.9. Calculate the annual maintenance cost as 5% of the capital cost of the total of both new and rehabilitated water points, i.e. K75 per borehole and K37.50 per dug well [see Section 1]. Thus for EPA 1 at Mchinji [Table B.5.1], the annual maintenance cost for 15 existing (rehabilitated) boreholes and 210 new waterpoint units is (15 x 2 + 210) x K37.50 = K9,000. The cost of maintenance is written in for three years after the construction phase of the project, i.e. K27,000 for Mchinji EPA 1 [J].

Note: At the present time (November, 1982) the establishment of a community-based maintenance system still depends on development work to produce both shallow and deep lift pumps that are truly maintainable at village level [Chapter D]. The form such a maintenance system might take is described in Chapter E. The annual cost of 5% [in Design Principles in Section 1] written into these preliminary cost estimates is for the establishment of the maintenance system, including such items as training courses and training materials as well as recurrent costs.

5.2.10. Calculate the contingency cost. The contingency cost is 15% of the total project cost, i.e. (G + H + J) x 0.15 = [K].

Note: The contingency sum is intended principally to cover such factors as:

a) Underestimates in requirements for new water-points due to changes in population growth or distribution between planning and implementation.
b) An underestimate of the occurrence of deeper water levels requiring slightly more expensive boreholes.

c) An element for cost inflation. If there is a long time period between the preliminary planning stage and submission to donor the cost estimates may have to be revised in relation to the costs of projects being implemented at that time.

5.2.11. Calculate the total cost of the project including contingencies, i.e. (G + H + J + K) = [L]. This can be divided by the total number of people served at the 1990 planning horizon to give the overall per capita cost of the project of around K 7.

Table B.5.1.

Preliminary Cost Estimates, Mchinji RDP : Integrated Project for Rural Groundwater Supplies

a) Calculation of Waterpoint Requirements.

EPA	1977 Population [Table B.4.1]	Estimated 1990 Population to be served	Existing Boreholes	Population served by existing bore-holes	Estimated population remaining to be served	New waterpoint units
	A	B	C	D	E	F
MC1 Mkanda	20,000	30,000	15	3,750	26,250	210
MC2 Dambe	11,000	16,500	40	10,000	6,500	52
MC3 Nduwa	6,600	10,000	4	1,000	9,000	72
MC4 Zulu	17,500	26,300	8	2,000	24,300	194
MC5 Mlonyeni	17,600	26,400	12	3,000	23,400	187
MC6 Mavwere	28,000	42,000	29	7,250	34,750	278
TOTAL	100,700	151,200	108	27,000	124,000	993

Table B.5.1.

Preliminary Cost Estimates, Mchinji RDP : Integrated Project for Rural Groundwater Supplies

b) Calculation of Project Costs (Malawi Kwacha).

EPA	New waterpoint Units F	Cost of new waterpoint units @ K750 G	Rehabilitation costs, boreholes @ K750 H	Establishment of maintenance system (cost for 3 years) J	Contingencies, 15% of total cost K	Total cost per EPA L
MC1 Mkanda	210	157,500	11,250	27,000	29,400	225,500
MC2 Dambe	52	39,000	30,000	15,000	12,600	97,000
MC3 Nduwa	72	54,000	3,000	9,000	9,900	76,000
MC4 Zulu	194	145,500	6,000	23,700	26,300	201,500
MC5 Mlonyeni	187	140,250	9,000	24,000	26,000	199,500
MC6 Mavwere	278	208,500	21,750	37,800	40,200	308,500
TOTAL	993	744,750	81,000	136,500	144,400	1,108,000

Table B.5.2. Preliminary Cost Estimates, Dedza Hills RDP : Integrated Project for Rural Groundwater Supplies

a) Calculation of Waterpoint Requirements.

EPA	1977 Census Population	Estimated 1990 Population to be served	Existing Boreholes (1) and wells (2)		Population served by existing boreholes (1) and wells (2)		Estimated population remaining to be served	New waterpoint units
	A	B	C		D		E	F
			(1)	(2)	(1)	(2)		
DE5	25,621	38,000	13	63	3,250	7,900	27,000	216
DE6	31,795	48,000	14	11	3,500	1,400	43,000	344
DE7	30,158	45,000	10	8	2,500	1,000	41,500	332
DE8	21,758	33,000	6	-	1,500	-	31,500	252
DE10	6,216[1]	9,000	4	18[2]	1,000	2,200	6,000	48
TOTAL	115,548	173,000	47	100	11,750	12,500	249,000	1,192

Notes : [1] Population of DE10 is 11,794 less 5,578 in Dedza Urban area

[2] Wells in DE10 outside Dedza Urban area.

Table B.5.2. Preliminary Cost Estimates, Dedza Hills RDP: Integrated Project for Rural Groundwater Supplies

b) Calculation of Project Costs (Malawi Kwacha)

EPA	New waterpoint units	Cost of new waterpoint units @ K750	Rehabilitation costs		Establishment of maintenance system (cost for 3 years)	Contingencies, 15% of total cost	Total cost per EPA
			boreholes @ K750	wells @ K750			
	F	G	H		J	K	L
DE5	216	162,000	10,000	23,500	34,500	34,000	264,500
DE6	344	258,000	10,500	4,000	43,500	47,500	363,500
DE7	332	249,000	7,500	3,000	40,500	45,000	345,000
DE8	252	189,000	4,500	-	30,000	33,500	257,000
DE10	48	36,000	3,000	7,000	9,000	8,000	63,000
TOTAL	1,192	894,000	35,500	37,500	157,500	168,500	1,293,000

PRELIMINARY SURVEY AND PROJECT COSTING

STEPS IN PROCEDURE

1. Locate and delineate Project area on maps [Section 2]

2. Examine hydrogeological maps and reports [Section 4.2]

3. Extract borehole data from cardex system [4.2]
   - yields
   - depth of water
   - depth of weathering
   - water quality

4. Extract dug well data [4.2]

We now have overall impression of
HYDROGEOLOGICAL FEASIBILITY OF PROJECT

5. Obtain :
   a) 1977 population census data in district booklets [4.3.2]
   b) Enumeration Area (EA) maps [4.3.2]

6. Overlay boundary of Project on EA map [4.3.2]

7. For EAs completely within Project boundary, sum population for each EA number using district booklet [4.3.2]

8. For EAs partially within Project boundary, estimate proportion inside [4.3.2]

9. Sum EA populations for Project area [4.3.2], Extension Planning Areas (EPAs) if appropriate*

10. Eliminate for each EPA the 1977 population of existing or planned piped-water projects [4.3.3]

11. *Eliminate for each EPA the 1977 population of urban or institutional water supplies [4.3.3]*

12. *Eliminate for each EPA areas and populations in estates [4.3.3]*

We now have 1977 BASELINE POPULATION OF PROJECT

13. *Make field familiarisation visit to Project area to give an indication of:*

- *population distribution and relation to topography*
- *likely proportion of dug wells and boreholes*
- *possibility of spring protection*
- *existing water sources*
- *access [4.4]*

14. *If existing data and field visit have indicated possible water quality problems - organise survey of electrical conductivity of all water sources [4.5]*

15. *Write report on Preliminary Survey [4.6]. If Integrated Project is hydrogeologically feasible and water quality is good, proceed to preliminary cost estimate*

16. *From the 1977 base population, estimate the 1990 population for each EPA [5.2.2]*

17. *Obtain the number of existing boreholes and protected dug wells in each EPA [5.2.3]*

18. *Make allowance for the 1990 population that will be served by these boreholes and dug wells [5.2.4]*

19. *Subtract (18) from (16) [5.2.5]*

20. *Divide the population remaining to be served by 125 [5.2.6]*

We now have an estimate of the NUMBER OF NEW WATERPOINT UNITS

21. *Cost the new waterpoint units at K750 each [5.2.7]*

22. *Calculate rehabilitation costs at K750 per existing borehole and K375 per existing dug well [5.2.8]*

We now have an estimate of
CAPITAL COST OF PROJECT WATERPOINTS
(K6 per head)

23. *Calculate annual maintenance cost [5.2.9]*

24. *Calculate contingency cost [5.2.10]*

25. *Calculate total Project cost [5.2.11]*

We now have an estimate of
TOTAL COST OF PROJECT
(K7 per head)

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* *Note : EPAs are convenient units to use in NRDP areas, and this case is given here. In Integrated Projects outside NRDP areas the whole Project area or any other convenient unit may be used.*

6. SELECTION OF OPTION

6.1. The project planning process has now reached a critical stage. A project area has been selected [Section 2] and more than one option for supplying the water may have been identified [Section 3]. The hydrogeologist has carried out the preliminary survey [Section 4] and, having assured himself that the proposed project is hydrogeologically feasible, has prepared a preliminary estimate of costs [Section 5]. In the meantime the Hydrology,Planning and Rural Piped-Water Sections of DLVW may have been carrying out an examination of the feasibility of the surface water option. These respective preliminary investigations should be summarised in brief option reports and circulated to senior members of DLVW staff. After due time for consideration a meeting of senior staff is called to discuss the option reports and select the best option to go forward as a funding request [Section 8].

6.2. The selection is based on a number of criteria which may be of greater or lesser importance in each case:

a) Availability and reliability of the resource.

b) Other existing or potential demands on the resource.

c) Chemical quality of the water.

d) Bacteriological quality of the water.

e) Technical feasibility of the option.

f) Capital cost of the option.

g) Treatment requirements and costs of the option.

h) Maintenance requirements and costs of the option.

j) Indirect costs of the proposal, e.g. resettlement.

k) Existing commitments and overall programme of Piped Water and Groundwater Sections.

l) Existing investment in protected supplies in the area.

m) Donor preferences and availability of funds.

6.3. The list of factors to be considered is a daunting one; the selection of option decision may not be straightforward and rapid. However, for most of the rural areas of Malawi with which the NRDP is concerned, there are no low-cost surface water options and groundwater development may be the only feasible solution. Where is more than one option, as in the two examples quoted in Section 3, the process leading to the "selection of option" decision will be a lengthy one.. The process is, for example, likely to include detailed and expensive feasibility investigations.

6.4.. Once the selection has been made, or perhaps even to assist the decision-making process the option reports should be put together into a Project Planning Report which can be used to provide (if requested) additional background information and justification to a donor agency in support of the Project Submission. This planning Report is registered and lodged in the Department's Planning Library. The responsibility for the preparation of this report lies with the Planning Section of DLVW.

7. PRELIMINARY ESTIMATE OF PROJECT NEEDS

7.1. PROJECT STARTING DATE

7.1.1. Once the groundwater option has been selected [Section 6], the procedure for obtaining donor funds for the proposed project can be initiated. Where the proposal forms the water supply component of an NRDP Project and has been prepared in response to a specific request from an ADD there may be no need for a separate submission document. The table of preliminary costs [Table B.5.1] and the planning report or groundwater option report are passed to the ADD for incorporation into their own proposal for the phase of the RDP in question. There is one very important step for the Groundwater Section before the Project is submitted to a donor.

7.1.2. The Groundwater Section must look critically at the demands that will be placed on its own resources by the proposed project. What does the project need in terms of rigs, vehicles and manpower in relation to the established programme of Integrated Projects and other activities of the Groundwater Section? Can the project be fitted into the programme at the preferred time of the ADD and donors? At this stage the timing may not be very precise but the start of the relevant RDP phase will be known. It may be quite possible for DLVW to schedule the commencement of construction within this four or five year phase largely to suit its own programming. This is a matter for discussion with the ADD and donor agency.

7.2. PROJECT NEEDS - RIGS

7.2.1. Having established an approximate start, perhaps only to the year at this stage, the Groundwater Section's programme and resources are reviewed. With the present complement in the Section of 11 drilling rigs, simultaneous construction of two Integrated Projects of the size of the Upper Livulezi should be comfortably carried out. At the moment, however, this is not possible as there is a backlog of boreholes awaiting drilling for urban, institutional and private clients in a dispersed, country-wide programme. The difficulties outlined in Chapter A result in this programme being very slow and expensive. Even if the backlog is cleared there is always going to be a programme of perhaps 60 such boreholes every year, requiring

the full-time committment of up to four rigs.

7.2.2. It has already been stated [Section 1] that in order to even approach the IDWSSD targets, three Integrated Projects of the size of the Upper Livulezi will need to be in progress at once. The drilling capability must therefore be enhanced. This can be done either by:

a) purchasing additional rigs for the Groundwater Section,

b) employing a private contractor to undertake part of the drilling programme.

7.2.3. Because the Groundwater Section's drilling capability is so stretched, a local contractor has been employed to carry out the drilling for the recently started Dowa West Integrated Project. This is very much an experiment to see if the same degree of close management and cost saving can be maintained using a contractor, without losing the essential features of community involvement. It is too early to judge the results; if the necessarily profit-oriented operation of the contractor proves to be incompatible with the overall philosophy of the Integrated Projects, then clearly Government should be implementing the Projects itself. In that case, a solution to the overall shortage of rigs can be found by employing the contractor on the dispersed programme and concentrating Government rigs in the Integrated Projects.

7.2.4. The second way of augmenting the drilling fleet by purchasing new rigs also requires comment. It will be seen from Chapter D, that considerable thought and experimentation has gone into the question of the most appropriate drilling rig for the Integrated Projects. While we think it should be a simple percussion rig, the exact size and specification required is still unresolved. If further drilling rigs are to be required a decision to that effect should be made at this stage so that appropriate funds for capital purchase can be included in the Project Submission Document [next Section]. This is currently being done for all new Integrated Project proposals so that funds are available in future projects when the most suitable rig has been identified.

7.3. PROJECT NEEDS - VEHICLES

7.3.1. The traditional mode of operation of the borehole construction programme [Chapter A] means that there is not an overall shortage of vehicles but many of them are inappropriate for Project use. Tractors and trailers, pick-ups and motorcycles have been successfully adopted as the main transport requirements of Integrated Projects [Chapter D]. The Groundwater Section has not been accustomed to using them extensively in its programme and needs to build up a fleet of transport more appropriate to the Integrated Projects. As in the case of rigs, project planning is the time to be giving preliminary consideration to vehicle requirements and, if necessary, putting a capital item into the submission document for vehicles. In all new proposals we are currently writing in the following vehicles:

one tractor and trailer
one 4WD pick-up
three or four motorcycles.

7.3.2. If a drilling contractor carries out the borehole construction, he will provide his own vehicles but there will still be a need for adequate transport for well teams, pump installation and apron teams and the supervisory and management staff.

7.4. PROJECT NEEDS - STAFF

At this very early stage of planning, the question is one of the overall manpower resources of the Groundwater Section rather than assigning individuals to the proposed project. The latter comes early in the project preparation stage [Chapter C]. Carrying out three Integrated Projects at once within the Groundwater Section would require two or three hydrogeologists on each Project with additional professional staff working on other activities such as urban and irrigation investigations. To meet this the Section has grown quickly in the last two years and must continue to grow steadily for the next few years. The training requirements at this and more junior levels are therefore considerable and are outlined in Chapter F.

8. SUBMISSION OF PROJECT FOR FUNDING

8.1. AIM

The aim of the Project Submission Document is to provide in a standardised form and sufficient detail the objectives, targets, costs and background of the proposed project so that it can be properly evaluated by Treasury and a donor agency. Either Treasury or the donor may call for additional supporting information. It is important to have this assembled in a readily accessible form; this is why the Project Planning Report referred to at the end of Section 6 is so important. The donor agency is quite likely to send a project appraisal mission to Malawi and the mission may wish to discuss the proposal in some detail with DLVW staff.

8.2. SUBMISSION ROUTE

8.2.1. All Development Projects of the Department of Lands, Valuation and Water are submitted through the parent ministry, the Office of the President and Cabinet (OPC). The projects are appraised in OPC by both Development Division and Economic Planning Division (EPD) against the background of Malawi's National Five Year Development Programme before being submitted for Treasury approval and presentation to prospective funding agencies.

8.2.2. This is the route followed by the submission document for the first Integrated Project, the Upper Livulezi, a proposal which originated in DLVW. In the case of proposals prepared in response to requests from NRDP the preliminary cost estimate [Section 5] and Planning Report [Section 6] may go from DLVW to the Department of Agricultural Development for incorporation in an overall RDP proposal and funding submission. NRDP donors may or may not require a separate submission document for the water component, but they will almost certainly wish to discuss details of the proposal with DLVW.

8.3. SUBMISSION DOCUMENT

8.3.1. The proposal is submitted in the form of a "Project Submission Document", the format of which has been standardised for all Government Departments by the Development Division of OPC. The format is shown in Figure B.8.1.

8.3.2. Explanatory notes are provided by OPC. The following are some major points to remember:

a) The objective of the project is the specific purpose of the particular project.

b) The goal of the project is a statement of the National Goal to which the project is a necessary condition but not necessarily the sole contributor (e.g. IDWSSD targets).

c) The project target explains and enumerates the outputs and services to be provided by the project which could not materialise in the absence of the project.

d) The background information gives details of the project's interrelationship with existing or expected future programmes. Any alternative means of achieving the same objective should be stated and reasons given for their rejection in favour of the chosen alternative.

e) The success achieved so far is a description of successful work of a similar nature and relevant to the likely successful outcome of the present project.

8.3.3. Each Project Submission should have a report number at the top left hand corner and the month and year at the top right hand corner of the front page. The report number should be obtained from DLVW Planning Section, with whom a draft of the submission should be discussed. The report number is required for internal use by the Planning Section and is essential for keeping a trace of the latest edition of a Submission Document which has been updated and revised. At least 30 copies of the Document should be prepared and at least one copy lodged with the Planning Section Library. Twenty copies are sent to the Controller of Lands, Valuation and Water together

Figure B.8.1.

Format of Project Submission Document

DEVELOPMENT PROJECT

PROJECT TITLE

RESPONSIBLE MINISTRY

1. OBJECTIVE OF THE PROJECT
2. GOALS OF THE PROJECT
3. PROJECT LIFE (NUMBER OF YEARS)
4. TOTAL PROJECT COST
5. FINANCIAL SUMMARY

(a) Funds requested by category and by financial year

Category	Year					
	1981/82	1982/83	1983/84	1984/85	1985/86 etc.	Total Project Life

(b) Previous expenditure

6. PROJECT TARGET

(i) Details of outputs or services to be provided by the project.

(ii) Phasing of the project output or services - indicating amounts produced annually.

(iii) Expected quantitative and qualitative contribution of project to the amounts of the service or output currently available.

7. BACKGROUND INFORMATION

(i) Is the project part of a wider programme which is already being implemented or is expected to be implemented in future programmes? Give details.

(ii) If there are other means of attaining the same objective state their nature and why they have been rejected.

8. SUCCESS SO FAR ACHIEVED
9. EXECUTION AND SUPERVISION

Figure B.8.1. (Continued)

(APPENDIX A)

PROJECT TITLE

RESPONSIBLE MINISTRY

1. Project Officer

2. Financial Details

(a) Details of Expenditure

Category	Year						
	1981/2	1982/3	1983/4	1984/5	1985/6	etc.	Total Project

(b) Notes on expenditure (Details of proposed work)

(c) Types of inputs required annually to implement the project: broken down by:

(i) Manpower:

Category	No.	Annual Wage	Total Cost

(ii) Physical Inputs:

Item	Quantity	Unit Cost	Total Cost

Figure B.8.1. (Continued)

(APPENDIX B)

RECURRENT ACCOUNT REQUIREMENTS

1. Financial Summary

Annual amounts required on completion of the project.

Category	198./..	198./..			

2. Types of inputs required annually to produce the estimated output: broken down by:

(i) Manpower:

Category No. Annual Wage Total Cost

(ii) Physical Inputs:

Item No. Unit Cost Total Cost

3. Annual Revenue from sales of output:

Type of Output Quantity Unit Price Total Revenue

4. Price assumptions used in costing the inputs. For labour the wage used - for other inputs the import or local price.

Ref. No. 2.3.5. October, 1981.

DEVELOPMENT PROJECT

PROJECT TITLE : UPPER LIVULEZI INTEGRATED PROJECT FOR RURAL GROUNDWATER SUPPLIES

RESPONSIBLE MINISTRY : OFFICE OF THE PRESIDENT AND CABINET/DEPARTMENT OF LANDS, VALUATION AND WATER

1. OBJECTIVES OF THE PROJECT:

To implement on a major project scale an integrated system of providing dug-well protection and borehole rehabilitation together with the construction of new low-cost boreholes and dug-wells in the Upper Livulezi Valley in Ntcheu District.

To optimise the utilisation of groundwater resources.
To provide minimum-cost development of groundwater for rural domestic supplies.
To develop the self-help concept within the borehole drilling programme.
To involve the community in handpump maintenance.
To participate in the UNDP/World Bank Global Handpump Project.

2. GOALS OF THE PROJECT

To supply clean potable water to 60,000 people in accordance with the goals of the International Drinking Water Supply and Sanitation Decade.

3. PROJECT LIFE

Eighteen months Construction Phase with a three year Mainenance Evaluation Phase.

4. TOTAL PROJECT COST

K443,000 for water supplies.

5. FINANCIAL SUMMARY:

(a) Funds required by financial year:

1981/82	1982/83	1983/84	1984/84	1985/86	Total
75,000	308,000	19,000	20,000	21,000	443,000

(b) Previous expenditure:

Up to February, 1981 there were 13 boreholes and 6 protected wells with handpumps in the Upper Livulezi Valley. From March to July, 1981 the Ground-Water Project of the Department of Lands, Valuation and Water has carried out a technical feasibility investigation for an integrated approach to rural water supply using groundwater sources; 24 low-cost boreholes and dug wells have been constructed and equipped at a net cost of K36,000.

(c) Proposed source of finance:

DANIDA, British Government, UNICEF and other external funding for pumps and materials, technical contribution from UK aided Groundwater Project and direction and monitoring of the field testing of handpumps by the UNDP/World Bank Global Hand Pump Project. Malawi Government will fund maintenance costs.

6. PROJECTED TARGETS

(i) Provision of water points in the Upper Livulezi Valley supplying a minimum of 27 litres per head of clean (but untreated) water to 60,000 people at a basic cost of K6 per capita. This is an area which cannot be served by piped water because of the lack of suitable rivers with protected catchments.

(ii) Water points will be constructed within 500 metres one-way walking distance of the great majority of the population to be served

(except in areas of very scattered settlement where walking distances could be greater). Dug wells will serve a maximum of 125 people and boreholes 250 people.

(iii) A project of four and a half years duration during which a system for integrating five components of the rural groundwater development programme will be extended to cover the whole of the Upper Livulezi Valley. The main work will be carried out in the first eighteen months period followed by a three year period for establishing a minimum-cost maintenance system. The five components are:-

(a) the protection of existing shallow wells,

(b) the rehabilitation of existing boreholes,

(c) the construction of new dug wells,

(d) the construction of new low-cost boreholes,

(e) the establishment of a system for maintaining water points. This will be largely community-based and will include training of community nominees.

(iv) The project will incorporate the field testing of rural water supply handpumps under the UNDP/World Bank Global Handpump Project. This component includes the development of locally-manufactured handpumps.

(v) Unquantifiable targets will be:-

(a) Optimum use of a limited natural resource.

(b) Low-cost development of rural groundwater supplies.

(c) Introduction of self-help participation in borehole construction.

(d) Improvement in general health and living standards of the poorest sector of the community.

7. BACKGROUND INFORMATION

The formation of the Department of Lands, Valuation and Water has enabled a more integrated approach to the problems of rural water supply than has been possible hitherto. In the newly formed Groundwater Section of the Water Resources Branch of the Department, the three functional units of Groundwater Resources, Borehole Programme and Dug Wells have been combined administratively for the first time.

Aiming towards the goals of the International Drinking Water Supply and Sanitation Decade, the Department is integrating the programme of all water supply functional units in a rational manner, in order to plan the most appropriate and most economical type of supply for each and every area. This will count upon maximising self-help participation. The overall national target will encompass all rural areas and a strategy is being evolved to do this. In the National Water Resources Master Plan, areas within each district where piped-water supply is possible will be defined and the remainder planned for networks of water points drawing on groundwater.

The Upper Livulezi Valley has recently been withdrawn from the piped-water programme owing to increasing cultivation in the catchment of the surface water sources. The Upper Livulezi groundwater project is to replace it and at the same time will be the first full-scale testing of the new integrated approach. The concentration of plant, vehicles and technical expertise and the closer liaison with the DDC made possible by such a scheme, will allow a much more cost-effective use of resources than has been the case with the previous dispersed borehole programme. It will cut significantly the *per capita* cost of providing groundwater points for rural communities. A low-cost borehole provided under such a programme would comprise a relatively shallow, PVC-lined, correctly gravel-packed and hydraulically efficient borehole and would cost in the region of K1,500 [Appendix B] compared with an average cost at present of K4,500 for a steel-cased, deeper and less efficient borehole. Dug wells are estimated to cost K750 [Appendix B]. Both costs include the handpump and water point surround.

The projected 1990 population of the area is 60,000 of which 7,000 has been served by the feasibility investigation and 4,000 by existing boreholes and wells.

8. SUCCESS SO FAR ACHIEVED:

The Groundwater Section of the Department, supervised by Groundwater Project staff has recently completed a small scale feasibility investigation in the Livulezi area in which 24 new low-cost boreholes and 10 dug-wells were installed at spacings to limit walking distance to 500 metres (maximum), 7,000 people have been provided with a minimum quantity of 27 litres per day of clean water. The total cost of this work was K36,000 not including the cost of pumps provided from Commodity Aid stocks. These pumps will eventually be replaced with Malawi Pumps.

9. EXECUTION AND SUPERVISION

The project will be executed and supervised by the Groundwater Section of the Department of Lands, Valuation and Water. The UK ODA Groundwater Team within the Department will provide overall direction of the pilot project.

10. HANDPUMPS

The Upper Livulezi Project is to be used for Malawi's handpump evaluation programme as part of the UNDP/World Bank Global Handpump Project. The prime objective of this latter project is the development of simple, reliable, shallow, medium and deep lift handpumps which can be locally manufactured, easily installed and largely maintained by the user community.

The Malawi Government has agreed to participate in the UNDP/World Bank Global Handpump Project. Handpumps for testing and evaluation will be supplied by external donors supporting the Upper Livulezi Project. The Government input will be:-

(a) Project Hydrogeologist who will coordinate Government's involvement.

(b) Field Accommodation for a UN Volunteer at the Project Headquarters in the Livulezi Area.

(c) Logistic support to the UNV at the discretion of the Project Hydrogeologist which will include office, stores, workshop, transport and secretarial facilities and essential running costs for any vehicle supplied to the UNV.

The UNDP/World Bank input will be:-

(a) assistance of the UNDP/WB Regional Project Officer (RPO) in the following activities:-

- (i) development, monitoring and evaluation of the project
- (ii) feed-back of information from other African projects
- (iii) provision of modifications and designs for locally-produced handpumps and accessories
- (iv) supply of selected materials for prototypes
- (v) selection and procurement of pumps
- (vi) identification of and liaison with other donors
- (vii) overall direction of the UN volunteer.

(b) recruitment and financial support of the UN Volunteer. The duties of the UNV will be :-

- (i) to supervise correct installation of handpumps
- (ii) to develop the system of handpump performance monitoring and evaluation
- (iii) to report failures to the maintenance team for immediate attention and to assist accordingly
- (iv) to assist in the development and quality control of locally-produced components
- (v) to report through the Department of Lands, Valuation and Water to RPO, Nairobi.

11. <u>EQUIPMENT AND MATERIALS</u>

Up to four percussion drilling rigs would be provided by the Department of Lands, Valuation and Water to carry out borehole construction under the direct supervision of the project hydrogeologist.

The following vehicles would also be provided by the Department:-

- (a) one tractor and trailer to service rigs and well-digging teams
- (b) one light pick-up for the project hydrogeologist
- (c) three motorcycles.

Major material requirements for the construction of new boreholes would be PVC screen and accessories purchased locally. Correctly-graded lakeshore beach sand would be used as a gravel pack and cement would be required for plinth, surround and washing slab. For the dug wells, the

major requirement is cement for casting rings and slabs and for the surface works (plinth, surround and washing slab).

12. MAINTENANCE

Maintenance of the handpumps and water supply will be effected by an improved multitiered system which will involve the maximum of community participation at the village level. It will comprise:-

(i) Central Government/Departmental Level

(a) Planning and strategy (handpump policy)

(b) Research and development in handpump design, with the major target to minimise and simplify maintenance

(c) Training of district pump technicians

(d) Procurement of pumps, spares, tools and equipment

(e) Monitoring of the maintenance programme

(f) Distribution of equipment to district stores

(ii) District and Regional Level

(a) Supervision of about 1,000 pumps by a trained technician (District Pump Technician) with support driver and one vehicle (1 ton pick-up)

(b) Store for spares

(c) Maintenance records for all water points within district

(d) Training of area pump mechanics

(e) Liaison with District Development Committee

(f) Periodic inspection of area water points

(g) Repair or replacement beyond capabilities of area mechanics

(h) Estimate of annual maintenance requirements for spares etc.

(iii) Area Level

(a) Project Maintenance Assistants chosen on the basis of skills shown during construction phase. Further training by District Pump Technician or DLVW training courses. Supervision of 150 - 200 pumps.

(b) Visits to each pump/village at least once every four months (bicycle)

(c) Recording all repair work and reporting to District Pump Technician.

(iv) Village Level

(a) Village Pump Attendants chosen by the village Development Committee responsible for all pumps in one village (could be men or women).

(b) Attendants ensure that the pumps are properly used, pump surrounds are kept clean and acts of vandalism are prevented.

(c) Minor replacement, preventive maintenance and all simple repairs will be effected at this level. When major repairs or replacement parts are required the attendants will notify the Area Pump Mechanic.

(d) The attendants will be trained on site by Project Maintenance Assistants at the time of installation.

JULY, 1982

APPENDIX A

PROJECT TITLE : UPPER LIVULEZI INTEGRATED PROJECT FOR RURAL GROUNDWATER SUPPLIES

RESPONSIBLE MINISTRY : OFFICE OF THE PRESIDENT AND CABINET/DEPARTMENT OF LANDS, VALUATION AND WATER

PROJECT OFFICER : CHIEF WATER RESOURCES OFFICER

Details of Expenditure, Total Project Cost K443,000

Category	Construction Phase		Maintenance Evaluation Phase			Totals
	1981/82	1982/83	1983/84	1984/85	1985/86	
003 Water Supplies						
(a) Borehole and dug wells	75,000	250,000				325,000
(b) Rehabilitation		16,000				16,000
(c) Establishment of a maintenance system			18,000	18,000	18,000	54,000
010 Special Expenditure (stores for materials)		10,000				10,000
Contingencies and inflation		32,000	1,000	2,000	3,000	38,000
Total	75,000	308,000	19,000	20,000	21,000	443,000

Notes on Expenditure

(1) Each completed water point, either borehole or dug well, will be invoiced together with a completion report on the basis of itemised costs (Appendix B)

APPENDIX B

1. Typical low-cost borehole

Percussion drilled to 20 m at 200 mm diameter, equipped with 8 m of blank 110 PVC casing and 12 m of slotted 110 mm PVC screen (12% open area, 0.75 mm slot).

Annulus filled with 0.7 - 2.5 mm graded (beach sand) filter, handpump installed and protective apron constructed (including drain and washing slab). All locally available building materials supplied by the community.

Sample Costs	Malawi Kwacha (1 $US = 1.1 MK)	
(a) Drilling : 0 - 15 m	450	
15 - 20 m	200	
Sub total		650
(b) Other operations:		
Development (4 hours)	80	
Testing (4 hours)	80	
Movement of rig (say 5 km)	35	
Rigging up and down	50	
Cement grout	20	
Sub total		265
Construction total		915
(c) Materials:		
PVC casing plain 8 m	70	
PVC casing slotted 12 m	195	
PVC end cap and centralisers	10	
Beach sand	60	
Cement for apron	60	
Sub total		395
Borehole cost (a) + (b) + (c)		1,310

APPENDIX B (Continued)

(d) Handpump:	Malawi Kwacha
(i) Locally manufactured Malawi borehole pump at K 250	
Typical borehole cost	1,560
(ii) Consallen pump at K 750	
Typical borehole cost	2,060
(iii) India Mark II at K 750	
Typical borehole cost	2,060

2. Typical dug well

6 m deep, 2 concrete rings (1 m diameter x 2 m deep) inserted with bottom cover slab, clay back-filled, top slab, handpump and apron with washing slab. Major self-help component.

Sample costs

Digging (to include wells team supervision, transport and all other site activities)	450
Locally made pump (Mark V or Madzi PVC pump)	150
2 concrete slabs	60
2 concrete rings	60
Cement for apron	60
Total dug well cost :	K 780

APPENDIX C

DETAILED PROJECT COSTS

388 "water point units" each unit serving 125 people. Each borehole supplies 250 people and comprises two water point units and each shallow well serves 125 people and comprises one water point unit. Possible water point totals: 144 boreholes and 100 shallow wells (final decision rests with Project Hydrogeologist on site).

COST BREAKDOWN	MALAWI KWACHA
(A) Construction	
20 typical boreholes fitted with Consallen pumps	41,200
25 typical boreholes fitted with India Mark II pumps	51,500
99 typical boreholes fitted with "Malawi" pumps	154,440
100 typical shallow wells	78,000
Rounded total	325,000
(B) Rehabilitation	
37 Malawi pumps (3 for old and 24 for feasibility boreholes)	9,250
Rehabilitating 13 boreholes (allow approximately 50% of construction costs, i.e. K460	5,980
Cement for 13 aprons	650
Rounded total	16,000
(C) Stores	
To be constructed in Project Area	
Total	10,000
(D) Maintenance	
Costed at approximately 5% per year of capital costs for three years to establish a maintenance system, designed as described under Part 2 above to maximise community participation. Cost per year K18,000.	
Total	54,000

APPENDIX C (Continued)

		MALAWI KWACHA
(E) Contingencies and Inflation		
At approximately 15% of total Project cost outstanding at July 1982	Total	38,000
(F) Project total		443,000

COSTS DISTRIBUTED BY DONOR (as at 30th July, 1982)

A. AGREED

(a) British Government

20 Consallen handpumps to be supplied by UK Overseas Development Administration (plus input by 2 Technical Co-operation Officers of the ODA Groundwater Project not costed to the Livulezi Project)		
	Total	15,000

(b) UNICEF

25 India Mark II handpumps CIF Malawi (estimated)		10,000
PVC borehole casing, screen and rising main for 50 boreholes		11,923
25 Malawi Mark I preproduction handpumps		6,250
300 bags cement		2,130
	Total approximately	30,303

B. PROPOSED

(a) UNICEF

(i)	111 Malawi (MALDEV) borehole handpumps estimated at K250 (NB 37 for rehabilitation, 74 for construction)	27,750
(ii)	100 dug well handpumps estimated at K150.00	15,000
(iii)	PVC borehole casing, screen, end caps for 94 boreholes (at K275.00 for 20 m boreholes)	25,850
(iv)	Cement for aprons for 94 new boreholes, 100 dug wells and 13 rehabilitated boreholes (at K60)	12,420
(v)	144 m^3 gravel pack at K60.00 per m^3 delivered (NB estimated 1 m^3 for each of 144 boreholes)	8,640

APPENDIX C (Continued)

		MALAWI KWACHA
(vi)	200 slabs and 200 rings for 100 dug wells	12,000
	(K30 per slab and K30 per ring)	12,000
(vii)	Buildings for maintenance organisation	10,000
		111,660
	Plus approximately 15% contingency	17,000
	Rounded total	129,000

(b) DANIDA

Construction of:

(i)	144 boreholes (at K915 for typical 20 m borehole)	131,760
(ii)	100 dug wells (at K450 for typical 6 m dug well)	45,000
(iii)	Rehabilitation of 13 boreholes at K460	5,980
	Total	182,740
	plus approximately 15% contingency on outstanding works at 30th July, 1982 (approximately 70 boreholes, 70 dug wells and rehabilitation)	15,000
	Rounded total	198,000

C. OTHER INPUTS

(a) Maintenance costs to be borne by Malawi Government

3 Years total 60,000

(b) Drilling and other Equipment

To be provided by the Groundwater Section of Department of Lands, Valuation and Water. Acknowledgement is made of the funds for equipment to be used in the Project from UNDTCD, "Design of low-cost boreholes for rural water supplies project" MLW/80/003.

(c) UNDP/World Bank Global Handpump Project

UNDP/World Bank will be providing the UN Volunteer and support costs together with periodic assistance from the Regional Project Officer in Nairobi.

with a draft covering letter explaining how the proposed project fits into the Five Year Plan, mentioning any changes from previous submissions, indicating possible donors and noting any other factors likely to influence reception. The Project Submission Document is formally issued by the Controller.

8.4. UPPER LIVULEZI INTEGRATED PROJECT

8.4.1. The full text of the Submission Document for the Upper Livulezi Project is included here to give an indication of the amount of detail required. The Upper Livulezi, as is made clear throughout this Manual is the first Integrated Groundwater Project in Malawi. The aims of the various components of the Project were clear at the outset but many of the solutions and operational procedures have been evolved gradually during the life of the Project. Because of the need to establish these procedures in the field the Upper Livulezi Project was commenced as a full scale pilot project (following on from the feasibility study) before external funding was confirmed. The first Submission Document was written in July, 1981; it was substantially revised in October, 1981 to incorporate the UNDP/World Bank Global Handpump Project and the appendices were rewritten again in July, 1982 in response to a change of donor.

8.4.2. Now (November, 1982) that the Upper Livulezi Project is well over halfway through its implementation stage the details of the operational procedures are becoming much more clearly established. Reviewing the Submission Document in this light, the design principles and costs on which it is based are more or less confirmed. The proposed maintenance structure given in Item 12 of the Document represented the outline envisaged in October, 1981. The way in which this has been modified and built upon is described in Chapter E of the Manual.

9. DONORS

9.1. BACKGROUND

The water development programme of Malawi is to a very large extent dependent on external funding by donor countries and organisations. As can be expected with having so many funding agencies the conditions attached to the funds are extremely varied. Three main categories can be identified as follows:

a) Loan funds which are repaid together with interest. The rate of interest varies from a 1% service charge to the international banking interest rate (currently 12%). However the real cost is reduced since repayments of capital are deferred over a period of up to 40 years.

b) Grant aid which does not have to be repaid but may have conditions attached to it, such as defining the country from which materials can be purchased.

c) Commodity aid which similarly does not have to be repaid and comes in the form of materials and equipment which can either be purchased locally or from the donor country.

9.2. POLICY

The Department's(DLVW) policy in using the limited funds available is to direct loan funds to projects which generate revenue by which to repay them. The urban water supply schemes do this by a combination of charging metered consumers and public sales at standpipe kiosks. They are thus established on a self-financing basis and are most suited to loan funding. In the rural areas Government policy has been to supply domestic water free of charge and this is likely to remain so for the forseeable future. Grant aid funding is therefore more suited to the rural water supply programme.

9.3. LOCAL COST CONTRIBUTION

9.3.1. Although a donor may have been identified and is willing to fund a project, implementation is often not possible due to a shortage of funds to meet the local cost contribution. Donors insist on this

condition, especially those providing grant aid. The local contribution usually varies; for example, within NRDP this may be 50% on salaries, 10 - 50% on other operating costs and a nil contribution on capital investments. UNICEF, an active donor in the water sector are, for example, very willing to provide funds for capital items and materials but not for running costs, for which another donor must be found. A brief explanation of the mode of financial operation of the Groundwater Section of DLVW will help to explain the problem.

9.3.2. All activities of the Groundwater Section are carried out under the operations of the Borehole Fund. This is a revolving Treasury fund which has to balance its accounts at the end of each financial year. Funds are allocated by Treasury at the beginning of each financial year against itemised estimates for salaries, wages, fuel and materials, based on the size of the proposed construction programme for that year. At the end of the year expenditure must be balanced by income from completed wells and boreholes. Thus every well or borehole must have a "purchaser" who pays the full, real cost of construction including all overheads. There is no provision within this mode of operation for a local contribution to construction. The Integrated Projects clearly had to be operated within this system and a solution had to be found.

9.3.3. The general procedure which has been adopted is to charge the donor through the RDP for each completed water point, giving an itemised breakdown of construction costs. Full details of the charging procedure are given in Chapter D. In the case of the Upper Livulezi Project, which is not funded through NRDP, materials costs are submitted to one donor (UNICEF) and construction costs to another (DANIDA) [see also Section 8]. Within the RDPs the donor is paying a very high proportion of the cost of the water component which must be offset by a higher local contribution to other components of the project.

9.3.4. The three year cost of establishment of the maintenance organisation [Section 5], as written into the preliminary costs, is a Malawi Government contribution. This amounts to a local cost contribution of 10 - 12%. Other activities associated with the Integrated Project [Chapter D] such as health and agricultural extension services may also be a local contribution. These may be very small in cash terms

but are a significant contribution to the overall success of the Project. The participation of the community in the self-help activities [Chapter D] is a substantial input which cannot be realistically costed as a local contribution. It is, however, absolutely vital to the success of the Integrated Project approach.

9.4. DONORS AND THE QUESTION OF BENEFITS

9.4.1. The National Rural Development Programme is presently the main source of funds for the Integrated Groundwater Projects. It makes use of loan funds which have a nominal interest rate to cover service fees. The overall economics of each RDP have to meet at least a 12% internal rate of return. The amount allocated to the rural water supply component of the project has therefore to date been limited as it is not yet considered to have any direct and quantifiable economic benefit in the form of increased agricultural productivity.

9.4.2. If the benefits of an adequate water supply to the rural farming population can be shown to have a more direct influence on increasing productivity, the percentage of funds allocated might be increased. For example in the proposed Balaka RDP water from the wells and boreholes will be used to spray cotton. Within the Upper Livulezi Project efforts are being made to stimulate the growth of income-generating activities associated with the waterpoints. If activities such as waterpoint gardens and brickmaking [Chapter D] become successful and widespread, the Integrated Project may have contributed significantly to increased productivity in the area.

9.5. PRESENT FUNDING POSITION

9.5.1. Within the next few years the programme of Integrated Projects is likely to be closely linked with the NRDP and to follow its priorities. In addition to the recently-commenced Dowa West Integrated Project, similar projects have been (or soon will be) submitted to donors by the ADD's for several other areas and our tentative programme currently (November,1982) looks like this:

Table B.9.1.

ADD	RDP/Integrated Project	1990 Population to be served	Total Project Cost Kwacha	Possible Starting Date	Duration of Construction Phase (years)
Lilongwe	Livulezi	60,000	443,000	Nov.1981	1¼
Kasungu	Dowa West	70,000	456,000	July 1982	1½
Salima	Nkhotakota	121,000	904,000	1983-1984	2½
Lilongwe	Lilongwe NE	247,000	1,600,000	1984-1985	4 - 5
Lilongwe	Dedza Hills	173,000	1,293,000	1983-1984	4
Kasungu	Mchinji	151,000	1,108,000	1985-1986	3
Mzuzu	SW Mzimba	78,000	722,000	?	1½
Liwonde	Balaka	93,000	790,000	1984-1985	2

9.5.2. This represents a very full programme for the next few years, building up to an operation comprising three projects of the size of the Upper Livulezi Project going on at once. These would ideally be one in each Region to spread the development activity evenly and with carefully staggered starting dates to facilitate adequate project preparation. A programme of this size would be the maximum that could be properly managed and staffed with the present complement of the Groundwater Section. The rapid growth of the programme is an indication of the great interest shown by donors in the Integrated Project approach. Indeed, it has been said that when the community-based maintenance structure is established and proven, funding independent of NRDP may be available for a programme of Integrated Projects to serve the remainder of the rural population still in need of improved supplies.

10. CONCLUSION OF PLANNING PHASE

10.1. The planning phase of the Integrated Project is now drawing to a close. The Project Submission Document is with Treasury and OPC or, in the case of an NRDP proposal, the Preliminary Cost Estimate is with the Department of Agricultural Development. There is then a considerable time interval between planning and preparation of the Integrated Project.

10.2. STEPS BETWEEN PLANNING AND PREPARATION

10.2.1. There is a period of relative inactivity for the Groundwater Section between the completion of planning and the commencement of chargeable activities in project preparation. However, several important steps may be going on which the Section should keep abreast of and to which it may have important contributions to make.

10.2.2. Where the Integrated Project is to be the water component of an RDP, the Department of Agricultural Development may wish to discuss the preliminary cost estimate and background to the Project before incorporating it in their overall proposal for the RDP.

10.2.3. The donor agency may send an appraisal mission at this stage or after the RDP proposal is complete. In either case the mission will wish to discuss the proposal for the water component in some detail with DLVW staff. Where the Integrated Project proposal has been submitted for funding outside the NRDP, a donor agency is also likely to appraise the proposal.

10.2.4. In the case of an NRDP proposal, the full proposal document will be circulated to interested Government departments for comment. The Groundwater Section should read the relevant passages very carefully to ensure that their proposal has been incorporated without significant alteration. Particular points to look out for are that:

a) The level of service and design principles have not been arbitrarily altered in a way that would affect the integrity of the Integrated Project approach.

b) The costs have not been changed.

c) The timing/phasing and starting date are as agreed.

An example of a serious problem which has already arisen is an RDP proposal splitting an Integrated Project so that the dug well and borehole components went to different donors and would therefore be separately planned and phased. This has been rejected by DLVW as it would have destroyed the nature of the Integrated Project (and costs would have been very much higher).

10.2.5. The procedure for invoicing for completed waterpoints will have to be agreed with the donor, and if necessary with the relevant ADD. The financial mode of operation of the borehole and well construction programme may have to be explained [see Chapter D].

10.2.6. Once all these issues are resolved the proposal goes on to the donor's headquarters and decision-making body. Eventually, if the Project is approved and signed, a target date is set for the release of funds. The setting of a target starting date, if it is not too far ahead, marks the end of the planning stage of the project. If there is a long time interval, updating of costs may be required.

10.3. TIMING

10.3.1. The overall time taken by the planning stage depends on many factors. If an Integrated Project proposal is being made for an RDP and there is only the groundwater option the preliminary survey [Section 4] and costing [Section 5] may be accomplished in approximately one month. A donor will probably be already identified and the appraisal of the RDP phase proposal may be completed relatively quickly. In the case of the only RDP Integrated Project (Dowa West) that has reached preparation and now implementation the timing has been as follows:

a) August, 1981. Initial request from Kasungu ADD and the donor (IFAD) for an Integrated Project proposal for Dowa West.

b) September, 1981. First proposal and Submission Document prepared for service provision to meet the(then) cash limit of K250,000 for the water component.

c) October, 1981. Meetings between DLVW, Kasungu ADD and donor's appraisal mission. Cash limit raised so that service can be provided to whole of EPA DO 1.

d) December, 1981. Project Submission Document prepared for 1990 population of DO1 for total Integrated Project cost of K456,000.

e) Early 1982. Funding agreed.

f) February, 1982. Meetings between DLVW, Kasungu ADD and donor to set target starting dates of 1st April for Preparation Phase and 1st June for Implementation Phase.

10.3.2. Where more than one option [Section 3] is to be examined the time taken is clearly much greater, particularly if there is a need for detailed feasibility investigations.

CHAPTER C

PROJECT PREPARATION

CHAPTER C

PROJECT PREPARATION

CONTENTS

PREFACE

The Integrated Project starts in earnest with the preparation phase. Funds are now being spent; the whole of the preparation activities are chargeable and must be accounted for as an overhead to the Project.

The preparation phase takes up the information gathering begun during planning. In the planning phase the hydrogeological data is collected and evaluated to investigate the feasibility of the Integrated Project. In the preparation phase the data is assembled in more detail in order to implement the Project.

Project preparation itself starts with an "office phase" in which the data is collected and administrative arrangements for the Project are set in hand. It then moves into a "field phase" of informing the local community and establishing the operational headquarters of the Project and gives way to the implementation phase of the Project as full scale waterpoint construction begins.

1. INTRODUCTION

1.1. The dispersed programmes of dug well and borehole construction [briefly described in Chapter A] do not bring together all of the available resources in an effective way. The large body of valuable existing data is not properly consulted, the expertise, local organisation and local knowledge of other Government Departments is not exploited and, in the borehole programme, the local community is hardly involved at any stage.

1.2. In preparing for an Integrated Project the aim is to utilise all these existing resources to the full by:

a) Liaising with other Government Departments both at Headquarters and in the Project area to ensure that their support and co-operation are enlisted from the start. This will greatly assist the efficient implementation of the Project and is essential for establishing the associated health, sanitation and agricultural inputs to the Project.

b) Bringing together all the available data on hydrogeological conditions and present and future population distribution to ensure optimum waterpoint siting.

c) Motivating the people in the area to take responsibility for their own waterpoints by keeping them informed at all times and allocating to them specific tasks.

Sections 3, 4 and 5 of this Chapter describe in detail how each of these is carried out.

1.3. The remaining Sections of the Chapter largely describe the administrative and logistical preparations for the Project. The prime aim is to bring together all the necessary plant, materials, vehicles and staff at the same time to begin the implementation phase of the Project.

1.4. The first step in the preparation is to select a hydrogeologist to carry the Project through from this point to successful implementation. Throughout the Chapter (for simplicity) reference has been made to the "Project Hydrogeologist". In practice an Integrated Project should have a more experienced hydrogeologist as the Project Manager supported by one or two hydrogeologists as assistant managers. If there were two there could be an apportioning of responsibility between them; one to dug wells and one to boreholes.

1.5. In writing the Chapter on Project Preparation, much has naturally been drawn from experience in the Upper Livulezi and Dowa West Projects. Both of these are so close to Lilongwe that day visits are easy. When preparing for a Project much further from Headquarters day visits would not be feasible. Rather than a single office phase followed by a field phase, the preparations would then require longer visits in which the liaison work and meetings would be concentrated, alternating with periods at Headquarters.

2. IDENTIFICATION OF PLANT, VEHICLES AND STAFF

2.1. CAPITAL PURCHASES

Once funding is agreed and a target starting date has been set, then the preparation phase of the Project can begin. It will be seen from the following sections that detailed preparations for the Project require about three months but any major capital purchases will probably need to be ordered well before this. This applies particularly to the drilling rig suggested in Chapter B, which may take up to a year to arrive from initial ordering. Obtaining new vehicles - tractor and trailer, pickup and motorcycle may be much quicker but will depend on each donors's purchasing regulations. Some donors may permit local purchase, others may require ordering directly from their own Headquarters to the manufacturer. Each case will have to be discussed individually with the donor.

2.2. PLANT AND CREWS FOR BOREHOLES

2.2.1. This is primarily a choice between using Government drilling rigs and employing a Contractor. A decision in principle may have been taken in the planning phase, based on the future drilling programme as it appeared at the time. A meeting of the Groundwater Section of DLVW should be held in the first week of the preparation phase to review the choice in the light of the current drilling programme and demands on the rigs.

2.2.2. If there are four Government rigs that can be fully committed for the duration of the Project, the Drilling Superintendent should be asked to identify them at the meeting and organise their programme through the preparation phase so that they are available in the Project at the target mobilisation date. If possible this programme should permit the headmen and supervisors to receive training periods in an existing Integrated Project [Section 6].

2.2.3. If there are not sufficient rigs to carry out the drilling for the new Project, existing Projects and other commitments then there may be no alternative but to employ a Contractor. The meeting should explore the possibility of using a Contractor for part of the

dispersed drilling programme while concentrating Government rigs in the Integrated Projects [Chapter B]. Informal discussions with Contractors should follow and a second meeting of the Groundwater Section should make a decision in the third week of the preparation phase. If the decision is to use a Contractor for the Project drilling, a formal contract will then have to be prepared by the Project hydrogeologist. The process of writing the contract, receiving and evaluating tenders and eventually signing an agreement may take some weeks and this may now determine the date that drilling commences.

2.2.4. The drilling contract for the Dowa West Integrated Project is included here as an example. It will be seen that the detailed instructions in the Technical Specification require the Contractor to carry out the construction operations as described in Chapter D. If a Contractor is to be used, the supervisors and rig headmen should have a two-week familiarisation period in an existing Integrated Project, exactly as in the case of Government drilling staff.

2.3. PLANT AND CREWS FOR DUG WELLS

The same Groundwater Section meeting [see 2.2.3.] should discuss the requirements of the Project for dug wells staff and equipment. A dug well supervisor [Section 6] for the Project should be identified at this stage.

2.4. VEHICLES

The Project hydrogeologist will require a vehicle and driver from the beginning of the preparation phase. The other vehicles for the Project may have been ordered [Section 2.1] or will be provided by the Contractor or will be drawn from the drilling programme along with the rigs at the time of mobilisation [Section 11].

2.5. PROJECT CIRCULARS

After the initial Groundwater Section meeting has identified the plant, vehicles and staff for the Project, the hydrogeologist should write a circular recording the decisions and informing all members

AGREEMENT

THIS AGREEMENT made the......................day of.................... one thousand nine hundred and eighty two BETWEEN the GOVERNMENT OF MALAWI (hereinafter referred to as "the Government") of the part and ....whose address is ....(hereinafter referred to as "the Contractor") of the other part.

WHEREAS the Government is desirous that such Works as are hereinafter mentioned for the drilling, lining, completion and testing of certain boreholes for rural water supplies shall be executed and completed in the manner and during the period hereinafter provided.

AND WHEREAS the Government has accepted a Tender for the execution and completion of such Works.

NOW THIS AGREEMENT WITNESSETH as follows:-

1. The following documents shall be deemed to form and be read and construed as part of this Agreement, viz:-

   a) The Conditions of Contract
   b) The Specification
   c) The Schedule of Prices

2. In consideration of the payments to be made by the Government to the Contractor as hereinafter mentioned the Contractor hereby covenants with the Government to execute and complete the Works in conformity in all respects with the provisions of the Contract.

3. In consideration of the execution and completion of the Works the Government hereby covenants to pay the Contractor the Contract Price at the times and in the manner prescribed in the Contract.

IN WITNESS whereof.......................................Controller of Lands, Valuation and Water for and on behalf of the Government and....................................for and on behalf of the Contractor have hereunto set their respective hands and seals the day and year first above written.

SIGNED SEALED AND DELIVERED on behalf of the GOVERNMENT OF MALAWI

by the said.....................................

in the presence of:..............................

....

....

THE COMMON SEAL of..

....

was hereunto affixed in the presence of:

....

....

CONDITIONS OF CONTRACT

1. Execution of Work

The Works shall be executed by the Contractor in the best and most workmanlike manner, with the best materials according to the particulars contained in or implied by the Contract and to the full and entire satisfaction of and in accordance with the instructions and directions given by the Government's Representative. The Government's Representative shall have full liberty at all times to inspect the work, examine and test the materials and workmanship and may reject any materials or workmanship which are defective, unfit or improper for the purposes to which they are applied, or to be not in accordance with the Technical Specifications, instructions or directions.

2. Supervision and Inspection of Work

The Contractor shall carry out the Works under the general direction and supervision of Government. Government shall be entitled at any time to inspect the work in progress and the Contractor shall provide every assistance and reasonable facility to the Government's Representative for such inspection, and for ascertaining full knowledge regarding progress, workmanship and materials used in the work. Such inspection will include, but not be restricted to, plumbing of borehole depths before payment is made.

The right of inspection and supervision shall not diminish the Contractor's responsibility for the proper performance of his obligations under the Contract.

3. Superintendence

The Contractor shall give all necessary and proper superintendence during the execution of the Works.

4. Sub-Letting

The Contractor shall not assign this Contract or any part thereof or any benefit or interest therein or thereunder, or sublet the whole or any part of the Work without the written consent of Government.

5. Sufficiency of Tender

The Contractor shall be deemed to have satisfied himself before tendering as to the correctness and sufficiency of his tender to cover all his liabilities and obligations set forth or implied under the Contract, and all matters and things necessary for the proper completion of the Works.

6. Prices to be Firm

The rates entered in the Schedule of Prices shall be firm from the commencement of works until 31st March, 1983 and no variations will be permitted. The only exception to this will be in respect of the Fuel Price Variation Clause at 12.

7. Precautions Against Accident or Injury

(i) The Contractor shall be responsible for and provide against all risks and contingencies that may arise from the Works. The Works shall be at the sole risk of the Contractor from the date of commencement of the Works until the date of completion and he shall be responsible for and make good any damage thereto during that time however caused and the Contractor shall insure against such risks to such an extent and in such a manner as he deems fit.

(ii) The Contractor shall take all due precautions against and be responsible for any accident to any person whether such a person is, or is not, in the employ of the Contractor.

8. Damage to Crops

The Contractor shall take all due precautions against and be responsible for any damage to adjoining lands or any crops thereon.

9. Indemnity

The Contractor shall keep the Government of Malawi indemnified against all claims for damages, compensation or otherwise in respect of any accident or injury, to any person and against all actions, claims and demands whatsoever arising from or in connection with the operations to which the Contract relates.

10. Payment

The Contractor, shall after the signing of the Form of Agreement be paid a Contract mobilisation charge in the form of a lump sum equal to 20% of the estimated cost of the minimum number (80) of boreholes required by the Contract. The estimated total cost of these 80 boreholes is K100,000. The Contract Mobilisation Charge shall therefore be a sum of K20,000 payable by Government to the Contractor within 14 days of the signing of the Agreement. This sum shall then be deducted in equal installments of K250.00 from the Contractor's invoices for the first 80 boreholes completed in the present Contract.

If the Contractor:

a) Has become bankrupt or has had a receiving order made against him; or

b) Has without any lawful excuse failed to commence the Works or has similarly suspended the progress of the Works after receiving from the Government's Representative written notice to proceed; or

c) Has failed to proceed with the Works with due diligence or despatch or with due regard to the Programme agreed with the Government's Representative; or

d) Is not executing the Works in accordance with the Contract or is persistently or flagrantly neglecting to carry out his obligations under the Contract; or

e) Is unable to proceed with the Works for any reason whatever

Then the Contract shall be determined by Government. In this case the Contractor shall be paid for all the Works completed to the date of determination of the Contract, less the balance of the Contract Mobilisation charge outstanding on this date. If after payment by Government for all such Works, a proportion of the Contract Mobilisation charge remains outstanding, then plant, vehicles and equipment belonging to the Contractor, whether being used in the Works or not shall become the property of Government in settlement of the oustanding amount. In this case the value of such plant, vehicles and equipment shall be estimated by an independent assessor.

The Contractor shall render on completion of each borehole in a form provided by Government full details of each borehole as laid down in the Technical Specification, together with his own payment certificate or invoice. Government will pay the sums laid down in the Schedule of Prices in respect of each borehole less the K250.00 specified above within 30 days of receiving the Contractor's invoice, provided the work has been completed to the full satisfaction of the Government's Representative and the expenses were justifiably incurred.

11. Variations and Extras

The Contractor shall on the written authority of Government vary the Works by way of addition to or omission from the specification, but the Contractor shall not make any variation or omission without such authorisation. No claim for any addition shall be allowed unless it shall have been executed by the authority of the Government's Representative as herein mentioned.

12. Variation of Price (Diesel)

If after the date of the Tender there shall be an increase in the prevailing price of diesel over the price of diesel at the date of the Tender, where the diesel is necessary for the Contract and purchased by the Contractor at ruling market prices after the date of the price increase, and this results in an increase of cost to the Contractor in carrying out the Works, the net increase shall form an addition to the Contract and be paid to the Contractor accordingly.

In the event of such a price increase the Contractor shall submit within 14 days a written request for the Variation of Price (Diesel) Clause to come into effect. He shall in the same letter submit an estimate of the effect of such an increase in the price on the cost of the Works remaining at the date of the price increase. Government shall then, at its discretion, allow the Variation of Price (Diesel) Clause to come into effect. Following this, the Contractor shall then set out in writing details of diesel purchased for and consumed in carrying out the Works. These details shall be submitted together with supporting vouchers, invoices or receipts at regular and agreed intervals to the Government's Representative who shall satisfy himself as to the validity of the claim before passing it for payment.

Before commencement of the Works the Contractor shall provide in writing details of the procedure he proposes to adopt to ensure adequate accounting for diesel consumed in carrying out the Works covered by this Contract only.

13. Special Risks

Neither party shall be liable to the other of them, whether by way of damage or compensation or charges in respect of any loss of working time or delay or otherwise arising out of or in any way connected with any strike of workmen, Act of God, unavoidable accident, political disturbance, public emergency or any other circumstance beyond the control of either of them. Payment for work done up to the time of such a contingency will be made to the Contractor in acccordance with the Schedule of Prices irrespective of whether boreholes are completed or not.

TECHNICAL SPECIFICATION

1. GENERAL INFORMATION

1.1. Description of Works

The proposed drilling programme consists of 80 to 100 boreholes to be constructed in the Dowa West Integrated Groundwater Project. This is a new approach to groundwater development for rural water supplies which aims for greater efficiency and improved construction by concentrating rigs, transport and professional supervision within a small area. A copy of the Project Document is attached.

By this approach the cost of borehole construction has been dramatically reduced, and continued efficient and cost-effective operations will be a major concern of Government in the present Contract.

1.2. Location

The Dowa West Project area is part of Kasungu ADD. The boreholes in the present Contract will be concentrated in EPA 1 (see attached map). The Department of Lands, Valuation and Water will establish its project headquarters at Madisi and the Contractor will be expected to do the same.

1.3. Timing of Programme

The proposed drilling programme will commence as soon as the preliminary survey work is completed and first sites are cleared by the community. It is anticipated that drilling will commence from 1st August, 1982 and the Works are likely to take less than 8 months.

1.4. Definition

The Government's Representative means the Dowa West Integrated Project Hydrogeologist, or any deputy of his who shall be notified in writing to the Contractor.

2. OPERATIONAL INSTRUCTIONS

2.1. Supply of Water

The Government's Representative shall be responsible for ensuring that the community supplies water for drilling. Domestic water will be supplied at the Project Headquarters for staff resident there and it will be the Contractor's responsibility to provide domestic water for drilling crews.

2.2. Transport of materials

All materials for borehole construction will be supplied by Government at the Project Headquarters in Madisi. Transport to construction sites from Madisi,or from any other station that the Government's Representative may set up, will be the responsibility of the Contractor.

2.3. Records and Reports

The Contractor shall submit daily log sheets and a construction report for each completed borehole on proformae to be provided by Government. The daily log sheets will include:-

a) date, borehole name and number

b) depth of borehole and water level at the beginning and end of each day's work

c) Strata encountered as in 2.4

d) rate of drilling as in 2.5

e) interim bailer tests as in 2.6

f) hole diameter

g) amount of temporary casing installed

h) depth at which water was encountered

i) statement of each operation conducted and time taken, including breakdowns

j) signature of driller.

The construction report will comprise:-

(i) a summary of the information from the daily log sheets

(ii) details of materials used in the completion of the borehole

(iii) results of development and testing of the borehole

The daily log sheets shall reach the Government Representative's office in Madisi by the following working day. Construction reports shall be submitted by the 15th day of the month following that in which the borehole was completed.

2.4. Sampling and Record of Strata

Unwashed drilling samples of about 1 litre volume are to be collected from the bottom of the bailer at 1 m intervals and kept on site until the completion of drilling and testing. The Contractor shall provide for each rig a partitioned box for samples. The samples are to be logged by the driller and a record of strata at 1 m intervals will be kept on a daily log sheet to be provided by Government. The record of strata will show:-

a) approximate lithology

b) degree of consolidation or hardness

c) if unconsolidated - nature of granular material (i.e. subjective description of grain size, degree of rounding, clay content, colour)

d) it is most important that an estimate is made of the depth of the weathered rock/unweathered (i.e. hard) rock transition.

2.5. Rate of Drilling

Daily drilling progress will be recorded on the daily log sheet. A time log will be kept showing the actual penetration time required for each metre of hole.

2.6. Interim Bailer Tests

Bailer tests will be carried out, after striking water, at 2 m intervals. A bailer with an efficient clack valve seal and capacity of at least 45 litres (10 gallons) will be dropped below water and lifted full of water at a rate of 2 bailers per minute for 10 minutes or until the hole is bailed dry, whichever is sooner. The water level will be measured before and immediately after the test and recorded, to the nearest 0.05 m, together with the hole depth, amount of temporary casing installed, and bailer capacity, on the daily log sheet.

When drilling is completed, or when the Government's Representative so requires, a longer bailer test lasting 20 minutes or until the hole is dry, whichever is sooner, will be performed.

2.7. Borehole Design

2.7.1. *Drilling diameter*

All boreholes are to be completed to at least 200 mm (8 in) diameter to total depth, unless otherwise specified by Government. If drilling conditions are such that temporary casing is required to maintain open hole, such temporary casing shall be conventional flush-jointed, square-threaded drilling casing of 200 mm diameter.

2.7.2. *Drilling depth*

Drilling will be continued to either hard, unweathered rock or to 12 m below the depth at which water was struck whichever is the shallower. The Contractor shall then contact the Government's Representative for further instructions. Hard,unweathered rock will be identified by:-

(i) visual log

(ii) reduction in drilling rate

and where struck, the depth is to be clearly recorded on the daily log sheet.

2.8. Casing and Screen

The material provided for casing and screen will consist of 110 mm PVC Class 10 rigid pipe in 3 m lengths. PVC casing must not be stored in direct sunlight at any time. Government shall provide covered storage facilities at Madisi.

2.9. Installation of Casing and Screen

On completion of drilling, screen will in general be installed from total depth to the depth at which water was first struck. The Government's Representative shall be consulted for details of screen positioning, and will provide a written specification for each borehole. An end cap/bail plug will be provided by Government and

fixed by the Contractor at the bottom of the slotted casing. Blank casing will then be installed from the depth at which water was struck to 0.5 m above ground level. To ensure that the casing is central and vertical in the borehole and to provide a uniform annular space for the gravel pack, centralisers will be provided by Government and must be fixed to screened sections at intervals of 3 m. The casing shall in stalled by hand, using a wooden clamp (one per rig), as demonstrated by the Government's Representative. The casing shall be joined according to the manufacturers instructions. The quantities of all PVC materials used, including centralisers, solvent cement and cleaning fluid, shall be recorded on the borehole construction report (2.3).

2.10. Gravel

Material suitable for a gravel pack will be provided by Government at Madisi. The gravel must be stored in such a way as to avoid contamination or heavy rain washing.

2.11. Installation of Gravel

Gravel installation will be carried out by continuously feeding uniformly into the annulus using water to flush as necessary. The Contractor shall make every effort to obtain a well-settled, uniform gravel pack around the screen. The top of the gravel shall never be allowed to fall below the temporary casing during its extraction, nor shall it rise so high as to produce a sand lock between the temporary and PVC casing. Thus the gravel level needs to be regularly measured. The gravel will be placed uniformly to 2.5 m below ground level. The volume used shall be recorded on the borehole construction report (2.3).

2.12. Development

2.12.1. *Method*

Development will be by interrupted overpumping carried out with the reciprocating cylinder pump operated by the rig, and with the cylinder set 1 m above the bottom of the borehole. Pumping will be carried out at approximately 0.25 l/sec until the water level is drawn down to pump suction or for 10 minutes, whichever is the sooner. Ninety percent recovery of water level will be allowed and the procedure will then be repeated at 0.5 l/sec, then 1 l/sec. Interrupted overpumping will continue at this latter rate until clear, sand free water is obtained to the satisfaction of the Government's Representative.

2.12.2. *Excessive development*

If the casing, screen and gravel have been properly installed, the total period of development required is expected to be short. Excessive development times will be an indication of poor borehole completion. Periods of development in excess of five hours per borehole will therefore by at the Contractor's expense.

During development the gravel will be topped up as necessary to maintain the level in the annulus at its previous level.

2.13. Test Pumping

After development at least 90% recovery of the water level will be allowed before the test pumping is commenced. The borehole will be test pumped for a minimum continuous period of 4 hours, or as the Government's Representative instructs, at a constant rate set by the Government's Representative on the basis of development results, with the cylinder set 1 m above the bottom of the borehole. In the event of interruption of the test due to mechanical failure, no payment will be made for this incomplete test pumping period and the test will be recommenced after 90% water level recovery.

The Contractor shall supply water level dippers to give water level measurements to an accuracy of at least 0.01 m. The datum point is to be recorded (in relation to ground level). The Contractor shall supply weir tanks graduated at 0.25, 0.5, 0.75, 1.0, 1.5 and 2.0 l/sec. Water levels will be recorded as specified on test pumping proformae provided by Government. To permit pumping from the borehole at several different constant discharge rates, the Contractor shall provide cylinders capable of producing at any discharge between 0.25 l/sec and 2.0 l/sec simply by varying the stroke rate.

After completion of the test pumping, two water samples of 1 litre each will be collected in bottles supplied by Government. One of these samples shall have added to it approximately 2 ml of acid (supplied by Government). The bottles shall be clearly labelled with borehole number, depth of cylinder, whether acidified or not, date, and name of driller.

2.14. Sealing the annulus

After test pumping is completed and the gravel topped up if necessary as at 2.12.2 above, the annulus will be sealed with clay backfill from the top of the gravel pack to 1 m below the ground surface.

2.15. Temporary Capping of Borehole

Government shall be responsible for the installation of handpumps and construction of the cement plinth and apron. In the meantime, on completion of the borehole the Contractor shall install a temporary cap provided by Government to prevent any foreign material from being introduced into the borehole.

2.16. Verticality

The Contractor shall construct all boreholes straight and vertical.

2.17. Briefing Meetings

The Contractor's supervisors may be required to attend briefing meetings with the Government's Representative in Madisi, to report on the Works.

2.18. Dry Boreholes

The bailer tests described in Item 2.6 of this Specification will, if performed correctly, go a long way towards ensuring that boreholes with low yields are not completed with permanent linings and gravel packs. In the event, however, of a borehole being completed, developed and tested and then abandoned on the instruction of the Government's Representative as having too low a yield to sustain handpump operation, the Contractor will be paid for all work on the borehole, provided that the interim bailer tests have been carried out to the complete satisfaction of the Government's Representative.

2.19. Access to Sites

Government shall be responsible for ensuring that the community provides reasonable access tracks for wheeled transport and drilling rigs to each borehole site.

2.20. Waiting Time

Government shall make payment to the Contractor as set out in the Schedule of Prices for delays resulting from failure of Government to ensure access to sites, failure to provide borehole materials or failure to provide further instruction or direction as specified.

2.21. Rehabilitation

In addition to the above construction work, the Contractor shall move his rigs to such existing boreholes as the Government's Representative may require, in order to carry out rehabilitation work. This will consist of any or all of the following steps:-

(a) bailing the hole to its original depth or to any depth required by the Government's Representative

(b) installation of PVC screen and casing as instructed

(c) installation of gravel as instructed

(d) development as at 2.12

(e) test pumping as at 2.13

(f) sealing the annulus as at 2.14

(g) temporary capping as at 2.15.

The Contractor shall be paid at the rate given in Item 12 of the attached Schedule of Prices for time spent on operations (a), (b), and (c) above and at the other appropriate rates given in the Schedule of Prices for movement between sites, rigging up and down and operations (d), and (e) as specified.

SCHEDULE OF PRICES

A. Drilling charges (in Kwacha per metre of depth)

Depth range (m)	Borehole Diameter (mm)			
	150	200	250	300
0 - 15	35	35	50	60
15 - 30	40	40	60	70
30 - 45	45	50	70	80
Below 45	50	60	80	90

B. Other operations

Item No.	Description	Pay Unit	Rate
2.	Bailer test, per ten minute test	No.	5.00
3.	Development of borehole as specified	hr.	20.00
4.	Test pumping continuously as specified, first eight hours	hr.	20.00
5.	Test pumping continuously as specified, each additional hour	hr.	15.00
6.	Test pumping continuously as specified but where separate from and not following directly after development	hr.	25.00
7.	Making recovery measurements	hr.	5.00
8.	Movement of rig and plant between sites, minimum moving charge K35.	km.	3.50
9.	Rig up and down at site	sum per borehole	100.00
10.	Operating vehicles	km.	1.00
11.	Operating passenger vehicles	km.	0.60
12.	Cleaning of existing boreholes as specified in 2.21 (a), (b), (c)	hr.	25.00
13.	Waiting time as specified	day	150.00

DOWA WEST CIRCULAR 1

It is proposed to have a series of circulars for the Dowa West EPA 1 Integrated Groundwater Project with the same aims as the Livulezi Project circulars. This circular lists preparations to be made before the proposed commencement of drilling - 1st August, 1982. A meeting is suggested to discuss points raised here and to apportion responsibility for the actions to be taken. Comments to Charles Ruxton, please.

1. PREPARATIONS ALREADY MADE:

   1.1. 1:50,000 maps obtained
   1.2. Census maps
   1.3. Location of private lands
   1.4. Map of DRIMP roads in the area
   1.5. Aerial photographs ordered
   1.6. Locations of all existing boreholes obtained
   1.7. Decision taken to use drilling contractor
   1.8. Project headquarters to be in Madisi

2. IMMEDIATE NEEDS:

   2.1. Establish the following staff at Madisi:
      - Project Hydrogeologist
      - Storeman /clerk
      - Builders (1 or 2)
      - Driver
   2.2. Obtain locations and all available details of existing shallow wells.
   2.3. Decide arrangement to be used for fuel supplies.
   2.4. Obtain permission for use of LPO, RIV and requisitions for fuel by Project Hydrogeologist.

3. COMMUNITY

   3.1. Hold main meetings (leaders) as soon as possible in order to:
      - Form main project committee
      - Explain the aims and methods of the project
      - Assess community reaction to the proposals
      - Set in motion (through group village headmen) the process of village committee formation

- Delineate community input (see 3.2)

3.2. Community input (responsibility of village headman and committee):

<u>Shallow wells</u>:

- Choose site
- Provide 4 - 5 men per day for digging
- Break 25 pails of stone (for rings)
- Provide stones, sand, bricks, water and 4 men (for apron)

<u>Boreholes</u>:

- Choose site
- Bring water to rig
- Provide stones, sand, bricks, water and 4 men (for apron)
- Provide caretakers for pump maintenance training.

4. STORES/EQUIPMENT TO BE DELIVERED TO MADISI

4.1. Headquarters. Materials for construction of:

- A block with office (10 m^2) and two stores (3 m x 6 m and 3 m x 3 m). A covered workshop (6 m x 12 m) for ring moulding, vehicle maintenance and PVC pipe storage.
- Three houses(20 m^2, 2 rooms) for Project Hydrogeologist Assistant Project Hydrogeologist, Pump Supervisor
- Two houses (10 m^2, 1 room) for driver and storeman

NB The possibility of ADMARC, Local tradesmen, KADD providing buildings is also under discussion.

4.2. Equipment for contractors' rigs:

- 4 water level dippers
- 200 mm temporary steel casing
- 200 mm clay cutters
- 4 clamps for lowering PVC casing

4.3. Stores for borehole construction:

- 50 (at least) 3 m lengths plain 110 mm class 10 PVC casing
- 50 (at least) 3 m lengths slotted 110 mm class 10 PVC casing
- Centralisers, string, bottom caps, sleaning fluid, solvent cement, magic marker pens, paint brushes, mutton cloth, gravel, plastic sheets, shovels.

4.4. Shallow wells construction equipment and stores:

- 2 sets shear legs with pulley, rope and bucket
- 2 suction pumps
- 2 wheelbarrows, picks, hoes, shovels, measuring tapes
- 4 ring moulds, 3 pillar moulds, 2 slab moulds, cement mixer
- 200 bags cement
- River sand (local river)
- Aggregate (Community)
- 10 lengths (6 m) plain 110 mm class 6 PVC pipe

4.5. Finishing:

- 15 Malawi pumps with footvalve, cylinder, rising main, pump rods, cover plates, rubber gaskets
- 20 x 50 mm galvanised outlet pipes (3 m)
- 10 Mark V shallow well pumps with footvalve, cylinder, rising main and pump rods.
- Pallets, shovels, brushes, wheelbarrows,string for builders.
- Cement included in 4.4

4.6. Mechanical:

- Vehicle maintenance tool kit, puncture repair kit with tyre levers (NB, check that air and pressure gauge available Madisi)
- Vehicle spares
- pump installation/maintenance tool kit, fuel, oil, etc. (see 2)
- hand cleaner

4.7. Office equipment and furniture:

- Radio with aerial
- 2 desks and chairs
- Bookshelf
- Lever arch files,paper punch, staples, graph paper, tracing paper, forms, departmental stamp and ink pad, notice boards, drawing pins, map pins.

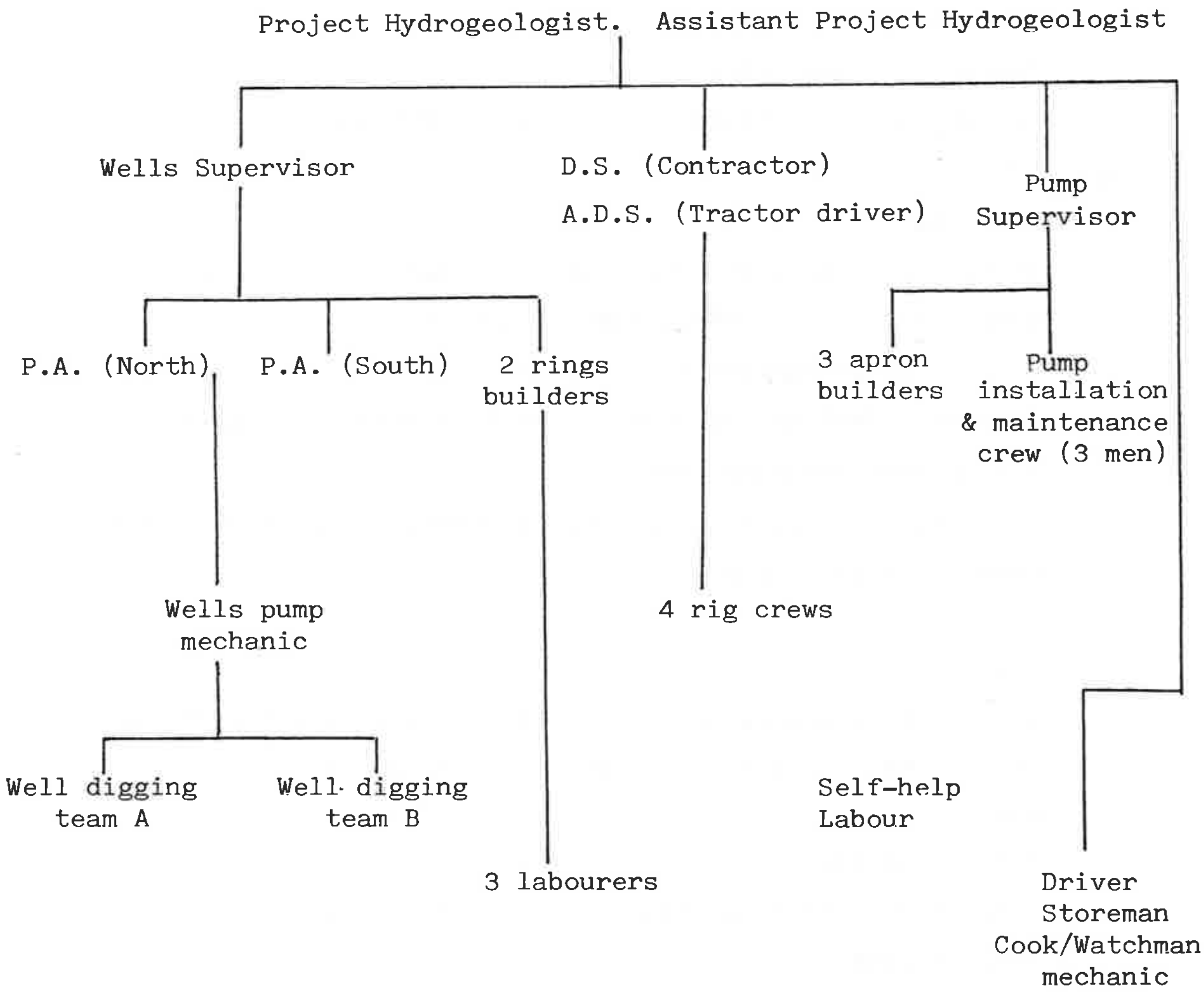
4.8. Vehicles:

- 1 pickup (for delivering materials etc)
- 4 motorcycles(for supervisory staff)
- 7 bicycles (builders and pump crew)

NB The wells teams and wells project assistants will continue with the present bicycle arrangement.

5. <u>STAFF</u>

5.1. Organisation



5.2. Staff list (Government staff)

- 2 hydrogeologists (Ruxton, Chavula)
- 1 Wells supervisor (Chiponda)
- 1 Pump supervisor
- 2 dug-wells Project Assistants (Chitakwele, Phiri)
- 1 Well pump mechanic (Foreman)
- 2 Well diggers
- 2 rings builders
- 3 Labourers for rings building (? Local)
- 1 Driver
- 1 Storeman (E.S. Phiri)
- 1 Cook/watchman
- 3 Apron builders
- 3 Pump installation/maintenance crew (1 Foreman + 2 crew)

- 1 Mechanic ?
- 1 Carpenter)
  Local labour) for starting period)

Total staff = 26

NB 1. DS refers to Drilling supervisor and
ADS refers to Assistant Drilling Supervisor
(Contractor's staff)

2. The dug-wells project assistants are already working in the area and have houses and bicycles

3. The wells foreman and diggers will bring their own tents

4. The Carpenter and rings builders will bring their own tents

5. If local labourers are to be employed, permission must be sought.

6. FURTHER ACTION TO BE TAKEN BEFORE DRILLING STARTS

6.1. Conduct survey of relevant section of the Bua River in order to identify sources of:
- river sand for concrete
- Coarse sand of suitable grade for gravel pack

6.2. Identify sources of stone for hand-knapping

6.3. Conduct initial survey of all villages to ascertain:
- Population distribution
- Present water sources
- Borehole/shallow well areas
- Any problems of access and to liaise with village committee

6.4. Give final approval for 10 borehole sites and ensure that they are prepared.

6.5. Arrange for headquarters water supply

6.6. Decide on borehole numbering system.

7. COSTING/CHARGING

7.1. Costing to be achieved by careful evaluation of direct and indirect costs using the system derived for the Livulezi Project. Emphasis to be placed on prompt submission of borehole and shallow well daily and construction reports.

7.2. The new standard charging structure to be used. Method of invoicing KADD to be discussed.

C. Ruxton
HYDROGEOLOGIST

of the Section of the preparations being made for the Project. The first circular of the Dowa West Project is included here as an example. The circular should be followed by a second Section meeting at which details of staffing, vehicles, accomodation arrangements and other matters can be discussed, and similar meetings may be required at intervals through the preparation phase, leading up to implementation.

3. LIAISON WITH OTHER DEPARTMENTS

3.1. As a result of the steps in preparation described in Section 2, some of the resources required for the Project have been identified. Two other very important resources which should be utilised to the full are:

a) The village communities living in the project area

b) The knowledge and expertise of the staff of the other Government Departments.

The details of the way in which the former is put into practice are described in Section 5, but contacts made at this early stage with other Government field staff working in the project area will be of great assistance when informing and motivating the people.

3.2. MINISTRY OF AGRICULTURE

3.2.1. *The Agricultural Development Division*

A planning meeting with the programme manager of the relevant ADD should be arranged by the project hydrogeologist in the first week of the preparation phase. If the Integrated Project is the water component of an RDP, the ADD will have been involved right through the planning phase. The hydrogeologist should take this opportunity to remind the programme manager of any commitments by the ADD to assist the Integrated Project that may have been made at meetings in the planning phase. If the Integrated Project has been planned independently of the ADD and is being separately funded this meeting is an opportunity to brief the programme manager on the background, aims and requirements of the Integrated Project. In either case, the following subjects should be discussed:

a) Location of Integrated Project headquarters. If possible this should be at the RDP headquarters or at an EPA centre as this will encourage close co-operation between the Integrated Project and the ADD. Headquarters site requirements are given in Section 8.

b) Accomodation for supervisory staff. At an RDP headquarters or EPA centre the ADD may be able to provide permanent brick houses for the duration of the implementation phase. If this is not possible they may be able to assist with temporary (tin) housing or the loan of caravans.

c) Names and locations of agricultural extension staff.

d) Community participation. The hydrogeologist should outline the aims and requirements of the main community meetings [Section 5]. Other means of raising the level of awareness of the Project amongst the community should be considered, for example organising visits for local leaders to see an existing Integrated Project (particularly one actually being implemented). The ADD may be able to provide suitable transport for these visits and perhaps accomodation at an RDP headquarters or training centre if the Project to be visited is far away.

e) Other related components of the RDP. This would include health and sanitation, for example an existing or planned programme of pit latrine construction should be linked to the Integrated Project. The hydrogeologist should outline the potential for waterpoint gardens and arrangements should be initiated for this to be described by ADD staff at the main community meetings.

3.2.2. *Central Services Construction Unit*

This section of NRDP builds rural roads in the RDPs. Information about their programme can be obtained from their Lilongwe headquarters. Maps should be obtained showing roads under construction or planned, and an approximate timetable of road and bridge construction should be asked for [see also 3.5.].

3.3. DISTRICT ADMINISTRATION

A visit should be made by the Project hydrogeologist to the District Commissioner (DC) in the first or second week of the preparation phase. The DC should be informed of the aims, requirements and benefits of the Integrated Project and of the target starting date for construction to begin. The main community meetings should be discussed, emphasising the importance of holding them early enough

for news of the Project to be widely disseminated before construction begins. An arrangement should be made for the Project hydrogeologist to attend the next DDC meeting to present the Integrated Project to the Committee.

3.4. MINISTRY OF HEALTH

The Ministry of Health can co-ordinate its activities with the Integrated Project in two ways:

a) By carrying out sanitation programmes in conjunction with the Integrated Project

b) By providing health education talks at waterpoint opening ceremonies, village caretaker and village repair team training courses and at any other suitable occasions.

These possibilities should be discussed at the very beginning of the preparation phase with the headquarters and regional health inspectorate and in detail with the District Health Inspector (DHI). Communication with the DHI should be established on the hydrogeologist's first visit to the area [see 3.3. above] and the DHI should be invited to the DDC meeting and the main community meetings. The DHI will have a very important role to play from now on and the hydrogeologist should make every effort to keep him as fully informed and involved as pssible.

3.5. MINISTRY OF WORKS

3.5.1. The Chief Civil Engineer (Rural Roads) should be contacted to find out if the DRIMP road construction programme includes the Project area. Maps and an approximate road and bridge construction timetable should be obtained from him. This information, together with that obtained in 3.2.2. could be important in programming construction. In the Dowa West Project, for example, areas in which DRIMP road construction is still underway are being left until the roads are complete. The Project will then be able to take advantage of the improved access provided by these roads.

3.5.2. It may be possible to request that priority be given in the rural road building programmes to the Project area. This subject is best

discussed during the planning phase [see Chapter B] but it may be possible to influence road building programmes during preparation also. Certainly any arrangements made with DRIMP or CSCU during the planning phase should be confirmed now.

3.6. LANDS DIVISION (DLVW)

All Project waterpoints should be placed on communal land so that the village community will always have unimpeded access to the pump. Information is therefore needed on land ownership in the Project area. The Lands Division of DLVW have a master set of 1:50,000 scale maps with private land marked on them. The information should be copied onto the hydrogeologist's field set of maps in preparation for the initial village survey [Section 9]. This information is also available at Department of Surveys, Blantyre, but may take longer to obtain from them. Information should also be collected about any special projects in the area, for example smallholder tobacco schemes.

3.7. OTHER ORGANISATIONS

3.7.1. The piped-water programme will have been involved or at least contacted during the planning of the Integrated Project. At this stage the project hydrogeologist should familiarise himself with any nearby piped-water projects. There may be considerable potential for co-operation; in the Upper Livulezi for example, the Integrated Project and the adjacent Nanyangu Piped-Water Project are liaising to ensure that no villages along the common boundary of the two projects are left without improved supplies. The hydrogeologist should also inform himself of any dug well construction already in progress in the Project area.

3.7.2. There may be missions in the area working on improving water supplies and sanitation and full co-operation should be sought with them.

4. COMPILATION OF HYDROGEOLOGICAL DATA

4.1. INTRODUCTION - DATA SOURCES

4.1.1. Early in the preparation phase, at the same time as identifying and mobilising staff for the Project, the hydrogeologist should be collecting and analysing all the available data from the area. For this he will need to use the following sources:

a) Topographic maps at 1:50,000 scale : Department of Surveys, Blantyre

b) Aerial photographs : Department of Surveys, Lilongwe

c) Census maps and district booklets : National Statistical Office

d) Geological Survey memoirs and maps : Groundwater Section DLVW

e) Master set of 1:100,000 scale hydrogeological maps : Groundwater Section, DLVW

f) Hydrogeological maps at 1:250,000 : Groundwater Section, DLVW

g) Hydrogeological bulletins : Groundwater Section, DLVW

h) The borehole cardex system : Groundwater Section, DLVW

j) Dug well data : Groundwater Section, DLVW

k) Water chemistry files : Water Quality Laboratory, DLVW

l) Borehole maintenance records . : Groundwater Section, DLVW

m) Land use maps : NRDP

n) Soil survey maps : Land Husbandry Department

Items a), b) and c) should be ordered [Section 7] right at the beginning of the preparation phase.

4.1.2. Once the data compilation is initiated, much of the routine work can be carried out by the staff of the Groundwater Section's data archive. This should be arranged through the officer responsible for the archive. The Integrated Project will itself produce a large volume of valuable hydrgeological data from perhaps several hundred waterpoints. In addition to its prime aim of providing improved water supplies, the Project should be seen as an opportunity for increasing our knowledge of the hydrogeology of the area. The data compilation should be carried out with this in mind in addition to providing the basic information for the survey and siting work.

Ideally the hydrogeologist should use the Project data to produce a hydrogeological report on the area. It is worth noting that data collected during a Project could possibly form the basis of a postgraduate thesis.

4.2. BOREHOLES

4.2.1. From the master set of 1:100,000 hydrogeological maps of the water resource units,plot the locations of all boreholes in and near the Project area onto a fresh set of 1:50,000 scale field maps. Obtain the old borehole numbers from the cross-reference ledgers of the cardex. Where the plotted position does not agree with that already printed on the map, the former should be taken as correct. During the course of the Project the grid references of all existing boreholes can be checked and the master set of hydrogeological maps corrected if necessary.

4.2.2. Make a list of all the boreholes with numbers and grid references and the hydrogeological data obtained from the cardex (borehole depth, water struck, rest water level, geological log, casing details and yield). If there are a manageable number of boreholes it may be worthwhile preparing duplicate cards for retention at the Project Headquarters.

4.2.3. Some initial conclusions about the hydrogeology of the area can now be drawn. If there are only a few boreholes in the area a perusal of the data is all that is necessary to gain an idea of depths to bedrock, aquifer thickness and likely water levels. A larger number of boreholes warrants the preparation of tracing paper overlays for each of these three parameters, copied from the data on the 1:100,000 master set of hydrogeological maps. These tracing paper overlays can be updated during project implementation by plotting on them the information from Project boreholes and dug wells.

4.2.4. In addition the construction details of the existing boreholes together with their maintenance records will provide the data necessary for planning their rehabilitation [Chapter D]. For this a duplicate set of cards at the Project headquarters would be particularly useful.

4.3. DUG WELLS

Information sheets on the locations, depths, lining material and pump types of the dug wells in and near the area will be available from the nearest Wells Programme Supervisor (if there is one). If there is no Wells Programme Supervisor, the headquarters in Lilongwe will have information sheets on any protected wells that have been dug in the area. It is intended that there will eventually be a cardex storage system for dug wells similar to that for the boreholes. The sheets are prepared by the Wells Project Assistants and grid references are often inaccurate. It is probably more reliable to use the village names (from the census map) for locating the wells. In this way the approximate locations of the dug wells can be plotted on the 1:50,000 maps.

4.4. LAND OWNERSHIP

The locations of boreholes and dug wells should be plotted on the same map as the private lands [see Section 3.6] and this map can be taken on the initial survey. A knowledge of the number of boreholes or dug wells that a village already has will determine the allocation of project waterpoints, while the location of private lands will influence their siting.

4.5. WATER QUALITY

If a potential water quality problem has been identified from existing data at the planning stage, a field survey of electrical conductivity may have been carried out [Chapter B]. Some parts of the Project area may have even been eliminated because of poor water quality. The Project hydrogeologist should obtain this conductivity data and plot it on one of the map overlays [4.2.3. above] to assist in planning water quality sampling to be carried out during the initial village survey. Any further chemical data that has been collected since the planning phase should also be abstracted from the records of the Water Quality Laboratory and from the cardex.

4.6. GEOLOGY

The hydrogeologist should obtain for his own retention the geological memoirs and maps for the Project area. The airphotos should be examined stereoscopically and a simple geological overlay prepared. The air photo interpretation is described in detail in Chapter D, but geological interpretation work should commence as soon as the photographs are received. A knowledge of the geology and the distribution of outcrops is important in estimating depth to bedrock and may also have an influence on water quality. The land use and soil survey maps should also be consulted at this stage.

4.7. LOCATION OF COMMUNITY LEADERS AND GOVERNMENT STAFF

On a separate map the locations of Group village headmen, Ward Councillors, Area Party Chairmen, agriculture field assistants and health surveillance assistants should be marked. This will enable the hydrogeologist to make full use of these leaders and Government staff as he moves about the area.

4.8. ACCESS MAP

An examination of the 1:50,000 map together with a knowledge of any road building programme in the area will indicate areas which will be difficult to reach during the rainy season. These areas should be marked with light hatching on the map. More detailed information about access will come to light during the initial survey. The access map together with any road building programme [Section 3] will be an important aid in deciding when to drill in which areas. An approximate programme of construction should be drawn up which ensures that areas of poor wet-season access are drilled in the dry season, leaving more accessible areas so that drilling can continue in the rainy season. This demarcation should not, however, be done on such a small and local scale that a disjointed and inefficient drilling programme will result.

4.9. TIMING

The activities mentioned in this section are time consuming but depend little on other people or departments for their timing once the ordered materials have been received. The work is best carried out by the Project hydrogeologist and supporting technical staff as a continuing process while the steps described in Sections 3, 5 and 7 are being performed. The work must be completed during the "office" component of the preparation phase (the first six to eight weeks) as the hydrogeologist will not have time to do it later. It is the knowledge gained in this data compilation step that will enable the hydrogeologist to make good technical and management decisions in the implementation phase.

5. COMMUNITY PARTICIPATION

5.1. As stated at the beginning of this Chapter, the resource of community participation must be used to the full. Without this resource, project implementation would be very difficult and operation and maintenance would be impossible. During project preparation, the main aim is to make every section of the community as aware as possible of the project. All available means should be used for this, the chief being large meetings held at strategic points in the project area.

5.2. ARRANGEMENT OF MAIN MEETINGS

5.2.1. The hydrogeologist will have visited the DC in the first or second week of the preparation phase [Section 3] and should visit the District Party Chairman at the same time to inform him of the Project. The hydrogeologist will have arranged to present the Project at the next DDC meeting.

5.2.2. At the DDC meeting the aims of the Project should be briefly explained, and a detailed list of what is expected of the community should be presented. The most important result of the DDC meeting will be firm dates and places for the main community meetings. It should be possible to start holding the meetings two weeks after the DDC meeting. If the Project hydrogeologist has seen the DC in the first two weeks of the preparation phase the DDC meeting may come in weeks three to five and the main meetings in weeks six to eight. Every effort should be made to ensure that this is achieved and the main meetings are over by the end of the eighth week so that people in the area are fully informed before camp construction and preliminary village survey work begins. The month of July should be avoided for the main meetings as most of the time of the local community leaders is taken up by District and Area Independence celebrations.

5.2.3. Once the dates are set, most of the arrangements can be left in the hands of the DC. The hydrogeologist should make clear to the DC all the points that he wants to be raised at the meetings so that an

agenda can be prepared. The Project hydrogeologicst should invite:

- the Controller of Lands, Valuation and Water
- the Officer-in-Charge, Groundwater Section (DLVW)
- any dug-wells programme supervisors from the area (DLVW)
- the project engineer of any piped-water projects in or near the area (DLVW)
- appropriate ADD staff, e.g. the RDP Project Officer
- the District Health Inspector
- the District Community Development Officer

5.2.4. In addition to the Government officials listed above, the following local leaders should be invited to the main meetings through the Malawi Congress Party (MCP):

- District Party Chairman
- Members of Parliament (MPs)
- Area Party Chairmen
- Ward Councillors
- Chiefs and Sub-Chiefs
- Group village headmen
- Village headmen

5.3. THE MAIN MEETINGS

5.3.1. At least one meeting should be held in each Traditional Authority area and they should be within a reasonable walking distance for those who are expected to attend.

5.3.2. The aims of the meetings are as follows:

a) To form a main project committee, consisting of the DC, District Party Chairman, MPs, Chiefs and other important local leaders. Problems which may arise later with the community participation in the implementation of the Project [Chapter D] are referred to this main project committee if they cannot be solved at the village level.

b) To explain the aims, methods and benefits of the Project, emphasising that the Integrated Project is a means by which Government wishes to help the local people to improve their own water supplies. The idea of village responsibility for maintenance should also be explained in simple terms.

c) To assess by means of a question and answer session the reaction of the community to the Project. Doubts or worries can be answered at this point.

d) To make arrangements for every village to have a water committee of four or five people, if possible including some women. The village headmen are told to return to their villages and, under the supervision of Councillors, Group village headmen and Area Party Chairmen undertake that committees will be formed and names sent to the Integrated Project headquarters or the EPA Centre by a certain date, say two weeks after the meeting. If the villages already have active health committees, it may be sensible for this committee to embrace the impending water activity rather than starting another new committee.

e) To explain very clearly what tasks the community will be expected to perform [see full list in Chapter D].

5.3.3. An example of the minutes of such a meeting held in the Upper Livulezi Project is included here. It was in this case held after the construction of waterpoints was well underway, as the overall approach of the Integrated Projects was still being evolved. It was the first of its kind in an Integrated Project and it can be seen from the minutes that the topics outlined above were well covered. Two similar meetings were held in the preparation phase of the Dowa West Project. These were at the end of July, 1982 with commencement of construction in the middle of August.

5.3.4. These meetings are a unique opportunity to inform the community - a second chance will not come. Full use should, therefore, be made of them and arrangements for any further events involving the community should be initiated here, for example, visits for local leaders to existing Projects. It may also help to have a handout explaining, perhaps pictorially, the Project and the community's part in it.

5.4. OTHER METHODS OF INFORMING THE COMMUNITY

5.4.1. Visits by community members to existing Integrated Projects have proved to be a very successful way of informing and motivating people. Two personnel-carrying trucks, provided by the ADD, took village headmen

Councillors, Area Party Chairmen and other local leaders from Dowa West to the Upper Livulezi Project. They saw completed waterpoints and met their counterparts who described the operation and benefits of the Project. The leaders are then able to explain to their own people the facilities enjoyed on an existing Project. The Agricultural Development Officer and the MCP can arrange the selection of people to go on these vists. It is a good opportunity to reach people who did not attend the main meetings. A good proportion of women should be invited as they are especially able to appreciate the value of improved water supplies close to the villages.

5.4.2. Agriculture and health field staff can be asked to encourage villages to prepare for the Integrated Project. By involving these staff at this stage they will feel a commitment to the Project throughout its life.

5.4.3. The initial survey [see Section 9] as well as being an information gathering exercise should be used as a means of encouraging villages to prepare for the Project. The survey should enable work about the Project to be spread to any villages who were not represented at the main meeting.

MINUTES OF MEETING ON UPPER LIVULEZI INTEGRATED PROJECT FOR RURAL GROUNDWATER SUPPLIES HELD ON 20TH APRIL, 1982 AT KANDEU COURT

PRESENT : MR S.H.B. MAGOMBO, ASSISTANT DISTRICT COMMISSIONER (CHAIRMAN)
INKOSI GOMANI III PARAMOUNT CHIEF
MR R.D. KAFUNDU, OFFICER-IN-CHARGE, BOREHOLE FUND
MR CHIWAYA, PROJECT OFFICER, NTCHEU RURAL DEVELOPMENT PROJECT
MR. MWASE, COMMUNITY DEVELOPMENT OFFICER
MR CHING'AMBA, DISTRICT HEALTH INSPECTOR
MR. F.B. MSONTHI, PROJECT HYDROGEOLOGIST, LIVULEZI GROUNDWATER SUPPLIES PROJECT
MR. C. RUXTON, HYDROGEOLOGIST, LIVULEZI GROUNDWATER SUPPLIES PROJECT
MR. SINGINI, PROJECT ENGINEER, NANYANGU/KASINJE PIPED WATER PROJECT
MR. NGONDO, DEVELOPMENT OFFICER, EPA 2 HQS, NTCHEU RURAL DEVELOPMENT PROJECT

CHIEFS : Njolomole
Ganya

GROUP VILLAGE HEADMEN : Charlie Sikumbiri I
Kamphulusa
Chimphuza

COUNCILLORS: Mr. Wakhutamoyo
Mrs. Malili
Mr. Kachikondo
Mr. Machewere

AREA PARTY CHAIRMEN : Mr. Chimala
Mr. L.A. Majamanda
Mr. L. Guba
Mr. B. Kampingule
Mr. L.N. Kalima
Mr. G. Kampango
Mr. S. Kamezangoma
Mr. J.J. Chimaimba

OPENING REMARKS

The meeting opened with a prayer at 12 midday.

The Assistant District Commissioner (Chairman) welcomed all the members to the meeting and thanked everyone for having left other work to come to this meeting. He apologised for the absence of the District Commissioner who was engaged in other important work.

The Chairman outlined in short the purpose of the meeting which was to form (a) a main committee which will have the overall responsibility for the project and (b) village water committees which will have responsibility for individual waterpoints. The composition of these committees is outlined in the attached appendix. The village water committees will help in:

(1) organising the self-help input in the construction of boreholes and wells

(2) making sure that the surroundings of all waterpoints are clean

(3) selecting people who will be trained in pump maintenance

(4) organising the model gardens at each borehole and dug well to make use of the waste water.

BRIEF PROJECT REPORT

The Project Hydrogeologist (Mr. Msonthi) gave a brief report on the project and problems being encountered. 28 boreholes have been completed, with eight already fitted with pumps and 10 dug wells, all with pumps. The problems beings faced so far are:

(a) Land ownership

(b) Lack of community participation in the construction of the boreholes and wells

(c) Lack of provision of construction materials such as sand, bricks, stones and water.

Commenting on the problems being faced by the project, Inkosi Gomani III emphasised the importance of the project and being the first of the kind that it is now the duty of the village committees to make sure that there is maximum co-operation with the project staff. He continued by saying

that the problem of land ownership should be resolved by the village headmen, councillors and area party chairmen,

On community participation he emphasised that the people of the area were very lucky to have a project of this kind because the work required to be done by them,was lighter than that required in the piped-water schemes where deep trenches have to be dug. He told the people that everyone should be grateful for what the Government is helping them to do. He further told the audience that the various committees formed should make sure that they carry out their duties properly and that if possible the project officer (Mr. Msonthi) should from time to time arrange visits of people from one village to another so that they can see what others are doing in taking care of their water points and model gardens.

Commenting further on the above issues, the Officer-in-Charge, Groundwater Section, Mr. Kafundu asked the people if there were any complaints regarding the quality of the borehole or well water. People responded that they were very happy with the water and Mr. Kafundu continued that it must be realised that the waterpoints that are being provided with the help of the project should be accepted by the people as their own and not belonging to Government and therefore they should take care of the boreholes and wells and work hard to produce better crops in the model gardens.

ORGANISATION OF COMMITTEES

It was agreed upon that the main committee will be composed of the District Commissioner as the chairman, all councillors, area party chairmen, traditional authorities and group village headmen with the member of parliament for Ntcheu North and Inkosi Gomani III as ex-officio members (see Appendix I).

The area party chairmen, the group village headmen and the councillors were told to go to the villages under their charge and elect five people in each village who will form the village water committees and the names must be passed on to the Project Hydrogeologist (Mr. Msonthi) by the end of the week starting on Sunday, April 25th, 1982. All the names of villages in the project area with their respective group village headman, area party chairmen and councillors were given to the

6. STAFFING

6.1. INTRODUCTION

It is an obvious but nevertheless important point that the successful implementation of an Integrated Project depends a great deal on the staff of the Project. They are going to be living together and within the community for many months and putting together a good "team" in the preparation phase is a major priority of the Project hydrogeologist, who will be concerned that the staff are:

a) fully aware of the aims and methods of the Project, particularly the community participation aspect

b) motivated to help the community in making the Project a success

c) adequately trained in their respective skills and properly prepared by a short period of familiarisation in an existing Project

d) fully aware of their own job responsibilities

e) provided with adequate accomodation at the Project base, proper support from headquarters and adequate tools and transport for their duties.

The staff who will supervise the various activities of the Project are the most important members of the team.

6.2. SUPERVISORY STAFF

6.2.1. The main construction activities of the Project are borehole drilling, well digging and pump installation/apron construction. It is important that each activity has supervisory staff of roughly equivalent grades reporting to the hydrogeologist. In this way each component of the construction programme is seen to be of equal importance and is treated as such by the hydrogeologist in allocation of professional supervision time, vehicles, fuel and so on.

6.2.2. *Borehole Drilling*

In an Integrated Project in which Government rigs are being used, there will be a need for two drilling supervisors with two rigs each. The supervisors are responsible for the day-to-day management of the rigs, reporting to the Project hydrogeologist. They have a particularly important role to play in ensuring that all the drilling records [detailed in Chapter D] are promptly completed. The duties of the drilling supervisors are outlined in the attached job description. The supervisors are drawn from the group of trained drillers (TOs) in the Groundwater Section. If they have not been working in an Integrated Project before, they should spend at least two weeks as counterparts to drilling supervisors in an existing Project. These staff must therefore be identified early enough in the preparation phase that they can leave their current activity at a convenient time and fit in this training before mobilisation of drilling rigs and equipment takes place [Figure C.6.2.]. If a contractor is employed to carry out the drilling it will be his responsibility [Section 2] to provide the first line of day-to-day management of the rigs. A Government drilling supervisor is required, however, to ensure that on a daily basis the conditions of the contract are exactly met. This applies particularly with respect to the taking and recording of measurements and proper reporting.

6.2.3. *Well digging*

The dug-well assistants will be accustomed to working largely unsupervised in their previous activity in the dispersed national dug-well programme. In the Integrated Project, however, a greater level of supervision is possible and the resulting level of concentrated activity (and therefore higher productivity) can support the overhead of a dug-well supervisor. The supervisor will have responsibility for up to four well-digging teams and will be particularly important for his role in leading the wells assistants in organising and motivating the community [see attached job description]. If the dug-well supervisor has not worked in an Integrated Project before a period of two or three weeks training in an existing Project should be arranged.

6.2.4. *Pump Installation*

A supervisor with considerable experience in handpump installation and maintenance will be required. Again, a period of training in an existing Project should be arranged. A job description is attached.

6.3. OTHER STAFF

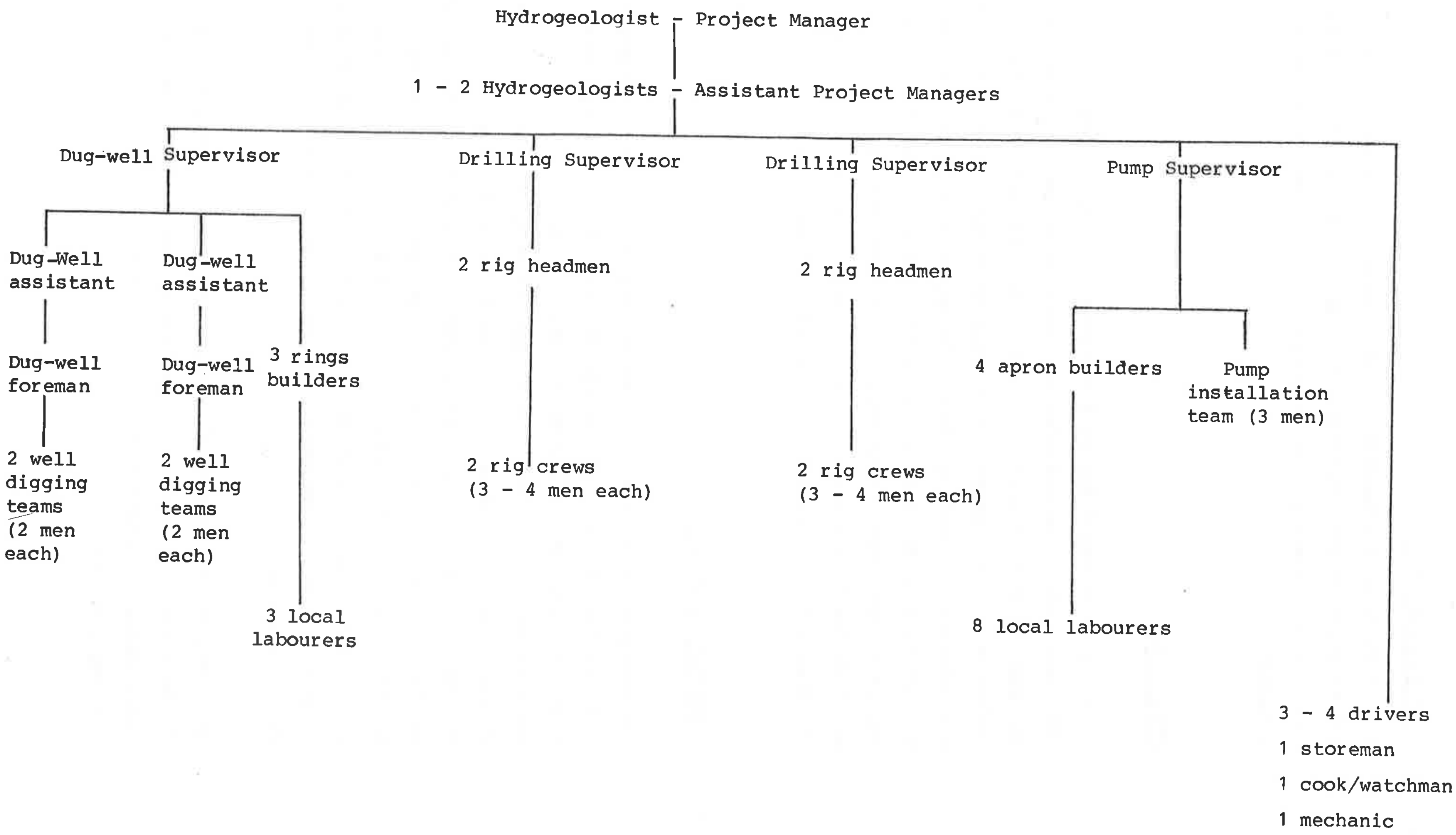
A full list of staff for an Integrated Project is given here [Key Page C.2.]. An organisation chart is shown in Figure C.6.1. The exact number of staff will depend to some extent on the method of dug-well construction adopted [Chapter D] and also on the availability of local builders. The aim should be to use a skilled Project builder to train local builders to carry out lining of dug wells and apron construction. The list does not include non-DLVW staff in any associated low-cost housing, agricultural extension, health education and sanitation activities.

6.4. HEADQUARTERS SUPPORT

6.4.1. The headquarters of the Groundwater Section will have a considerable contribution to make. Senior hydrogeologists will have overall responsibility for the Integrated Projects and will make regular supervisory visits. Procurement and delivery of stores will be arranged through Lilongwe on receipt of requests from the Project storeman. Ideally a clerical officer or storeman in Headquarters should have specific responsibility for supplying the Integrated Projects and have a delivery vehicle at his disposal. Throughout the Project delivery of materials should be efficiently organised as this is a major component [Chapter D] of the overhead cost of the waterpoints.

6.4.2. Other Headquarters staff of DLVW will be closely involved with some of the activities of the implementation phase. These include particularly the staff of the Water Quality Laboratory and the Planning Economist.

Figure C.6.1. : Staff Organisation of an Integrated Project



Key Page C.2.

STAFF LIST FOR AN INTEGRATED PROJECT

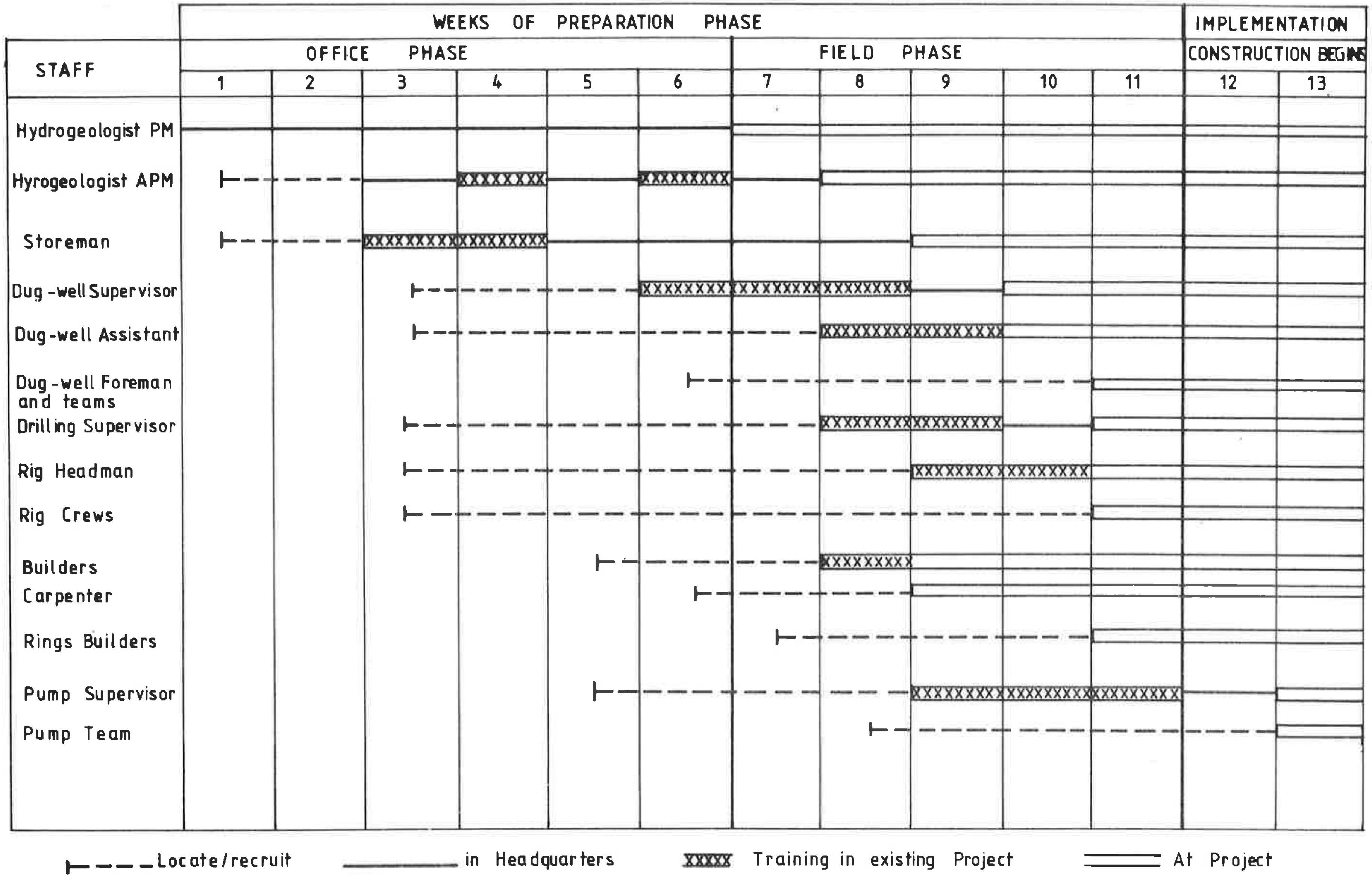
1	Hydrogeologist - Project Manager (PO)
1/2*	Hydrogeologist (PO)
2*	Drilling Supervisors (TO)
1*	Dug-Well Supervisor (STA/TO)
1*	Pump Supervisor (STA/TO)
4*	Rig headmen
12	Rig team members
2*	Dug-well Project Assistants (TA)
2	Dug-well Foremen
8	Dug-well team members
3	Well-ring builders
3	Pump installation team members
4*	Skilled Project builders (for 4 Apron teams)
8**	Apron builders (local)
3/4	Drivers
1*	Storeman
1**	Cook/watchman
3**	Local labourers for ring-making
1	Carpenter) Camp construction
Up to 8**	Local labourers) Camp construction
1	mechanic - not full time on Project

A total of about 70 staff members, of whom about 50 are Groundwater Section staff and about 20 are locally employed labour. Voluntary labour used at all stages of the Project is not included. Staff for related activities (e.g. housing, sanitation, agriculture) are not included.

* Should be given training in an existing Project during preparation phase

** Temporarily employed locally

Figure C.6.2. GENERAL GUIDE TO STAFFING SCHEDULE FOR PROJECT PREPARATION



6.5. TIMING

The approximate timing of staff movement into the Integrated Project through the preparation phase is shown in Figure C.6.2.

JOB DESCRIPTION

DRILLING SUPERVISOR (TO)

The drilling supervisors are trained drillers of TO grade with a Polytechnic Diploma in mechanical engineering, a formal drilling training of three years and several years drilling experience. In the Integrated Projects they are each responsible for the day-to-day management of two drilling rigs and crews, reporting to the Project hydrogeologist. The duties include the following (for Government drilling):

a) supervise the rig headmen in drilling, bailer testing, completion, development and testing of all boreholes

b) assist the hydrogeologist in making sure that the community clears access to approved boreholes sites

c) carry out routine maintenance and repairs to the rigs

d) keep drilling diaries of rig activities

e) make sure that daily log sheets are completed by rig headmen

f) submit completed borehole construction reports promptly to the hydrogeologist

g) liaise with the storeman to ensure than an adequate stock of borehole materials is always kept

h) liaise with the other supervisory staff and the hydrogeologist to arrange efficient daily use of Project vehicles

j) report daily to the Project hydrogeologist

JOB DESCRIPTION

DUG-WELL SUPERVISOR (STA, TO)

The dug-well supervisor will be an experienced member of the wells programme staff and should have had some community development training. The duties will include:

a) motivate and organise the community to participate fully in well digging, together with the wells assistants

b) supervise the wells assistants, the dug-well foremen and digging teams

c) assist the hydrogeologist in checking dug-well sites chosen by the villages

d) liaise with the pump supervisor in motivating the community to provide apron materials at dug well sites

e) ensure that dug-well team diaries are properly kept by the dug-well foremen

f) submit completed dug well construction reports promptly to the hydrogeologist

g) liaise with the storeman to ensure that an adequate stock of materials is always kept

h) report daily to the Project hydrogeologist

JOB DESCRIPTION

PUMP SUPERVISOR (TO, STA)

The pump supervisor will probably be from the Borehole Maintenance sub-section and will have considerable experience in handpump installation and maintenance. The duties will include:

a) motivate the community through the village water committees to bring sand, bricks and stones to each waterpoint for apron construction

b) supervise the builders installing pump pedestals

c) supervise the builders constructing apron, drain and washing slab

d) supervise the installation of all borehole and dug-well handpumps

e) complete the handpump installation forms, including a record of all materials used.

f) organise an opening ceremony for each waterpoint

g) make all local arrangements for the training courses for village caretakers and village repair teams

h) liaise with the storeman to ensure that an adequate stock of pump materials is always kept

j) liaise with the other supervisory staff and the hydrogeologist to arrange efficient daily use of Project vehicles

k) report daily to the Project hydrogeologist

7. PROCUREMENT

7.1. INTRODUCTION

The purchasing and procurement of stores in the preparation phase can be divided into three important components:

a) Materials essential to the preparation phase itself

b) Materials to establish the Project base camp

c) Materials for the early part of the construction programme.

In the first week of the preparation phase application should be made through the Officer-in-Charge of the Groundwater Section for a sub-head specifically for the Integrated Project to be opened within the Borehole Fund vote. This enables purchases to be made for each of several Projects from the Borehole Fund and recorded in separate ledgers. The Fund is then reimbursed by the ADD (or the donor directly) against invoices for completed waterpoints [Chapter D].

7.2. MATERIALS FOR PREPARATION PHASE ACTIVITIES

Materials needed for the hydrogeological preparation work should be ordered as soon as the sub-head number is available. They may take several weeks to arrive and this may delay later stages of project preparation. The materials are:

a)	1:50,000 topographic maps of the area 3 copies of each sheet	Department of Surveys
b)	Full set of the latest aerial photographs. The numbers of photographs required can be obtained from the Air-Photo Interpretation Section of Land Husbandry Department (principal points and numbers should also be marked on the 1:50,000 maps)	Department of Surveys
c)	Census maps, two copies of each sheet and District booklets	National Statistical Office

7.3. MATERIALS FOR BASE CAMP

7.3.1. The immediate requirements of the Project headquarters will depend on the availability of staff housing from the ADD [Section 3]. If houses are available for Project supervisory staff then the activities of the UNDP Rural Low-cost Housing Project [Chapter D] are not so urgent and the houses for maintenance assistants can be built during the implementation phase. If the Low-cost Housing Project is to build the houses, stores and pit latrines in the preparation phase they will be responsible for organising their own materials (using the Project sub-head for purchases). The Integrated Project should provide transport to collect materials and deliver them to the site. If houses from either of these sources are not going to be available early in the Project, up to six caravans will be required and these should be identified and secured at the earliest opportunity.

7.3.2. A covered workshop approximately 6 m x 14 m with concrete floor will be required for moulding rings and slabs for dug wells (if this is to be undertaken at the Project headquarters) and for storing PVC pipes. Timber and iron sheets for this should be ordered by the second week of the preparation phase so that they are available in good time for camp construction to begin by weeks six to eight.

7.3.3. If tin houses are to be provided by the ADD [Section 3], these should be collected and delivered to the site as camp construction begins.

7.3.4. Most of the non-supervisory staff of the Project will bring tents with them from their previous work. Any additional requirements should be drawn from Groundwater Section stores.

7.3.4. Arrangements must be made to ensure regular fuel supplies. An Integrated Project of four drilling rigs, four digging crews and associated vehicles will use about 1,000 litres of diesel and 750 litres of petrol each month, including that issued in the camp to delivery vehicles [Chapter D]. It may be possible to arrange for one of the major suppliers to install tanks and deliver on a regular basis. Otherwise drums will be required; up to four for petrol and five for diesel. If the drilling is to be carried out by a contractor, he will be responsible for his own fuel for rigs

and vehicles. The fuel requirements of the Government side of the Project will be correspondingly less but a small fuel store should be maintained so that operations are not interrupted by local fuel shortages.

7.4. MATERIALS FOR WATERPOINT CONSTRUCTION

7.4.1. A well-run stores procedure involving co-ordination between Project and headquarters staff is essential for the smooth running of the Project. The procedure is described in detail in Chapter D although it will be established in the preparation phase. The Project storeman should be identified or recruited in the first week of the preparation phase and seconded immediately as counterpart to a storeman on an existing Integrated Project for a training period of two weeks. The storeman should then return to Lilongwe to assist the Project hydrogeologist and Headquarters stores organisation in the procurement of stores,assembling them for delivery to the Project. Stores records should be initiated from this time and the storeman should have a triplicate book for requesting stores through the Project hydrogeologist. The storeman will move to the Project headquarters as the buildings are being constructed.

7.4.2. The materials required for each construction operation are given in the respective Sections of Chapter D, and a general list of procurement requirements for the preparation phase is given in the Dowa West Project circular [Section 2]. The aim in the preparation phase is to establish a substantial opening stock of materials for:

a) 25 - 50 boreholes

b) 25 - 50 dug wells

c) 25 each of shallow and deep lift handpumps

d) 30 aprons

The major items will have to be carefully specified [Chapter D] when ordering. They are likely to be large orders and will have to be passed through the regulation Government purchasing procedure, for which adequate time should be allowed. Orders for such items as

PVC pipe, cement and handpumps should, therefore, be initiated at the earliest opportunity.

7.5. VEHICLES

7.5.1. Vehicle requirements will have been identified after the decision has been made whether to use a contractor or Government rigs [Section 2]. New vehicles to be supplied for the Project by the donor will have been ordered long ago; the hydrogeologist will have to keep himself informed about their likely arrival dates. A vehicle and driver will have been made available to the hydrogeologist from the first week of preparation. Checks will have to be made throughout the preparation phase to ensure that the other vehicles allocated to the Project become available as required during the weeks immediately before construction begins.

7.5.2. Bicycles for appropriate Project staff [Chapter D] should be ordered by the middle of the preparation phase so that they are available as the staff arrive at the Project.

8. PROJECT HEADQUARTERS

8.1. LOCATION

8.1.1. The question of a site for the Project headquarters should be discussed with the ADD programme manager [Section 3] and if possible a site should be chosen at an EPA headquarters. There are many advantages in this. An EPA centre is likely to have an existing water supply, which will save problems during the period before a camp borehole can be drilled, and a telephone. The possibility of housing for supervisory staff has already been mentioned; office space and a lecture room at the EPA centre may be available to the Integrated Project. The potential for close co-operation between the Project and ADD staff is also much greater if the two are based together. The other important factor in the choice of site is access for delivery of materials especially in the wet season.

8.1.2. If the Project headquarters is not to be located at an EPA headquarters then the question of land ownership will arise. It would then be necessary to approach the Chief or Sub-Chief to arrange a site. This was done in both the Livulezi and Dowa West Projects, the latter case because the drilling of a camp borehole at the Madisi EPA centre produced water that was chemically unfit to drink. For the Project headquarters an area of roughly 300 m by 200 m is required, preferably with several large trees to provide shade.

8.2. SITE PLAN

Project staff will be living and working at the headquarters basecamp for between one and two years. Careful thought about the locations of different parts of the camp will greatly assist in making for smoothly run operations and pleasant living conditions:

a) The covered workshop and stores should be close to the camp access and located to allow easy loading and unloading of delivery vehicles.

b) The camp borehole should have a clear space around it, unoccupied by living quarters for at least 25 m.

c) The camp borehole should be sited so that the waste water can command a substantial demonstration garden.

d) Pit latrines should be located as far away as possible and down gradient from the borehole, and in any case no nearer than 30 m.

e) Tents and caravans are best kept apart from offices and stores, and using the shade trees.

f) Any permanent houses should be built in locations which will be appropriate even when the base camp has been removed.

8.3. ESTABLISHING THE BASECAMP

8.3.1. Initiating efforts to select a headquarters site in the first week of preparation allows plenty of time for resolving problems of water supply or land ownership. The site will be required and occupation of it will begin six to eight weeks into the preparation phase, about the same time as the main meetings are held.

8.3.2. In the two weeks before the site is required for occupation local labour can be employed to clear it, prepare access and dig pit latrines. One or two Government builders should then be brought to the site to construct the covered workshop (for ring moulding) gravel and sand bays and pit latrines. Two labourers should be employed locally to assist. A carpenter will be needed for roofing the workshop and latrines. The Rural Low-Cost Housing Project [Chapter D] may be able to do this and begin building permanent houses and stores at this stage.

8.3.3. The stores, workshop and sand bays should be completed before construction begins so that the storeman can be well established at the Project headquarters, construction materials can be stockpiled and a careful inventory kept.

8.3.4. The Project hydrogeologist will move to the basecamp when the office phase of preparation is largely completed and the initial survey is about to begin. This is likely to be six to eight weeks into the preparation phase and will probably coincide with the main Project meetings [Section 5]. Caravans and tents should be brought to the site now in readiness for the Project staff to move to the basecamp during the remaining weeks leading up to the commencement of construction [Figure C.6.2.]. The office equipment and furniture (in particular, the radio) should be moved to the basecamp as the hydrogeologist settles in.

8.3.5. Careful records must be kept of all expenditure incurred during camp construction (especially the costs of delivery of materials). This may involve the hydrogeologist himself recording expenses during the period while he is at the base camp and the storeman is at Lilongwe HQ. The cost of camp construction is a Project overhead which will be spread over the cost of all waterpoints [Chapter D] and accurate recording of costs is vital right through the preparation phase.

9. INITIAL SURVEY AND ADVANCE SITE SELECTION

9.1. Once the hydrogeologist has completed the bulk of the office phase of project preparation he can begin the initial survey. This may even start before the main community meetings, though it will only get into full swing after they have taken place. The overall aim of the survey is to visit every village in the area and to allocate water-points to each. Additional information can also be gained about such things as recent agricultural developments, construction materials [next Section] access and rehabilitation requirements. The survey can also be used to continue informing and motivating the village communities [Section 5]. A good part (half if possible) of the Project area should be completed before construction begins, in order to give the hydrogeologist a "feel" for the area, and to ensure that the survey is always a long way ahead of construction.

9.2. The survey is a part of project implementation [where it is described in Chapter D] although it begins in the preparation phase. Similarly site selection must already have begun before waterpoint construction begins so that sites are ready for drilling and digging. There should be enough sites ready for at least three or four weeks work as the first few weeks of construction will probably leave the hydrogeologist with little time to prepare sites ahead. The first sites should be chosen in an area close to the base camp and, if it is the dry season, in an area that will not be accessible during the wet season. Full details of the site selection procedure are given at the beginning of Chapter D.

10. MATERIALS SURVEY

10.1. There are various materials required for construction work in the Project which should be obtained locally. Some of these form part of the community's contribution to the Project while others may be very expensive if transported from outside. Suitable sources should be noted down during the initial survey.

10.2. Many thousands of bricks will be required for aprons, dug-well lining (possibly), houses, stores and workshops and perhaps a pit latrine programme. These are usually moulded and baked by villagers in the dry season. Most villages are likely to have areas of suitable brick clays nearby; the major brickmaking enterprises can be marked on the aerial photographs.

10.3. Stones and sand for apron construction can usually be readily supplied by each village.

10.4. Crushed stone for making well rings should come from a suitable source of unweathered rock, located from the topographic maps, geological maps, aerial photographs and when surveying the Project area. In most areas of Malawi suitable outcrops on hillsides or in river beds will occur; only in the extensive alluvial areas will this be more difficult. Stone-crushing is carried out by the community [Chapter D]. Up to 10 m^3 of crushed stone will be needed for each month of construction.

10.5. At present the gravel pack material [Chapter D] is transported (at considerable cost) to the Upper Livulezi and Dowa West Projects from Grand Beach, Salima. A detailed survey of the lakeshore has indicated several other suitable beaches which may be nearer to future Integrated Projects but as yet no suitable river sand has been found. The beds of any sizeable rivers in the Project area should therefore be surveyed for gravel pack material [specified in Chapter D]. Suitable deposits may be visible on the aerial photographs and the more accessible of them should be visited on

the ground to see if the sand is clean, reasonably well rounded and of the correct grading without any substantial requirement for sieving. Samples should be collected from any promising sites and their grain size distributions determined. For an Integrated Project with four drilling rigs up to 25 m^3 of gravel pack material may be required each month.

10.6. The sand for the concrete used in rings, slabs and camp construction should be a clean river sand. The Project builders should assist in identifying the locations of suitable river sand.

10.7. By identifying and noting these sources at an early stage considerable cost savings may be achieved in efficient collection of the materials. The search for suitable materials can be largely carried out as the hydrogeologist covers the area in his work and thus will incur little additional cost.

11. MOBILISATION

11.1. Mobilisation - the movement of staff and plant to the Project for the start of construction - is a critical activity. All staff and plant must be present before construction can start, yet if some of the plant or staff arrive too early the delays will be costly. This especially applies if rigs and crews are brought to the Project and then cannot begin drilling because, for example, sites are not ready. In the case of the Contractor, these delays may be an actual charge to the Project for standing time [see drilling contract in Section ?]. In the case of a wholly Government Project they are a costly overhead which must be borne by all the subsequent waterpoints. Thus, while the camp construction and initial survey work are progressing through the second half of the preparation phase the hydrogeologist must always bear in mind the need to bring everything together at once for construction to commence. The hydrogeologist will be in the Project area for most of this time so good radio communication with Lilongwe is essential.

11.2. The following should therefore all arrive in the Project at approximately the same time:

a) Drilling rigs and crews. Ensure that the Contractor or Government Drilling Superintendent have been given adequate warning of any revisions of the target starting date.

b) Drilling equipment, tools,casing, development and testing equipment [see detailed list in Chapter D].

c) Drilling headmen. Ensure that their training in an existing Project is completed in good time.

d) Drilling supervisors. Ensure also that their training in an existing Project is completed.

e) Well digging teams. Ensure that they have been informed of their move in good time by the officer responsible for the wells programme.

f) All necessary transport - tractor and trailer, pickup, motorcycles, bicyles.

In addition the initial survey and site selection should be sufficiently well advanced [Section 9] and camp construction [Section 8] and procurement [Section 7] should be at a sufficiently advanced stage to allow waterpoint construction to begin.

11.3. There are other staff whose timing is not tied to the main Project mobilisation. The hydrogeologist, driver, storeman and builders will already have been in the Project for several weeks. The wells project assistants may have been visiting villages to inform and motivate the people to begin well digging. The pump installation supervisor and his team need not arrive until after the first few waterpoints have been completed. The assembling of staff for the Project is summarised in Figure C.6.2.

Weekly Steps in Project Preparation

WEEK 1
- Obtain vehicle and driver [2.4]
- Meet ADD programme manager [3.2]
- Identify/employ storeman [7.4]
- Make field familiarisation visit
- Hold Groundwater Section meeting [2.2]
- Initiate discussions - Government/Contractor drilling [2.2]

WEEK 2
- Obtain Project sub-head [7.1]
- Open accounting [7.1]
- Make advance orders [7.2, 7.3]
- Visit DC and DHI [3.3, 3.4]
- Write first Project circular [2.5]
- Hold discussions with contractors [2.2]
- Initiate compilation of borehole data [4.2]

WEEK 3
- Hold Groundwater Section meeting [2.5]
- Decide between Government/contractor drilling
- Identify rigs, supervisors and crews if Government [2.2]
- Begin preparing contract if contractor
- Visit DRIMP and CSCU to obtain roads programmes [3.2, 3.5]
- Organise accomodation for supervisory staff [3.2,7.3]
- Identify dug-wells supervisor and assistants [2.3]
- Send storeman for training in existing Project [7.4]

WEEK 4
- Attend DDC meeting [5.2]
- Initiate compilation of maintenance data [4.2]
- Continue preparation of contract
- Continue compilation of hydrogeological data

WEEK 5
- Identify pump supervisor [6.2]
- Issue invitations to main meetings [5.2]
- Identify or recruit Project builders [6.3]
- Complete compilation of hydrgeological data
- Start procurement of camp construction materials [7.3]
- Start on air photo interpretation [4.6]

WEEK 6	Plot location of Government field staff [4.7]
	Prepare for main meetings - write agenda [5.2]
	Send dug-well supervisor for training in existing Project [6.2]
	Identify dug-well foremen and teams
	Identify or recruit carpenter
WEEK 7	Move to Project headquarters [8.3]
	Begin clearing headquarters site [8.3]
	Hold main meetings [5.3]
	Identify rings builders
	Start initial survey[9.1]
WEEK 8	Hold main meetings
	Continue initial survey
	Send dug-well assistants for training on existing Project
	Send drilling supervisors for training on existing Project
	Send builders for training on existing Project
	Identify pump team
	Complete clearing headquarters site
WEEK 9	Begin construction of covered workshop [8.3]
	Prepare minutes of main meetings [5.3]
	Send rig headmen for training on an existing Project
	Continue initial survey
	Transfer storeman to Project headquarters
	Send pump supervisor for training on existing Project
	Move builders to Project headquarters
WEEK 10	Continue initial survey - first villages selecting sites
	Move dug-well supervisor to Project headquarters
	Move dug-well assistants to Project headquarters
WEEK 11	Move rig supervisors to Project headquarters
	Move rigs, headmen and crews to Project headquarters
	Move rings builders to Project headquarters
	Move dug-well foremen and teams to Project headquarters
	Approve first sites
	Villages start digging wells and clearing borehole sites
	Complete gravel bay - begin collecting gravel

WEEK 12 Move rigs to sites and begin drilling
Complete covered workshop
Begin moulding rings

WEEK 13 Move pump supervisor and crew to Project headquarters
All waterpoint construction activities underway

IMPLEMENTATION PHASE HAS BEGUN.

CHAPTER D

PROJECT IMPLEMENTATION

CHAPTER D

PROJECT IMPLEMENTATION

CONTENTS

PREFACE

The preparation phase has ended with the arrival at the Project Headquarters of all the plant, vehicles, staff and materials required for implementing the Project. During this period of mobilisation some of the activities described in this Chapter will begin, particularly the selection of waterpoint sites. Mobilisation gives way to the implementation phase of the Project, during which all the diverse but interrelated activities described in this Chapter are in progress at once.

During the implementation of the Project the staff will live within the community for about a year or possibly more. This is an opportunity to gain the confidence of the community and its leaders and for the Project to inform, educate and involve them in all its activities. The establishment of a sense of both pride in and ownership of the waterpoints by the participation of the community in construction and in the maintenance training courses held during implementation is a strong foundation on which a long operating life for the Project is built.

1. INTRODUCTION

1.1. Stated in the simplest terms, the aims of the implementation phase are to meet the Integrated Project objectives and to meet the production targets. The project objectives will have been stated in the Project Submission Document [Chapter B] and can be summarised as:

> *the provision of well-designed and well-constructed waterpoints to give clean water throughout the year to the design population at design consumption levels [Chapter B] in such a way that the life of the supply will be maximised, all for the minimum necessary cost.*

1.2. At the beginning of Chapter B the defining of the area to be covered by the Integrated Project is discussed at some length, but the size of the Project in terms of the number of construction teams is only referred to in passing. Both the overall size of the Project team and the relative sizes of the various components within it are important. The Integrated Project construction unit must be of a size that is easily managed and there must be the right balance between "productive" plant and staff (the drilling and digging teams) and the "overheads" vehicles and staff (tractors, pickups, managers, supervisors). The tractors and trailers, for example, must be sufficient to move and supply the construction teams without any delays and loss of operating efficiency, but not so numerous as to be an unnecessarily high overheads cost. An Integrated Project which can be effectively managed ideally consists of four drilling teams and four digging teams, supported by two tractors and trailers. This is taken as a standard Project unit. The same strict balance is sought in assembling all the remaining staff and vehicles for the Integrated Project around this standard production unit of eight construction teams. The outcome in terms of the detailed staffing of the Project is described in Chapter C and in terms of the vehicle requirements in Section 11 of this Chapter.

1.3. The production targets for this construction unit can now be set. Both borehole and dug-well teams should be able to produce an average of one completed waterpoint each week. In the Upper Livulezi Project this target is being met by the borehole teams, who have sometimes managed to complete a borehole from start to finish in three days. The dug-well teams have not been meeting this target [see Section 13], largely because the optimum ratio of vehicles to construction teams [defined above] has not been kept. We have learned in the Upper Livulezi Project that imposing too severe a restraint on vehicles can impair operational efficiency.

1.4. Taking the production target of one completed waterpoint per team per week and assuming 45 productive weeks in the year (the remainder being annual leave and training courses) the "standard" Integrated Project should produce 180 boreholes and 180 dug wells each year. This would serve about 67,000 people at a cost of about K450,000 (1982 prices). In the next two years we aim to expand the programme of Integrated Projects so that three construction units of this size are operating at once, all implemented by the Groundwater Section of DLVW. Even with a programme of this size we will only be providing new waterpoints for 200,000 people per year. In the longer term this level of production will need to be greatly increased if a serious attempt is to be made to meet the IDWSSD targets.

2. SITE SELECTION

2.1. SITE SELECTION IN MALAWI

2.1.1. Borehole site selection was the major activity of the Groundwater Section when it was a part of the Geological Survey Department. For the past forty years or so site selection has been carried out in a very routine manner by a geologist (not a hydrogeologist) with a geophysical team comprising a Technical Assistant and four or five labourers. The geologist and team often spent long periods in the field, travelling with two vehicles and usually a caravan. This has always been an expensive operation.

2.1.2. Although carried out in a routine way, each siting was treated as an individual exercise unrelated to anything around it; the large body of geophysical and construction data from existing boreholes was not generally consulted. A very small and rapid survey was carried out using the "Cooper - array" resistivity survey technique [see Bibliography]. A series of constant separation traverses were made in the vicinity of the village. When a "good" site was indicated by low resistivity readings a peg was driven into the ground and the team moved on.

2.1.3. The villages which the team visited were generally nominated for a borehole, on a list submitted by the District Development Committee to the Development Division of OPC. Little contact was generally made by the siting team with the village. Perhaps months later a drilling team would arrive to drill a borehole at the marked site. In the meantime the peg might have been moved by the villagers or even removed altogether. Later, possibly again after several months, a pump installation team would arrive to install a handpump in the borehole. It has happened that only at this point has the village been fully aware of what is happening and someone has pointed out that they cannot use the pump because it has been sited close to a graveyard!

2.1.4. It thus became apparent at an early stage in the evolution of the Integrated Projects that there were many problems with the existing approach to borehole siting. In summary, these were:

a) the routine and inflexible use of geophysics lacked an

appreciation of the principles underlying the survey method and its interpretation

b) the approach lacked an understanding of the hydrogeology and occurrence of groundwater as revealed by existing data

c) the communities - the users of the boreholes - were not involved at any stage

d) the siting was costly in relation to the yield requirements of handpump boreholes.

2.1.5. The yield requirement should be the starting point for designing any borehole site survey. Experience has shown that adequate yields for handpumps [see next Section] can be obtained without geophysical surveying if a borehole is properly designed and constructed, wherever there is adequate saturated aquifer thickness (be it weathered basement or alluvium). It is thought that these conditions occur very widely in Malawi. It has become a principle of the Integrated Projects to site waterpoints without geophysical surveys wherever possible as this permits the involvement of the community in the selection of their own sites.

2.2. THE AIMS OF SITE SELECTION IN INTEGRATED PROJECTS

In an Integrated Project the aim is to overcome many of these problems by complete involvement of the community but without ignoring essential hydrogeological considerations. The starting point is the design principles outlined in Chapter B. Some of the major considerations are worth repeating here. With waterpoint sites in an Integrated Project we aim to provide the following:

a) An adequate yield of water throughout the year, ideally 0.5 l/sec sustainable from boreholes and 0.25 l/sec sustainable from dug wells. Yields of half these figures are, however, acceptable.

b) Water of acceptable quality [see Section 16].

c) A sufficient number of waterpoints. The service levels currently aimed for are no more than 250 people per borehole and 125 people per dug well.

d) Maximum amenity value of the water so that it is readily accessible and available to be used to the maximum extent by the community for domestic, agricultural and industrial purposes [see Section 10]. To achieve this, waterpoints should be so placed that all but the most scattered houses are within 500 m, even if this occasionally means providing more waterpoints than population figures alone would suggest.

e) Maximum involvement of the village in the selection of their own waterpoint sites, preferably through the democratic process of an elected Water Committee [see Section 9] to assist in creating the sense of waterpoint ownership.

f) The correct choice of the most appropriate method of groundwater abstraction. If the dry-season groundwater level is at a depth of 4 m or less and the ground is sufficiently soft for digging, a well should be dug. If the groundwater level is at 6 m or more a borehole should be drilled. Either construction is appropriate for water levels between 4 and 6 m. Ideally a village should have both dug well(s) and borehole(s). The dug wells require a major contribution by the community in materials and labour which encourages the sense of waterpoint ownership, whereas boreholes, although unable to absorb the same level of self-help contribution, provide a safer source of water in terms of both drought resistance and protection from pollution.

2.3. WATERPOINT SITE SELECTION PROCEDURE

2.3.1. *Solutions*

The approach that has been evolved to meet these aims comprises a hydrogeological evaluation by the Project hydrogeologist as a first stage, prior to guiding the village communities in the selection of their own waterpoint sites. Furthermore, careful data collection during siting and construction facilitates improved hydrogeological appraisal of future sites.

2.3.2. *Compilation of Hydrogeological Data*

This is an activity that should be completed in the preparation phase and is described there in detail [Chapter C]. The hydrogeologist will carry with him to the Project basecamp all the data on geology, hydrogeology, water quality, existing boreholes and dug wells, population, land ownership and access that he has collected in the office phase of preparation.

2.3.3. *Initial Survey of Project Area*

This should also be largely performed during the preparation phase, though areas where construction will not start for some time may be surveyed even after the implementation phase has begun. The aims of the survey are to:

a) inform and motivate the community at the individual village level

b) identify the population centres (the maps and air-photos alone cannot provide this information)

c) provide field checking of the data collected in the office phase of project preparation

d) arrive at an allocation of boreholes and/or dug wells for each population centre

e) produce base-line information about the area against which the benefits of the Project can be measured.

The survey should be done in the company of as many local leaders and Government field staff as possible, as their involvement at this stage will ensure their involvement later, when they can be of great help in encouraging the community. As a minimum, the relevant Group village headman should accompany the Project hydrogeologist, but in addition the Agricultural Field Assistant, Health Surveillance Assistant, Councillor and Area Party Chairman should be included whenever possible. Every population centre should be visited; the Group Village headman will be able to make sure that none are missed. Experience in the Upper Livulezi and Dowa West Integrated Projects indicates that anything five or more villages can be visited in a day. At each village the following should be carried out:

a) record the village name (including alternative names and census name if this is different)

b) note the 1977 census population. If this is not recorded an estimate must be made from the number of families, houses or

better still the number of farm families (obtained from the Agriculture Field Assistant). Multiply the number of farm families by five to get an estimate of population

c) record brief directions to the village to enable others to find it

d) ask for the headman or his representative [see Section 9] and the Village Water Committee. Record the position of the headman's house and check that the Committee is correctly formed (ideally two men and two women, preferably within the Village Health Committee if this already exists) and that names have been sent in as requested at the main meetings [Chapter C]. If necessary give further explanation of how the Project hopes to help the village

e) determine the distribution of houses. Are they scattered, in more than one group; are there any sub-villages?

f) determine the locations of existing water sources. Let women also answer this question

g) Visit the existing water sources. If the source is:

a river -	record its name, reliability of dry-season flow. Villagers' subjective assessment of quality. Measure EC [Section 16]
a spring -	record the reliability of dry-season flow. Villagers' subjective assessment of quality. Measure EC
an unprotected well -	record the depth to water, depth of well, month in which it dries up, alternative dry season source. Villagers' subjective assessment of quality. Measure EC
a protected well -	record type, date of construction, whether operating, and if not, why not. Check against extracted dug-well data. Villagers' subjective assessment of quality. Measure EC
a borehole -	record its number, date of construction, type of pump, whether operating and if not, why not. Check against extracted borehole data. Villagers' subjective assessment of water quality. Measure EC.

Plot all the above on the field set of 1:50,000 maps and the aerial photographs [see below].

h) ask about any other sources the village uses

j) ask about any disused sources (e.g. old boreholes) and why they are disused. The answer could give information on water quality

k) estimate distance from houses to sources using aerial photographs, counting paces or using a vehicle mileometer

l) describe the situation of the village - dambo margin, ridge top etc.

m) locate and mark rock outcrops

n) make brief notes on access in dry and wet season

o) estimate the projected 1990 population, which is the population from b) above multiplied by 1.5 [see also Chapter B]. Divide the 1990 population by 125 to give the number of waterpoint units (rounding up to the nearest whole number of units) that the village should receive. Remember one waterpoint unit serves 125 people and a borehole is two waterpoint units while a dug well is one waterpoint unit. As a school greatly increases the day-time population of a village (with children coming from neighbouring villages) an additional waterpoint should be sited at or near the school wherever possible

p) According to the terrain and probable depth to water, distribute the waterpoint units to give an estimate of the required numbers of boreholes and wells. Wherever possible a mixture of both boreholes and dug wells should be allocated; remember a dug well maximises the community involvement whereas a borehole maximises protection against drought and pollution

q) Ask the community to commence moulding bricks [see Section 9].

Examples of the type of record sheets used in both the Upper Livulezi and Dowa West Projects are shown in Figures D.2.1. and D.2.2.

2.3.4. *Airphoto Interpretation*

A full set of the latest aerial photography of the area will have been ordered very early in the preparation phase [Chapter C]. During the preparation phase the geological interpretation of the photographs is begun and may even be completed. The Project hydrogeologist then takes his photographs and stereoscope with him to the Project basecamp.

During the field survey alternate photographs should be annotated as follows:

a) Delineate each population centre in blue and write its name. Put a letter "s" by each school

b) Mark existing dug wells, boreholes and springs

c) Delineate in brown areas suitable for construction of dug wells

d) Delineate rock outcrops and steep gradients in red using hatching or the letters "R" and "G".

We now have potential dug-well sites within the areas delineated in brown which overlap or are close to the villages delineated in blue. Boreholes can be sited anywhere within or near to the villages except where rock outcrops or steep gradients are marked (in red), bearing in mind pollution avoidance [see Section 16]. Before revisiting each village [see below] the hydrogeologist should examine relevant photographs stereoscopically and take the marked photo with him - he will then be in a position to make decisions about siting.

2.3.5. *The Role of the Community*

During the preparation phase the community will have been alerted about the Project and will have formed Water Committees in each village. Now comes their first practical involvement. The village can begin its own preparations as soon as it has been visited on the survey. The villages should be revisited well in advance of the planned construction work in their village to:

a) Explain to them their allocation of waterpoints

b) Listen to any complaints and try to resolve them

c) Encourage them to commence site selection

d) Check that the Water Committee, and through them the whole village, are involved in the selection of sites (and not just the headman). The Water Committee should be shown the areas in which boreholes can be drilled and wells can be dug. Simple explanations should be given. The dangers of pollution should be explained and the Committee should be told that water-points should be sited a safe distance [see Section 16] from cattle kraals, pit latrines and graveyards. The potential for waterpoint gardens [Section 10] should also be explained; the site should be chosen on a slope rather than in a hollow to

avoid standing water around the waterpoint. Private land should obviously be avoided

e) Check on the moulding of bricks by the village.

2.3.6. *Site Check*

Subsequently the Project hydrogeologist visits the village again to inspect all sites chosen by the community, preferably accompanied so that a second opinion can be given by the second Project hydrogeologist. If the above criteria [2.3.4] are not met or the site is hydrogeologically unsuitable, the village must be asked to choose again. When the hydrogeologist is satisfied, the site should be:

a) Marked with a peg

b) Cleared by the community to a diameter of 30 m

c) Made accessible by the community

d) For a borehole, shown to the drilling supervisor in preparation for the arrival of the rig

e) For a dug well, the community should be instructed to start digging and an appropriate rod should be given to the Water Committee as a guide to diameter

f) Entered onto the siting record sheets [Figure D.2.1 and D.2.2].

2.3.7. *Conclusion*

Experience gained so far in the two Integrated Projects confirms that, with careful waterpoint (especially borehole) design, an adequate yield can be obtained without sophisticated siting techniques. It is believed that this is the case over much of the low-relief areas of Malawi. The Project hydrogeologist will soon learn of specific problems in the area and, if he feels it would help, can and should resort to geophysical techniques, perhaps as a "negative" tool to rule out areas with very thin weathered profiles. At the time when the Integrated Project approach was evolving (late 1980) an experienced geophysicist was seconded to the Groundwater Section of DLVW for three months. Several different geophysical techniques were extensively tested [see Bibliography]. The general conclusion was that routine use of geophysics for handpump supply boreholes

should be discontinued and that further work was required to decide on the most appropriate techniques to be employed for siting higher-yielding boreholes. It must be emphasised that site selection by the community itself is very important and it is better to have to abandon a few boreholes whilst drilling, if a decision to abandon is rapid [see Section 3], than to pursue at great cost 100% drilling success by using geophysics while excluding the community.

Figure D.2.1.

Siting Record Form for Upper Livulezi Project

BOREHOLE/DUG WELL SITING

VILLAGE	1990 POPN	AIRPHOTO INTER-PRETATION	COMMUNITY DECISION	SITE NO.	DATE		CHANGES TO SITE	RIG NO	DATE ON SITE
					F.M.	C.R.			
M'MANJA	540	2 BH	1 BH	BH 1	28/4	3/5		2406	4/5/82
KUMBUWA (A)	225	1 BH	1 BH	BH 1	13/4	15/4	8/5 Move to new site	365E	11/5/82
MAZONDA	1560	6 BH	5 BH	BH 1	19/4	19/4		2408	23/4/82
				BH 2	8/5	9/5		"	11/5/82
				BH 3	"	"		"	19/5/82
				BH 4	"	"		"	25/5/82
				BH 5	"	"		"	4/6/82
MATAWELA	391	1BH 1DW	1BH 1DW	BH1	17/5			365E	19/5/82
				DW1	4/6	6/6		Team no. 1	12/6/82
CHIMPUNZA	676	2BH 1DW	2BH 2DW	BH 1	22/4	24/4		2221	5/5/82
				BH 2	22/4	"		"	17/5/82
				DW 1	4/6	6/6		Team no. 1	19/6/82
				DW 2	5/6	"		Team no. 2	21/6/82

Figure D.2.2. Extract from Siting Ledger, Dowa West Project

VILLAGE NAME	CENSUS POP^N 1977	VILLAGE COMMITTEE	DIRECTION & DISTANCE OF SOURCE	TYPE OF SOURCE	DETAILS OF SOURCE	QUALITY	SITUATION OF VILLAGE	ACCESS NOTES	ALLOCATION	INSTRUCTIONS GIVEN AND REMARKS
			GROUP VILLAGE HEADMAN CHAKHAZA							
KHOMBE	290	Not yet formed	N.E./300m	Well	Water Table 0.5m/Depth 0.9m/does not dry	Cloudy	Flat ground No rocks	Good in wet season	1 B.H. 1 D.W.	Form committee Choose sites Mould bricks (4000)
			S/500m	Well	W.T. 0.2m/Depth 0.4m/does not dry	Muddy				
			W/900m	Borehole	No. W29. Poor surround	Good				
CHIZAICHI	Part of 431	2 men 2 women	S/600m	Well	W.T. 0.5m/Depth 0.8m/does not dry	Cloudy	Flat ground No rocks	Good in wet	1 B.H. 1 D.W.	Choose sites Mould bricks (4000)
			S/700m	Colonial Well	No. 43/38. Unused and stagnant	Stagnant				
MBAYO	161	Not yet formed	S.W./400m	River	Kasangadzi River	V. muddy in wet season	Top of river slope	Dry season only	1 BH	Form committee Choose site. Bricks (1000)
MANDALA	118	2 men 2 women	S/400m	Wells	W.T. 2m/depth 2.7m/dry in Oct.	Cloudy	Flat land	Good in wet season	1 BH	Bricks (1000) Site. The wells are shared with Chefu village
			S/500m	River	Phadzi River (dry season source)	$C=2.8\times10^3$ µS/cm				
MTSITSA	Part of 115	4 men	N/400m	River	Phadzi River. The village have dug a well which awaits protection	$C=2.1\times10^3$ µS/cm	Dambo margin	Possible in wet	1 D.W. (ready)	Correct c'tee Mould bricks (2500) V. small village

3. BOREHOLE DESIGN AND CONSTRUCTION

CONTENTS

As this Section is such a long and important part of the Manual and the borehole construction procedures are so central to the Integrated Projects, a more detailed list of contents is given to facilitate easy reference for the regular user.

3.6. OPERATIONAL PROCEDURE FOR BOREHOLE CONSTRUCTION

3.6.1. Site

3.6.2. Community Tasks

3.6.3. Mobilisation

3.6.4. Drilling

3.6.5. Recording

3.6.6. Bailer Testing

3.6.7. Stopping the Drilling

3.6.8. Borehole Design and Ordering of Materials

3.6.9. Installation of Casing and Screen

3.6.10. Gravel Pack Installation

3.6.11. Borehole Development

3.6.12. Test Pumping

3.6.13. Borehole Construction Report

3. BOREHOLE DESIGN AND CONSTRUCTION

3.1. INTRODUCTION

3.1.1. It is commonly assumed, particularly with regard to handpumped rural water supplies, that a production water borehole simply comprises a hole in the ground, of indeterminate depth and diameter, lined if the rock formation is unconsodidated with a pipe which is perforated in part to allow water entry. This is not the case at all. An analogy could be a bridge - a properly designed and constructed bridge will do its job effectively, and economically for many years; a poorly designed and constructed bridge will quickly become expensive to maintain and eventually unusable, possibly even collapsing. Exactly the same can be said for a borehole. Not only will a poorly designed and constructed borehole eventually become unusable but we also have strong suspicions that poor borehole design is the biggest single cause of handpump break-down in Malawi. So, in essence, good borehole design is one very important key to the success of an Integrated Project. In order to design a borehole or a dug well a general understanding of water occurrence and movement through rocks (the science of hydrogeology) is important.

3.2. HYDROGEOLOGY

3.2.1. An Integrated Project is managed by professional staff (geologists or engineers) with some postgraduate training or experience in hydrogeology. This subject is absolutely fundamental, as an understanding of groundwater occurrence, movement, quantification, abstraction methods and protection from pollution all have a part to play in an Integrated Project. The hydrogeologist is therefore the key person in a Project.

3.2.2. There are many books on both general and specific aspects of hydrogeology, some of which are listed in the Bibliography. This Manual is not the place for a lengthy treatise on the subject, however there are several important points that relate to the design and construction of boreholes and dug wells that will be discussed briefly.

3.2.3. It is important to remember that an aquifer is defined as a lithological unit (or continuous group of units) that yields water reliably in sufficient quantities for the required use. Therefore an aquifer for handpumped domestic water supply may very well not be regarded as an aquifer for irrigation supplies. Thus in the Manual the term aquifer refers to a potential handpump supply - for a borehole a preferred sustained discharge (or potential yield) of 0.5 l/sec, although 0.25 l/sec is acceptable and for a dug well a preferred sustained discharge of 0.25 l/sec with 0.125 l/sec being acceptable. Higher test yields obtained in a handpump-supply borehole will have the advantage that drawdown (i.e. pumping head) will be lower, as assuming laminar flow (when drawdown is directly proportional to discharge), a borehole with a potential yield of 1 l/sec will have a drawdown of only half that of a 0.5 l/sec borehole, at a uniform handpump discharge. However, too high a potential yield (say, as a rule of thumb over 1.5 l/sec) implies that the borehole is overdesigned, i.e. probably deeper than necessary, and thus more expensive to construct than it need be. This is dealt with further below.

3.2.4. The type of aquifer has an important bearing on borehole design. An unconfined aquifer has no clay or other material restricting water movement at the top of the aquifer so there is a free water surface (or water table) where the groundwater pressure is equal to atmospheric pressure. Groundwater levels are free to rise or fall in response to recharge to and discharge from the aquifer. During drilling in an unconfined aquifer the water remains at the level where it was first struck. A confined aquifer is a layer of water-bearing material overlain by a relatively impermeable "confining" layer. It is completely filled with groundwater and does not have a free water table, as the water is contained under a pressure higher than atmospheric. The top of the aquifer is where the water is first struck during drilling, and the "piezometric level" to which the water rises characterises the pressure condition in the confined aquifer. Many aquifers in Malawi are best described as semi-confined where overlying strata are of low permeability and do not transmit significant water laterally yet are sufficiently permeable to allow some seepage to or from the aquifer. Examples of this are indicated when water seeps into a borehole overnight to a static level which is immediately attained when water is subsequently struck in under-

lying more permeable strata. A confined or semi-confined aquifer is better protected from contamination than an unconfined aquifer where very rapid entry of pollutants into the aquifer could occur from above.

3.2.5. Hydrogeologists are well aware of the concepts of groundwater hydraulics. For other users of the Manual a few simple concepts of special relevance to borehole design need to be presented.

3.2.6. The porosity of a formation is the total volume or void space expressed as a proportion of the total volume (i.e. the amount of water it can hold). The effective porosity or specific yield (Sy) is the total volume of linked void space which drains under gravity. The non effective porosity or specific retention (Sr) is the volume of linked void space which does not drain under gravity. Clays, for example those found near the surface in the weathering profile of basement rocks on the plateau and in the alluvial sequences in the lakeshore and in the Lower Shire Valley have a high porosity (often over 40% but a very low specific yield (perhaps 1%). By contrast sandy material found at the base of the basement-rock weathered profile has a much lower porosity (perhaps only 10 to 20%) but this is almost all effective porosity (i.e. the specific yield approaches the porosity). The porosity of a formation can be made up of both primary (or original) interstices between grainsand secondary interstices (fractures etc). For example the hard unweathered basement rocks in Malawi have extremely low porosity in the rock material itself and virtually all the void space is contributed from joints and fractures.

3.2.7. The storage properties of an aquifer are described by the storage coefficient or storativity (S) which is defined as the volume of water released from storage per unit surface area per unit change in head (pressure). For an unconfined aquifer it is virtually equivalent to the specific yield (Sy) and thus the actual volume of water available in the aquifer is the product of Sy, the surface area, and the saturated thickness. Seasonal fluctuations of water level give a direct indication of recharge if the Sy is known. For example if the Sy is 10% and the water level rise in the wet season is 1 m then the recharge is 100 mm (this is only an estimate as simultaneous groundwater discharge is not taken into consideration).

The whole question of storage in a confined aquifer is rather more complicated. When water is pumped, the aquifer does not dewater, but the pressure of water is reduced,resulting in elastic compression of the aquifer matrix and expansion of the water itself (a smaller effect). So water pumped from a confined aquifer is said to be released from elastic storage. The Storage Coefficient (S) of a confined aquifer is the elastic storage(Se) which is a very small proportion of the aquifer volume - commonly 0.001% to 0.1%. The drawdown and extent of the cone of influence will thus be larger when pumping from a confined aquifer because of the very small Storage Coefficient. Water level fluctuations in a confined aquifer cannot be used to estimate recharge. The Storage Coefficient of a semi-confined aquifer varies depending on the water level; it initially comprises the elastic storage alone and then specific yield will dominate once water levels fall below the top of the aquifer. It is thus unreliable to obtain estimates of recharge from seasonal fluctuations in water level. Natural seasonal water-level fluctuations in an unconfined aquifer are caused by recharge and the subsequent discharge of groundwater. In a confined aquifer seasonal fluctuations to the piezometric surface are caused by changes in hydraulic head (pressure) in the unconfined aquifer transmitted downgradient into the confined aquifer and are therefore likely to be smaller and certainly less rapid. Where there is significant groundwater discharge from springs in the recharge area the changes in pressure transmitted into the confined aquifer may be very small and hence the fluctuations in piezometric level will be small. The situation is more complicated for a semi-confined aquifer where any recharge may result in considerable fluctuations in water level due to the difference in "storage coefficient" between confined and unconfined aquifers.

3.2.8. The permeability (K) or hydraulic conductivity of an aquifer is defined as the volume of groundwater that will move in unit time through a unit cross-sectional area under a unit hydraulic gradient. The permeability generally increases with grain size but it can be very variable depending on the sorting, grain shape and the packing of the aquifer material as these factors control the porosity and size of the interstices. A very small change in porosity can result in a large change in permeability. The rate of groundwater flow per unit head is very slow compared with that of surface water, and very

variable ranging from less than 10^{-3} m/day in some of the fine grained clays in the rift valley alluvium and clays at the top of the weathered basement to several metres per day in some of the coarse unconsolidated sands or gravelly material in the alluvial sequences. The actual velocity of water flowing through some fractured bedrock may be high but the overall permeability is likely to be relatively low because of the very low primary porosity. Faulting may increase or decrease the permeability depending on whether it increases the porosity and/or size of interstices or not. The aquifer material in Malawi is commonly anisotropic with a lateral permeability suspected to be several times greater than the vertical permeability.

3.2.9. The transmissivity (T) of an aquifer is the volume of water flowing in unit time through a full vertical section of the aquifer of unit width under a unit hydraulic gradient i.e. it is the product of permeability and saturated aquifer thickness. The transmissivity remains constant in a confined aquifer as the saturated thickness is always the same. However, when pumping from an unconfined aquifer (for example some alluvial sands) or a semi-confined aquifer where the drawdown is large enough to cause dewatering, the saturated thickness decreases as pumping starts and the pumping level is lowered. The transmissivity is reduced as a result. The larger the drawdown the bigger the decrease in transmissivity. This factor is very important in boreholes drilled into the shallow weathered-basement aquifer where large drawdowns commonly greatly reduce the saturated aquifer thickness in the vicinity of the borehole.

3.2.10. The specific capacity (S.C.) is the yield divided by the drawdown and it is a useful guide to aquifer and borehole performance which can be obtained during test pumping. For low discharge rates the incremental drawdown for an increase in pumping rate is likely to be relatively constant, however at high pumping rates there is likely to be a significant reduction in transmissivity and also possibly borehole efficiency and therefore a decrease in specific capacity. Thus to compare the performance of different boreholes the specific capacity used should strictly be for the same discharge rate and a uniform test time, since the steady state condition when drawdown is constant for a given discharge will not be reached

in the short pumping tests undertaken in an Integrated Project. The very small specific capacities (many < 2 l/min/m) of most old poorly designed boreholes in Malawi are thought to reflect poor borehole design rather than aquifer performance.

3.3. DRILLING RIGS

3.3.1. *General Introduction*

The selection of the most appropriate equipment and materials for borehole construction, or any rural development activity, is an important process that should be carefully considered and continuously reviewed. Equipment and material that is employed should carry out its task efficiently and quickly, at the same time it should be as simple as possible, of relatively low cost and locally manufactured wherever this is feasible. The concept of "Appropriate Technology" is now much misused, for example there may not be justification for using bamboo in a particular structure when steel is available and will do the job very much better (albeit at higher cost). There is often the need to compromise, to understand the relationship between different items of equipment - making one smaller and lighter may result in an associated item being larger and more complex, resulting in false economy. All equipment and materials must come "under the microscope" so that the correct balance is achieved in the relationship of each item to the whole assemblage. An example of imbalance could be the use (and strong advocacy) of hand-drilling equipment in some rural groundwater programmes whilst continuing to use numerous vehicles. A vehicle is easier to misuse and damage, more sophisticated and thus more difficult to maintain and more expensive to run than a small percussion drilling rig. From our experience of putting together the Integrated Project "system" of designs and equipment there are no easy answers, and, in the case of much borehole equipment (for example handpumps) sometimes no wholly satisfactory answer at all unless we develop, or encourage the development of appropriate solutions. Unless we do that we must compromise with the best available option. The one item of equipment in rural groundwater supply programmes that causes the most problems in selection from the wide variety of options is the drilling rig. At one extreme, there are advocates

of hand-operated drilling equipment which can be assembled for a few hundred kwacha. At the other extreme there are advocates of the large multi-purpose rotary rig which can drill in almost any formation with great speed and efficiency but which will have to be imported at a cost of perhaps half a million kwacha, including ancillary equipment, and which require specialist operators.

3.3.2. *Requirements*

It is important to be fully aware of the requirements. In Malawi (and probably elsewhere) rural water supply boreholes for handpumps require an internal diameter of approximately 100 mm to accommodate adequately a handpump cylinder. The boreholes will commonly be less than 30 m deep, rarely over 50 m deep and only in very rare cases reach or exceed 80 m. Drilling formations will range from unconsolidated (and caving) sediments through semi-consolidated rocks (such as weathered gneisses and granites) to (more rarely) hard consolidated rocks. In unconsolidated and semi-consolidated formations a typical well-designed borehole will be drilled at a diameter of 200 - 250 mm, cased at 100 mm and have a 50 - 75 mm thick gravel pack of appropriate grain size. In hard rock a properly-developed open hole of 100 mm diameter is adequate. So an ideal rig will drill 200 - 250 mm holes fast and efficiently in soft rock and 100 mm holes in hard rock to a maximum depth of 80 m, together with the ability to drill both soft and hard rock in the same hole. For drilling rigs to be used exclusively for Integrated Project, an ability to drill larger diameters and to greater depths is not necessary and may well result in greater machine weight, complexity and cost, all of which are undesirable.

3.3.3. *Drilling Methods*

Table D.3.1. attempts to show the relative merits of hand drilling equipment, cable-tool percussion rigs, small air-flush rotary rigs and large multi-purpose rotary rigs. The Table amply demonstrates that there is no simple answer to the general question of "what drilling method is best for rural groundwater supply boreholes". The answers to the question are specific to particular requirements:

a) for 15 m deep, 200 mm diameter boreholes in unconsolidated formations, hand-operated drilling equipment may possibly be most appropriate

Table D.3.1. : Drilling Methods

	Hand-operated rig	Cable-tool rig	Small-air flush rotary rig	Large multi-purpose rotary rig
Capital cost	very low	low-medium	medium	very high
Running cost	very low	low	medium	very high
Training needs for operation	low	low-medium	medium	very high
Repair skills	very low	low-medium	medium	very high
Back-up support	low	low-medium	medium	very high
200 mm holes to 15 m in unconsolidated formation	fast	fast	impossible	very fast
200 mm holes to 50 m in unconsolidated formation	very slow and difficult	fairly fast	impossible	very fast
200 mm holes to 15/50 m in semi-consolidated formation	impossible	fairly fast	impossible	very fast
100 mm holes to 15/50 m in consolidated (hard) formation	impossible	very slow	very fast	very fast

Constraint is mobilisation time

b) for 50 m deep, 200 mm diameter boreholes in unconsolidated and semi-consolidated formations, cable-tool drilling rigs may possibly be most appropriate

c) for 50 m deep, 100 mm diameter boreholes in consolidated (hard) formations, small air-flush rotary rigs may possibly be most appropriate (although compressor size and complexity is a major drawback)

d) for all holes, if cost, manpower and back-up support are not constraints and speed is all-important the large multi-purpose rotary rig could be justified.

3.3.4. *Drilling in Malawi*

In 1980 the Groundwater Section had seven operating cable-tool percussion drilling rigs of medium capacity. A further old cable-tcol rig was repaired and recommissioned in 1981. All these rigs are Ruston-Bucyrus 22 RW machines made in the UK. The RB 22 RW rig weighs 5,750 kg, has a bullreel capacity of 778 metres and is rated to handle 566 kg of tools at 305 m. The rig is strong, reliable, relatively easy to operate and maintain and its design has changed little over very many years. The first of the rigs was purchased in 1950 and the second in 1956, and both have undergone major rebuilds (in 1976 and 1981). Further rigs were purchased as follows: one in 1965, one in 1966, four in 1967 and one in 1971. One rig was severely damaged in an accident and was broken for parts, leaving eight, all of which are operating after between 11 and 26 years. The rig is, however, considerably overspecified for the drilling of handpump-supply boreholes, with a depth rating of over 10 times the average and about four times the maximum hole depth required. Early in the development of the Integrated Project approach, much thought was given to the selection of drilling rigs. The possibility of hand drilling to shallow depths in some of the alluvial areas of Malawi was recognised, but for most areas in Malawi the need for machine-operated drills was clear. The cable-tool drilling rig has been used in Africa ever since drilling programmes started and their suitability is well demonstrated by the longevity of the RB 22 RW rigs in Malawi. In contrast,rotary rigs, particularly large multi-purpose machines, whilst being modern and efficient do not have a good reputation for drilling productivity in Africa.

3.3.4. (2) This is not because of mechanical or design failure; on the contrary, given proper care these rigs are extremely robust. The main reasons for the poor record of rotary rigs in Developing Countries are:

a) the need for very experienced operators (and therefore expatriates for several years, until local staff have been trained)

b) the high foreign exchange costs and logistical difficulties of keeping adequate spares

c) the relative complexity of the rigs resulting in difficult maintenance and repair

d) the problems of providing adequate back-up (hydrogeological supervision, fuel, support vehicles etc.) to match the high speed and efficient operation which is essential if the rigs are to be justified.

Attention was therefore devoted to cable-tool percussion rigs. As the RB 22 RW was considered overspecified for the work smaller rigs were investigated. In the technical feasibility phase of the Upper Livulezi Integrated Project in 1981 and in the earlier development of the "low-cost borehole" in 1980 [see Chapter A], very small site-investigation cable-tool rigs were used (Pilcon Wayfarers). These weigh 850 kg, are capable of drilling to 46 m at 150 mm and comprise a simple winch, manually operated clutch and brakes and a 6 m tripod. A total of 30 boreholes to a maximum depth of 30 m were drilled using these rigs. However, numerous problems were encountered, some of which resulted in major delays and even the loss of drilling tools. Most problems were a result of the lack of the Pitman Beam which on a larger cable-tool rig provides the spudding action. Raising and lowering of the drilling tools using manual controls commonly results in drilling with a loose line. A short tool string rocks against the side of the hole, causing the hole to deviate from vertical which itself prevents rotation of the tool string on the lay of the rope. The oval chisel bit then cuts an oval hole into which it continuously twists and jams. Freeing jammed bits was a very regular (almost daily) occurrence, and though in the majority of cases the tools were freed fairly rapidly by using a snatch block, sometimes several hours were wasted. In one case a drill line snapped whilst attempting to free the tools and, despite about a week of attempting to "fish" them out, they and the borehole were eventually abandoned. These experiences

3.3.4. (3) underscored the need for a proper spudding action if cable-tool drilling is to be employed. A search for a lighter rig than an RB 22 RW with a Pitman Arm revealed the Dando 200 which weighs 1,930 kg, is designed for drilling 200/150/100 mm boreholes to 60 m, and has a 6 m mast. One rig was ordered from UK in early 1981 and arrived in Malawi in early 1982. The rig was put into the Upper Livulezi Integrated Project with an experienced crew to evaluate its performance against three RB 22 RW that were operating very effectively. The Dando 200 drilled quickly and efficiently and was very manoevrable (although its centre of gravity is thought to be high). However cracks in the Pitman Arm, and damage to the jackshaft bearing occurred very quickly, the former being particularly serious. After completing several boreholes the rig was moved away from the Project to the Lower Shire to undertake borehole rehabilitation work. The inability of the rig to cope with the drilling work was possibly a result of some or all of the following:

a) excessively lightweight construction

b) poor operator handling (even though the operator was experienced with RB 22 RWs, the Dando 200 was probably unable to take similar treatment)

c) heavy tool strings - it is good policy to use a long stem to assist in maintaining verticality and drilling jars to ensure tool recovery. Together with a 200 mm chisel bit the tool string was close to the rig handling capacity.

The three RB 22 RW rigs have drilled over 100 boreholes in the Upper Livulezi Valley from the beginning of 1982 to date (November, 1982). No tools have been lost and there have been no major delays due to breakdowns. The rig is overspecified and perhaps too heavy for the task but it is clear that this is better than being underspecified and too light. There are cable-tool rigs heavier than the Dando 200 and lighter than the RB 22 RW. For example, the Dando 400 and the Axbe 250/6 (Swedish) may prove suitable. At 4,500 kg the Dando 400 is 25% lighter than the RB 22 RW, and is designed to handle up to 600 kg of tools at 250 m depth. The Axbe rigs are interesting in that they are of fairly modern design (using easily replaceable standard pillar block roller bearings,

for example, instead of bronze bushes). However no rig has been found that is wholly appropriate to borehole construction in our Integrated Projects.

3.3.5. *The Integrated Project Rig*

The above discussion of drilling rigs illustrates some of the problems of selecting appropriate equipment for the Integrated Project. All this has led to ideas for an "Integrated Project Rig" (or, for more universal application, a "Decade Rig"). As discussed above, we need 200 mm holes to a depth of 30 m - 50 m (and an absolute maximum of 80 m) in unconsolidated and semi-consolidated formations for which cable tool drilling is possibly most appropriate. However for similar depths in hard rocks we need a small air-flush rotary rig (although the compressor remains a daunting problem). A lightweight but strong combination cable-tool percussion rig with a "swing-in", mechanically-driven rotary facility all mounted on a two-axle trailer and designed specifically to carry the tool weights and line lengths necessary to give us the required depths and diameters could be the answer to our problems. The number of handpumped boreholes needed, not only in Malawi but all over the world, justifies the development of purpose-built rigs, rather than using off-the-shelf machinery designed for a range of tasks. It is hoped that, in time, the Integrated Projects will form a focus for development of such a rig.

3.4. CASING, SCREEN AND ANCILLARIES

3.4.1. Almost all boreholes in Malawi drilled for water supply prior to 1980 were either uncased or cased with nominal 150 mm (168 mm OD) or, less commonly, nominal 100 mm or nominal 200 mm steel pipe. The pipe was purchased from the UK in 6 m lengths, screwed and socketed. Deliveries have taken up to one year from placing the order. Screen comprises the steel pipe slotted with a gas torch (up until 1976) or manually with a hacksaw (to date). Torch-cut slots were cut vertically, 300 mm long by about 3 mm wide, at 300 mm intervals down the pipe and three slots around the circumference. This gives an approximate open area of 0.8%. Torch cutting was stopped and replaced by hacksaw cutting in an attempt to eliminate occasional severe sand pumping by reducing the

slot size. Hacksaw slots are cut horizontally, 100 mm long by about 1.5 mm wide, 300 - 400 mm apart prior to 1980 and 75 mm since 1980, with two slots (or, very occasionally three) staggered around the circumference. This gives an open area of 0.1 - 0.2% prior to 1980 and 0.5% open area more recently.

3.4.2. It is clear from the discussion on borehole design below that the open area of the slotted steel pipe has in all cases been inadequate and the slot width (particularly when torch cut) too large. A further major problem with steel borehole casing is its susceptibility to attack by acid groundwaters - which are very commonly encountered in Malawi. With these problems in mind (together with others such as weight, high foreign exchange cost, long delivery time) early in 1980 it was decided to look for alternative materials where the problems could be more easily overcome.

3.4.3. It was initially intended to import commercial screens of various materials (eg GRP, ABS, PVC) and costs. However in January 1980 a visit to Pipe Extruders Ltd. in Lilongwe immediately dispelled the need to import any materials as it was clear that their PVC pipe was of high quality. They are well equipped with three extrusion machines capable of producing a range of PVC pipe in diameters up to 160 mm. They also have a slot-cutting machine comprising a number of circular saw blades on a shaft driven by an electric motor, which is brought down by hand onto pipe resting on a guide bed. The slots are cut at right angles to the pipe axis and slot length can be controlled by setting adjustable stops preventing further downward movement of the blades. The original number of four blades has been increased to 12 by making new shaft spacers. Slot width is controlled by saw blade thickness.

3.4.4. A rapid study of the design specifications of commercial PVC well screens was carried out to give indications of pipe wall thickness and maximum open area for various slot sizes and to investigate acceptable slotting configurations. The first Pipe Extruders borehole casing and screen was made to the Groundwater Section's designs in June, 1980. Since that date almost 200 PVC-lined boreholes have been installed in Malawi for both motor-pump and hand-pump installations. To date (November, 1982) there has not been

a single problem with the casing or screen either during or after installation.

3.4.5. Various trials have been made to determine optimum unit lengths, diameters, pressure rating and slot sizes of the pipe.

a) Unit lengths of both 3 m and 6 m have been tried. The 6 m lengths were found to be awkward both to transport and to handle (particularly when inserting into boreholes). 3 m lengths have therefore become the standard for borehole use. These also give greater flexibility for borehole design.

b) Boreholes have been completed with 90 mm, 110 mm, 125 mm and 160 mm (all OD sizes) PVC pipe. 90 mm pipe poses problems with pump cylinder installation, although a good annular space was obtained in a 200 mm borehole for gravel packing. 110 mm pipe allows insertion of a 75 mm ID cylinder without difficulty although rather more care is needed when placing the gravel pack if the borehole is drilled at 200 mm. 125 mm pipe requires a 250 mm hole for adequate gravel packing. 160 mm pipe requires a 250 to 300 mm hole for gravel packing, but allows large motorised pumps to be operated (holes equipped with 160 mm PVC pipe have been pumped at up to 15 l/sec). Pipe sizes have now been standardised : 110 mm is used for all handpump supply boreholes and 160 mm pipe for all motor-pump supply boreholes.

c) Although "class 9" pipe was originally tried in the 110 mm pipe size, it was found that Class 10(100 m head/142 p.s.i.) gave wall-thicknesses of the various pipe sizes that most closely resembled commercial PVC well screen made in Europe. Class 10 pipe is now used as standard.

d) Slot sizes of both 0.75 mm and 0.375 mm have been used. It was hoped that the latter could possibly be used without a gravel pack and the borehole naturally developed. However difficulty was met with the smaller slot size - the PVC "flowed"to give uneven slots and cuttings were often left blocking the slots. Furthermore in order to maintain acceptable open areas the number of slots needed to be doubled - greatly weakening the pipe. For these reasons, 0.75 mm slots used with a gravel pack have become standard.

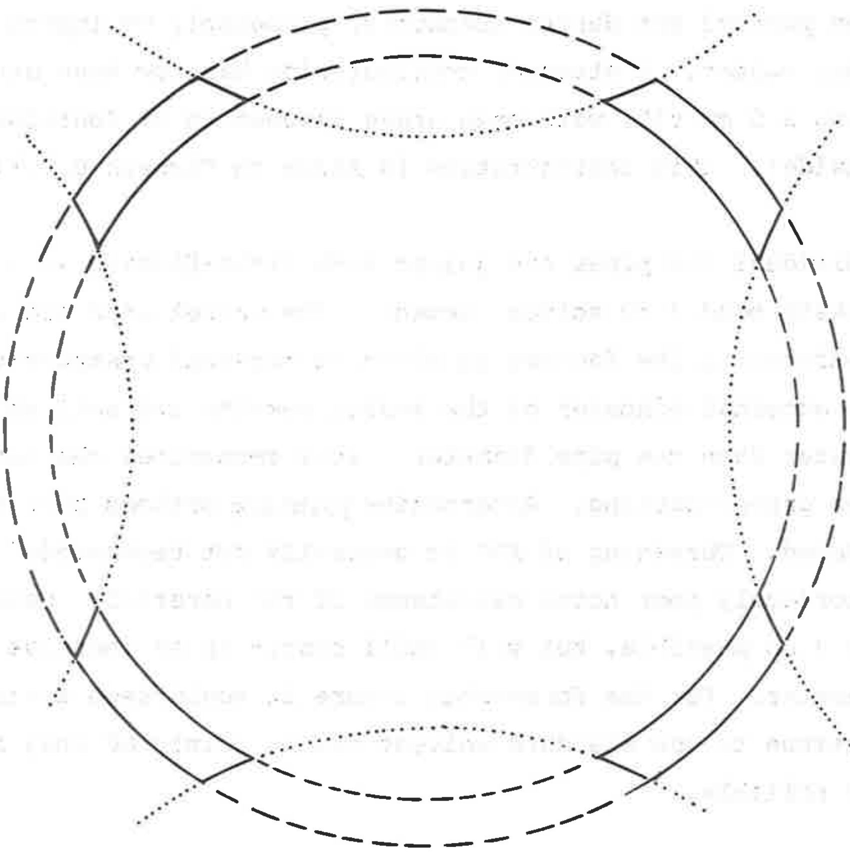
3.4.6. Slot configurations have also changed several times in order to arrive at an acceptable compromise between pipe strength and open area. Initially open areas of 14% (outside pipe surface) and 12% (inside pipe surface) were achieved in 110 mm PVC screen, by having a 3 mm rib between each 0.75 mm slot. However, this rib was slightly flexible and on rare occasions ribs have actually been punched out during transport, presumably by impact from a sharp object. A stronger configuration has now been standardised using a 5 mm rib, with open areas reduced to 9% (outside) and 8% (inside). This configuration is shown on Figures D.3.1 and D.3.2.

3.4.7. Individual PVC pipes are joined with tight-fitting spigot and sockets bonded by solvent cement. The socket ends are carefully chamfered in the factory to minimise external obstruction; however the external diameter of the socket remains two wall thicknesses greater than the pipe diameter. This emphasises the need for care when gravel-packing. Alternative jointing methods have been considered. Threading of PVC is generally not recommended due to the notoriously poor notch resistance of the material. Bayonet sockets are also possible, but will still result in an increase in external diameter. For the forseeable future it would seem advisable in continue to use standard solvent cement joints as they are simple and reliable.

3.4.8. Ancillary items required with the casing in each borehole are a number of centralisers and a bottom cap [Figure D.3.3]. The bottom cap prevents the movement of formation materials or gravel pack up inside the screen. It is made of PVC by Pipe Extruders Ltd. and is a press fit onto the base of the lowest length of pipe. Centralisers are used to ensure that the screen is in the centre of the borehole to guarantee a uniform gravel shroud around the slots. Various ideas have been tried for centralisers and the current solution is to make them out of 32 mm PVC pipe cut to about 70 mm length, split up the centre by 35 mm, the split halves are then heated and splayed to form a T, with a stem height of about 40 mm after the stem end is flattened. Three of these T-shaped centralisers are tied with string equally spaced around the circumference of the screen at the centre of each 3 m length. Centralisers are not used with the blank casing sections.

Fig D.3.1.   110mm CLASS 10 PVC SCREEN DESIGN

(Cross – Section)

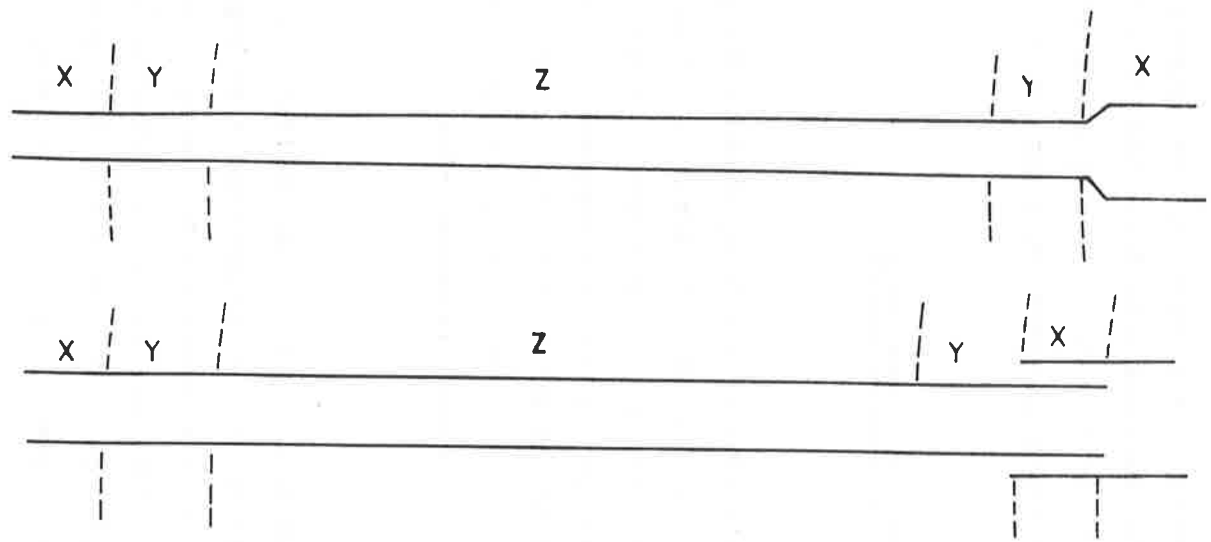


	DIAM mm	CIRC mm	SLOT mm	RIB mm
OUTSIDE	110	345	65	20
INSIDE	98.5	309	51	26

Fig. D.3.2. 110 mm CLASS 10 PVC SCREEN DESIGN (Longitudinal Section)

(A)
Standard spigot and socket

(B)
Flush – jointed with special socket



SLOT WIDTH 0·75 mm

RIB WIDTH 5·0 mm

	OD	ID mm	X mm	Y mm	Z (m)	Nº SLOTS (ROW)	Nº ROWS	TOTAL SLOTS	OUTSIDE PIPE AREA mm²	OUTSIDE SLOT L (mm)	OUTSIDE SLOT A(mm²)	OPEN AREA %	INSIDE PIPE AREA (mm²)	INSIDE SLOT L (mm)	INSIDE SLOT A(mm²)	OPEN AREA %	OUTSIDE RIB WIDTH mm	INSIDE RIB WIDTH mm
A	110	98·5	90	50	2·72	473	4	1892	1003950	65	92235	9·2	899190	51	72369	8·0	20	26
B	110	98·5	75	50	2·75	478	4	1912	1009130	65	93210	9·2	90383	51	73134	8·0	20	26

3.4.9. Whilst the screens now being used in Malawi are performing well and meet the other criteria of being locally manufactured and of acceptable cost, there is still room for improvement. The major problem with a conventional screen is the need for a gravel pack when fine-grained formations are encountered. A change from this either requires a wire-round screen which is prohibitively expensive and is unlikely to be able to be made in Malawi in the forseeable future or a radical change from the conventional ideas of well screen design. One such possible breakthrough is the filter "wraps" currently being developed, whereby different layers of synthetic fibre mesh are wrapped on a core pipe.

3.5. BOREHOLE DESIGN AND CONSTRUCTION PRINCIPLES

3.5.1. *Requirements*

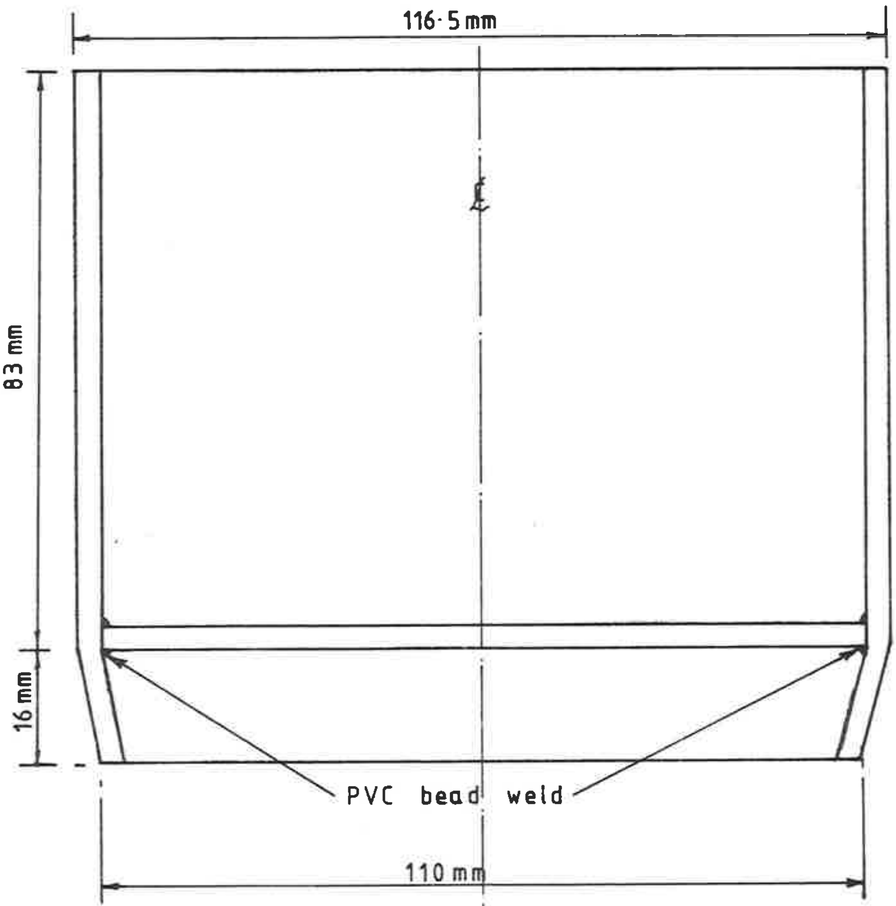
A completed borehole should give a sand-free, sustainable yield of 0.5 l/sec wherever possible, although 0.25 l/sec is acceptable where, for hydrogeological reasons, a higher yield cannot be obtained without great expense (or within a reasonable distance). Any boreholes with yields or potential yields lower than 0.25 l/sec should be abandoned, preferably prior to installation of production casing. This is further discussed below.

3.5.2. *Depth*

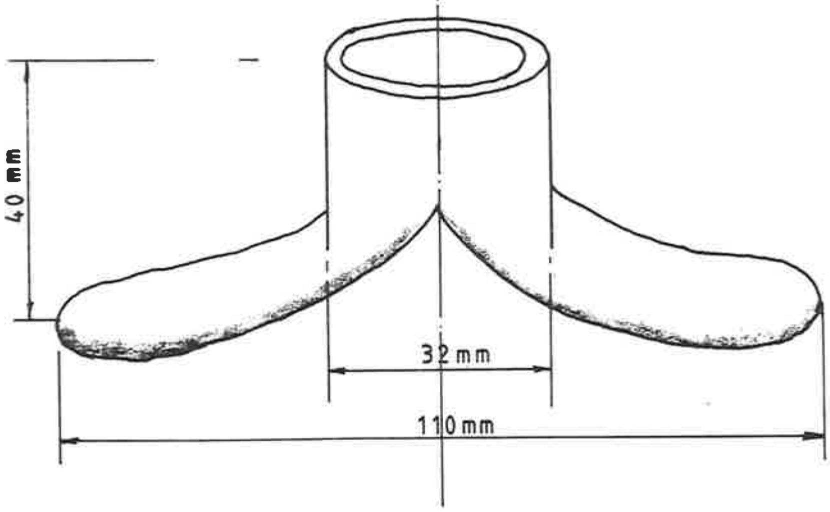
The depth at which to stop drilling has to be decided upon by the hydrogeologist on site and is neither an easy nor a straightforward decision to make. Too shallow a borehole may give an inadequate yield and it may be very susceptible to seasonal fluctuations in water level, possibly drying up altogether during long-term lowering of water levels caused, for example, by a prolonged drought. Too deep a borehole is expensive (invoice cost is directly related to borehole depth) and will take longer to drill (actual cost is directly related to drilling time [see Section 14]. So a compromise needs to be found; drilling only as deep as is necessary is one of the important features of the low-cost borehole design which is itself a characteristic of the Integrated Projects. Almost all the experience that has been gained with the new, low-cost, PVC-lined boreholes in Malawi is in basement rocks, where

Figure D. 3.3

Cross-section of PVC end cap



PVC Centraliser



3.5.2. (3) except fuel are expended and the relatively low cost of the abandoned borehole is an overhead cost shared among successful waterpoints in that month [Section 14].

c) The most useful guide as to when to stop drilling (although better as a positive guide to stop rather than a negative guide to continue) is the bailer test. The procedure for bailer tests is set out in Section 3.7. In principle, the test is carried out at 3 m intervals after first water is struck and involves the withdrawal of 600 litres of water in 10 minutes, with both drawdown and the amount of temporary casing being carefully recorded. Each metre of drawdown in a nominal 200 mm borehole contributes 30 to 40 litres of water from storage in the borehole (assuming no excessive overdrill below the casing), so if a 10 m drawdown is obtained during a bailer test this shows that about 400 litres was taken from hole storage and about 200 litres from the aquifer, which is the equivalent of a yield of about 20 l/min or 0.3 l/sec sustained for 10 minutes. The amount of temporary casing in the hole is important, as the casing may well seal off productive horizons in the aquifer, so a bailer test may be a test of just specific horizons comprising the uncased portion of the hole. Therefore the bailer test results should be treated with considerable caution and they require the subjective interpretation of a hydrogeologist. Nevertheless, the bailer test is the only quantitative guide during construction to the potential yield of the borehole. A rule of thumb, to be used with much discretion, is that:

i) with casing sealing potentially-yielding horizons, a bailer test which equates to a yield [see Table D.3.2] of 0.25 l/sec suggests an adequate borehole yield. For the standard 40 l bailer in a standard bailer test (15 bailers removed in 10 minutes) this is indicated by a drawdown of about 11m.

ii) with no casing below the depth at which water was struck, a bailer test yield equating to 0.5 l/sec suggests an adequate borehole yield. For the standard bailer in a standard test this is equivalent to a drawdown of about 7 m.

If bailer test results are positive, drilling can be stopped if saturated aquifer thickness is adequate (at the discretion of the hydrogeologist).

3.5.2. almost 200 have been installed between July 1980 and November 1982.

(2) It is likely that determination of borehole depth in alluvial strata will be simple, so long as careful consideration is given to possible seasonal and long-term changes in water level. In basement rocks we have three guides:

a) As a general rule of thumb, it has been found that, in weathered basement, 10 - 15 m of saturated aquifer thickness (i.e. below where water is struck, not the static water level if that is higher) is generally adequate to give yields of 0.5 l/sec or more. There should be good reason (e.g. poor bailer test results, see below) to continue drilling when 15 m of saturated aquifer has been penetrated. However only in exceptional cases (e.g. where bailer test results are very good or the piezometric water level is far above the top of the aquifer) should a borehole be stopped when there is less than 10 m of saturated aquifer thickness.

b) Rock hardness is an important factor in assessing when to stop drilling. Firstly, unweathered (and therefore hard) gneisses and granites are virtually impermeable, unless fractured. If well fractured the rock is likely to be at least partially weathered, and therefore relatively soft. Again as a rule of thumb, when drilling progress drops to 0.1 m per hour or less and remains so for one day (i.e. less than 1 m advance in a day) and the rock is seen to be fresh basement (and not, for example, vein quartz, which may be penetrated through to weathered rock again) drilling should stop. If inadequate aquifer thickness has been achieved and/or bailer test results are unpromising the borehole should be immediately abandoned and the rig moved to a new site in the same village. The reason for abandoning the borehole is that drilling on is unlikely to produce significant additional water due to the very low permeability of the hard rock. In addition, the slow rate of progress means that drilling on will be very expensive in terms of actual cost (time related) and give no income in terms of invoice cost (depth related). From experience it has been learnt that losses should be cut and a decision to abandon a borehole made sooner rather than later. This decision is almost always made on the second or third day of drilling. No materials

3.5.2. The general formula for a bailer test in a 200 mm borehole is
(4) as follows:

$$\frac{(N \times V) - (S \times 40)}{T} = Q$$

Where: N ~ No. of bailers

V ~ Volume of each bailer in litres

T ~ Test time in seconds

S ~ drawdown in metres

Q ~ yield in l/sec

The following Table gives drawdowns for various bailer sizes at a discharge of 0.25 and 0.5 l/sec, all for a standard test of 15 bailers in 10 minutes in a 200 mm borehole (slightly overdrilled).

Table D.3.2.

Discharge l/sec	Bailer Volume (l) 20	30	40	50
	Drawdown (m)			
0.25	3.75	3.5	11.25	15
0.5	-	3.75	7.5	11.25

It must be noted that a bailer test is likely to give an erroneously <u>low</u> estimate of potential yield if any part of the aquifer is cased out. Hence a positive test indicates adequate water, whereas a negative test does not necessarily indicate the opposite. However, it must be remembered that if excessive caving has occurred during drilling and this is not sealed by temporary casing then the bailer test yield could be erroneously high. It is clear that the hydro-geologist will have to use both experience and commonsense in combining the above three "devices" to decide when the borehole is "as deep as necessary". It should, however, be borne in mind that too much depth, and thus too high a yield, is far better than too little depth, and thus too low or too insecure a yield. It is better to err on the safe side, but the additional cost could be very significant.

3.5.3. *Borehole and lining diameter*

Lining and hole diameter depend on many factors, and both should be kept as small as possible in order to minimise cost.

a) As discussed above [Section 3.3.2] rural water supply boreholes require an internal diameter after completion of approximately 100 mm to accommodate a handpump cylinder, which may be up to 90 mm OD. If the aquifer material is unconsolidated or semi-consolidated a lining will be required to prevent the borehole from collapsing. This needs to be a pipe of ID 100 mm (e.g. PVC 110 mm Class 10 pipe which has an internal diameter of 98.5 mm). If the borehole is drilled in hard rock and no casing or screen is necessary, the hole diameter should be at least 100 mm.

b) If the formation is unconsolidated or semi-consolidated and contains more than 10% material smaller than fine sand grade a gravel pack will be required as well as a lining to prevent influx of fine material. This is commonly the case in weathered basement and alluvial aquifers in Malawi. The question of gravel pack grading and thickness is discussed below and it is concluded that a gravel envelope of 50 mm is adequate.

c) Questions are often asked about the effect of the hole diameter on yield. The various equations for steady-state radial flow show that:

$$Q \propto \frac{1}{\log r_o/r_w}$$

Where : Q ~ borehole yield
r_o ~ radius of cone of depression
r_w ~ radius of borehole

With r_w varying typically from 100 m for unconfined conditions to 2,000 m for confined conditions it can easily be shown that doubling borehole diameter will only increase yield by about 10%. This important observation shows that the search for the minimum possible borehole diameter is wholly justified.

In summary, a 200 mm drilled hole equipped with 110 mm PVC casing and screen is used where a gravel pack is necessary and a 100 mm uncased hole could be used on the rare occasions when the formation is consolidated. There may also be rare occasions in Malawi where medium to coarse sandy aquifers are penetrated where 110 mm screen could be installed in a 125 mm borehole and careful development could produce an effective natural gravel pack.

3.5.4. (2) An important principle of borehole design is that the pack size is chosen based on the grain-size characteristics of the aquifer and the borehole screen is designed on the grain-size characteristics of the pack and not the other way around, as is commonly assumed. However, in designing a standard gravel pack we have to make a number of assumptions. First of all, in most cases in Malawi it can be assumed that an emplaced gravel pack will be required as there are few aquifers coarse enough to allow the development of a natural pack with the well screens available (although with the minimum available slot size of 0.375 mm [see Section 3.4.5] some medium sand aquifers in the rift valley alluvium could be naturally developed). The next assumption in designing a standard pack is the nature of the water-yielding formation. The basement gneisses in Malawi break down in various stages to clays and the water-yielding horizons are the early-stage weathering products which are very poorly sorted, sandy in texture and have a fairly low clay content. The poorest water-yielding but still productive horizons in alluvial sequences will be fine to medium sands. It is normal to design a gravel pack on the finest formation in a given sequence which is to be screened. Designing a pack for a fine to medium sand with a median grain size (d_{50}) of between 0.2 and 0.3 mm would therefore be reasonable. Much work has been done on gravel pack design since the beginning of the century but nevertheless the basic principles remain empirical. The Pack-Aquifer ratio (P - A), the ratio between grain size of pack and aquifer, is the key factor and is dependent on the degree of sorting of both the aquifer and the gravel pack itself. Numerous P - A values have been proposed in the literature ranging from 4 for uniform formations and uniform packs up to as high as 17 for non-uniform formations and graded packs. Fairly cautious design would allow P - A values of 5 to 8, the latter figure being for non-uniform (poorly-sorted) formations. Graded gravel packs would further minimise the risk of formation movement through th pack. Taking our fine to medium, poorly to well sorted sands with a d_{50} of 0.2 - 0.3 mm, this gives us a gravel pack with a d_{50} of 1.0 - 2.4 mm. For safety it would be preferable to keep nearer the lower figure, although pack permeability will suffer slightly. It is important to emphasise that this gravel pack should work effectively for poorly-sorted, fine-medium sand with a d_{50} of 0.2 mm and all coarser material (although an appropriately coarser gravel pack would minimise head loss and thus be more efficient where the formation is coarser).

3.5.4. *Gravel Pack*

The nature and the role of borehole gravel packs has clearly been misunderstood to date, perhaps largely because of the misleading nature of the term "gravel". Gravel (or "stone-grout") used up to 1980 generally comprised crushed road stone in the 6 mm to 12 mm size range (most commonly 9 mm). Even allowing for overdrill the annulas space between the 168 mm OD steel casing used and the 200 mm borehole would be less than 25 mm, and possibly only 12 mm at the casing collars. Proper gravel emplacement is almost impossible and even if it were properly emplaced the gravel would be unlikely to serve any useful purpose (except possibly to stabilise the casing) as its grading bears no resemblance to that which would be recommended according to standard filter design practice. A properly-designed gravel pack will, however, serve as a filter in preventing fine material from migrating from the formation through the screen, infilling the borehole and damaging the pump. For high-yielding boreholes (and, ideally, for all boreholes requiring a pack) the gravel pack should be individually designed. However, both the cost and the complexity of doing this when constructing a large number of rural water-supply boreholes points towards a standardised gravel pack design that errs on the side of safety and will serve adequately in most cases. A gravel pack serves several functions:

a) it gives a zone of increased permeability immediately around the screen, thereby reducing groundwater flow velocities and as a result decreasing head loss

b) it prevents the movement of fine material through it into the borehole. Put simply, the gravel pack is designed in such a way that the pores between the gravel pack grains are small enough not to allow movement of formation grains

c) it allows a larger slot size in the borehole screen, thereby permitting a higher open area and lower entrance velocity of water into the borehole without an unacceptable reduction in pipe strength

d) it fills the space between the hole wall and lining pipe, preventing formation slumping and possible pipe damage.

3.5.4. (3) Thus the 0.2 mm d_{50} becomes the minimum acceptable figure for a formation to be screened [this minimum envelope is shown on Figure D.3.4]. Early in 1980 a search was made in Malawi for a suitable coarse quartz sand of grain size mostly between 1 and 2 mm. Several sites were located along the shores of Lake Malawi where near perfect, well sorted sands occurred [typical grading shown on Figure D.3.4]. Since that time these sands have been used to successfully gravel pack almost 200 boreholes. When sand is being collected from the lakeshore it should always be remembered that it is the 1 to 2 mm material that is required. This commonly occurs in the swash zone; the dunes above the beach comprise very much finer material. Gravel pack material should preferably comprise well-rounded grains of quartz or other resistant material (not, for example, limestone or other calcareous rocks). Beach sands are generally likely to form good pack material.

A further point to discuss with regard to the gravel pack is the thickness of the gravel annulus around the well screen. Laboratory tests have shown that a pack thickness of only a few grains is adequate to prevent movement of formation grains. So the question of gravel pack thickness is not a theoretical one but a wholly practical one. How large an annulus is required in order to guarantee that the gravel filter completely surrounds the screen? Clearly the gravel annulus should be no thicker than necessary in order to reduce both borehole diameter and gravel volume, both of which affect construction costs. The ideal range for gravel pack thickness is quoted as 75 to 150 mm and the use of a small diameter ("tremie") pipe is generally recommended for installation. However, we have settled on a gravel annulus of 50 mm for the following reasons:

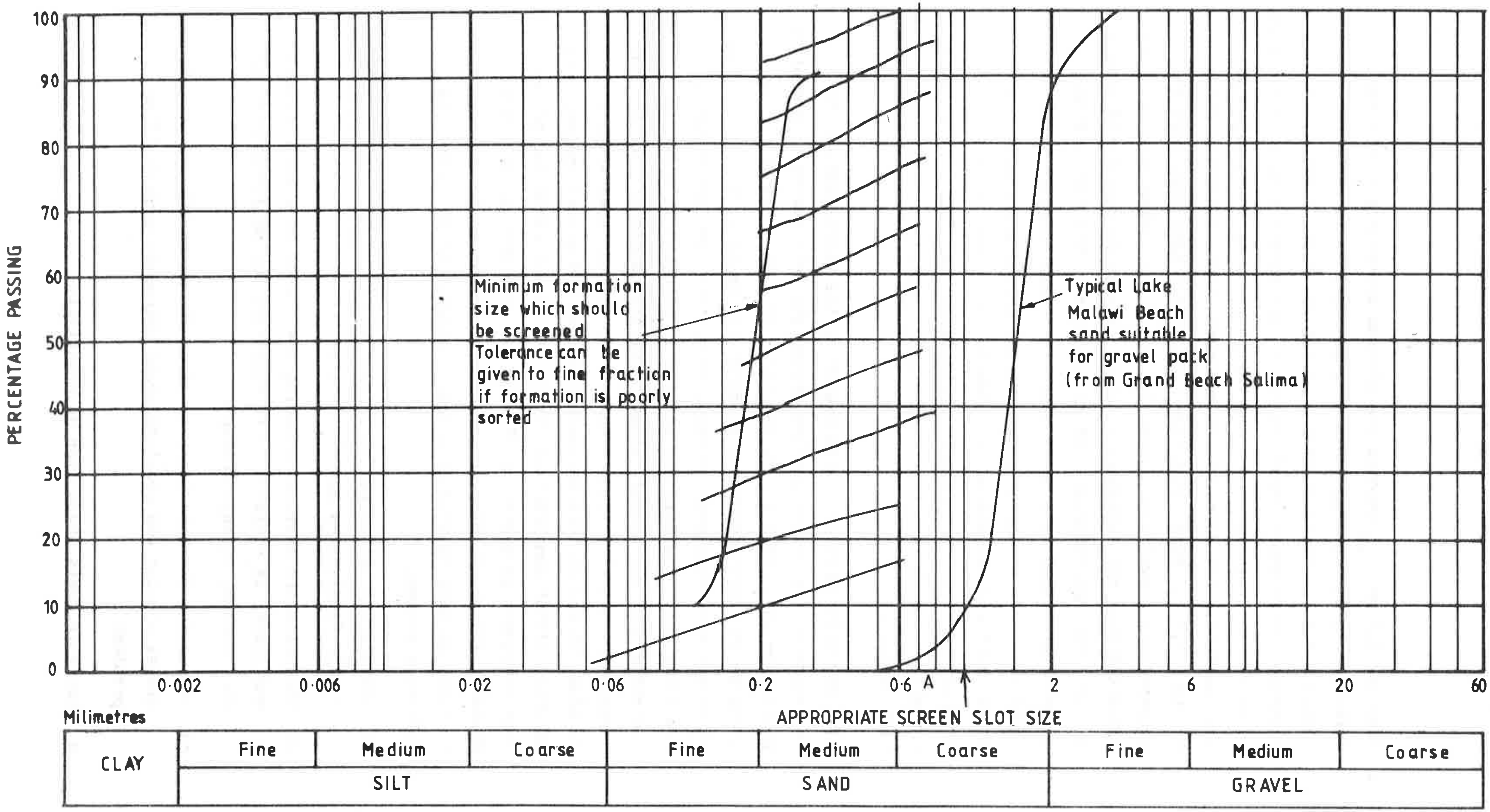
a) temporary drilling casing is used where the hole is unstable - this facilitates gravel settling

b) the holes are shallow, reducing the chance of gravel bridging and gravel is replenished if necessary during development as the bridges, if any, collapse

c) increasing the hole diameter (from 200 mm to 250 mm) if a 75 mm gravel annulus was required) would introduce many drilling problems

d) borehole costs would rise substantially

Figure D.3.4. FORMATION AND GRAVEL PACK GRADING CURVES



e) With almost 200 boreholes completed with a 50 mm gravel pack, only very rarely is any sand pumping noted, suggesting good gravel emplacement in almost all cases.

There is a final but nevertheless very important point to be made about the principles of gravel-packing procedure [the actual practice is discussed in Section 3.6.10]. A carelessly-installed gravel pack may well result in formation collapse against the screen and, regardless of the length of development, sand-pumping will probably occur for the life of the borehole, which will be limited. The borehole will slowly fill with sand and pump wear will be greatly accelerated. An important example of this is that all 20 carefully gravel-packed boreholes drilled in early 1981 in the Upper Livulezi feasibility study and equipped with conventional pumps and cylinders are still using original cylinder cup leathers after between 17 and 20 months (November, 1982) in contrast to the average cup leather life of five months in boreholes in Malawi. It is therefore essential if the long-term and trouble-free life of boreholes and handpumps is to be guaranteed, that one of the Project hydrogeologists supervises gravel-packing from start to finish.

3.5.5. *Screen Design*

Much debate has taken place in the past and continues to take place over the design of borehole screens, although it is only very recently that it has been recognised that even in a low-yielding rural water-supply borehole screen design is a significant factor. There are several important points to discuss:

a) As stated above the screen slot size is selected after choosing the gravel pack size. A number of different criteria have been proposed in the literature for the determination of slot size, depending on the uniformity (degree of sorting) of the gravel pack. However, a safe criterion which is generally used, particularly where perfect control of gravel pack size is not exerted, is that the slot should retain 90% of the gravel pack. As can be seen from Figure D.3.3. this represents a slot size of 1 mm for the beach sand. By using a slot size of 0.75 mm [see Section 3.4.5.] we are again erring on the safe side, which facilitates producing a "standard good design" for Integrated Project boreholes. Thus sand pumping should be minimised, though sometimes at the expense of a small reduction in borehole efficiency.

3.5.5. (2) b) Screen open area is an important design criterion. There are two inter-related factors to investigate. The first is what compromise can be sought between obtaining the maximum desirable open area of the pipe without reducing the pipe strength to an unacceptable level? Clearly the greater the open area of the pipe the lower the groundwater flow velocity, so the ideal is an open hole. However, there is little point in having a pipe open area that is too much greater than the effective porosity of the formation and gravel. If water moves through a gravel pack with an effective prosity of 10 - 20% there is no need for the open area of the screen to be much greater than 10 - 20%. Studies of the hydraulic characteristics of well screens abound and commonly reach different conclusions, however it would seem probable that, depending on the formation permeability, a decrease in performance would be expected if the open area is below 10 - 15% and little increase would be obtained where open area is greater than 20 - 25%. With a highly permeable formation the upper limit should be used if possible and with a low permeability the lower limit is probably more than adequate. The first 110 mm PVC screens used in Malawi had slot open area (measured on the inside of the pipe) of 12%. As the ribs between slots were very occasionally damaged during transport the ribs have been widened by almost 70% and the open area reduced to 8%. This is now the design open area of the screen used for the Integrated Project boreholes. The second factor governing open area is that it should be sufficient to keep groundwater flow velocity through the slots ("entrance velocity") below a maximum desirable value. The maximum entrance velocity has been fixed empirically by various writers at values between 1 cm/sec and 6 cm/sec, depending on aquifer permeability. However, it would appear that an empirical optimum design limit within the range 1.5 to 3 cm/sec using the actual slot area is best recommended (some writers quote 3 cm/ sec - 0.1 ft/ sec - taking an "effective" screen open area as 50% of the actual open area due to partial slot blocking by formation or filter material). To be safe, we should adopt a maximum entrance velocity of 1.5 cm/sec using the actual slot area.

Therefore we can see that at a discharge of 0.5 l/sec and a maximum entrance velocity of 1.5 cm/sec we require 333 cm^2 of slots. The total internal open area of 3 m of 110 mm PVC screen is about 720 cm^2. This shows that all that is necessary to maintain acceptable entrance velocities is half a length, or 1½ m of our well screen! All this of course depends on the permeability of the aquifer, a point so often ignored by screen designers. No screen, even a stainless-steel wire-wound one, will abstract more water than the formation is able to transmit. So only with a highly permeable formation does open area become a very important factor, though rarely to the extent where highly expensive wire-wound screens would be justified.

3.5.6. *Screen Location*

In a permeable sandy formation (which may be encountered in the alluvial areas of Malawi) it is clear that a single 3 m length of screen set against the sand would be more than adequate. In the basement areas of Malawi, however, the situation is very different as the permeability is very much lower. From experience it has been decided that an Integrated Project borehole in basement should have at least three 3 m lengths of screen and, except in exceptional circumstances, not more than five lengths. It has become customary to install screen from the depth at which water was first struck (assuming this is not a minor perched level) or just below this to the bottom of the borehole. In weathered basement it is common for the aquifer to be semi-confined, with water rising to a piezometric level of 1 to 15 m (though commonly 3 - 4 m) above first water. This piezometric head gives several metres of available drawdown prior to dewatering and reducing the saturated thickness of the aquifer. The justification for placing the well screen from where water is struck (which is often queried, as the pumping level is likely to drop well below this and therefore the top portion of well screen will be "non-contributing") is that the basement aquifer is thought to be extremely anisotropic and the zone at the top of the aquifer (often in or near the zone of seasonal fluctuation) is thought to be often fairly permeable. So it is quite possible (and has been noted) that cascading through the screen could be a major contributor. The gravel pack, of course, should act as a conduit, but the additional cost of installing the

extra slotted pipe is thought to be justified, and it also greatly simplifies design. If poor bailer tests result in drilling continuing beyond 15 m below the depth at which water is struck, then 15 m of screen should be alternated with blank casing, unless there is good reason for not doing so.

A further rule of thumb is that screen should not be set at less than 5 m below the ground surface, in order to allow a proper seal against pollution from the surface.

3.5.7. *Borehole Development*

The purpose of development is to stabilise the gravel pack and the formation immediately adjacent to the borehole. Development "cleans" the water, often increases the near-borehole permeability and will cause the movement of fine material into the hole which may otherwise have come in during normal pumping. The technique involves the creation of very much higher water entry velocities than would normally be encountered during pumping at the design discharge, together with "backwashing" into the formation. There are numerous development techniques, all much discussed and varyingly rated by different "experts". However with our boreholes we have two important considerations, firstly, we are dealing with PVC pipe which is fairly fragile and secondly we are looking for a design yield of 0.5 l/sec, and a production pumping rate of only 0.25 l/sec, both very low figures. Bearing both these points in mind and after trying various methods of development (including surging with compressed air and surge blocks), "rawhiding" or overpumping has been selected as the most appropriate method of development. Overpumping is self-explanatory: by intermittently pumping at rates several times higher than the design discharge figure until clean water is produced, the gravel pack and formation will be well stabilised at the low flow rates at design discharge. A further advantage of the "rawhiding" technique is that much of the fine material brought into the borehole is pumped out immediately. With surging all the fine material will settle in the bottom of the borehole and need to be bailed out after development is completed. Using a bailer in PVC screen would be very risky and damage to the screen at this stage would result in abandoning the borehole. From experience it has been found that rawhiding is rarely required for more than four or five hours to obtain sand-free discharge.

3.5.8. *Borehole Test Pumping*

Proper borehole test pumping is designed to provide information on the hydraulic condition or "efficiency" of the borehole itself (determined from a borehole test commonly carried out by increasing discharge in equal steps) and also on the hydrogeological characteristics of the aquifer, its hydraulic properties and the long-term effects of abstraction (determined from an aquifer test, usually carried out as a long, constant-rate test). For Integrated Project boreholes the collection of all this information would be time consuming and expensive and would be a very major task to analyse. In an Integrated Project, test pumping is only carried out to ensure that the borehole is able to sustain an adequate yield for a handpump (although water levels and discharge are recorded to provide a valuable store of information and to assist in pump setting). It is worth pumping the borehole at a rate considerably higher than that of a handpump as this will give more information about the boreholes and may further assist development. If sand-free water is obtained at 1.0 l/sec then it is guaranteed at 0.5 l/sec. At the same time it is better, where possible, to standardise test pumping yields to allow easier comparisons. For that reason, all boreholes should be tested at 1.0 l/sec if the development stage indicates that this can be sustained. If not then 0.75 l/sec is used, or 0.5 l/sec, or as a minimum test figure 0.25 l/sec. Any borehole that gives less than 0.25 l/sec should be abandoned unless there is absolutely no alternative as the handpump will draw the water down to suction and will pump air which will eventually damage the pump due to the additional stresses caused by air entrapment. It is hoped that this situation will rarely arise if proper care is exercised in determining when to stop drilling and poor boreholes are abandoned prior to completion. The length of the test pumping needs to be controlled, as each hour is charged. The test should be continued for four hours only. The procedure is set out in Section 3.6.12.

3.6. OPERATIONAL PROCEDURE FOR BOREHOLE CONSTRUCTION

3.6.1. *Site*

The site has been selected by the community and checked by the Project staff [Section 2].

3.6.2. *Community Tasks*

The community tasks are once again made clear:

a) Ensure reasonable access to the site and clear an area for the rig (and eventual pump and apron) - a circle whose diameter is about 30 m is sufficient

b) Provide water to the rig early (before 7.30 am) every morning. Each rig has a 500 litre tank which must be filled each morning and may need to be replenished during the day

c) Assist in loading and unloading drilling tools, pipes, materials (e.g. filter sand) from vehicles

d) Wherever possible the community should be encouraged to provide food at midday for the drilling crew although this cannot be required of them

e) Provide nightwatchmen to ensure rig and tools are safe from vandalism or theft

f) Provide labour to collect filter sand from the lakeshore

Note : The provision of one voluntary labourer each day by the village to work with the drilling crew has been tried. The idea was that the individual and through him the rest of the village would learn what the machine was actually doing. Although the idea was good this has not worked for unexpected reasons: the drilling crew form an efficient and tight-knit unit and resent the addition of different, unskilled individuals each day. For this reason, the practice has been stopped.

3.6.3. *Mobilisation*

The rig is moved to the new site from the previous one in the following stages:

a) Tractor takes trailer loaded with temporary casing and small drilling tools, in the meantime the crew are pulling out test-pumping rods and pipes and rigging down.

b) Tractor and trailer returns and tractor takes the rig leaving the trailer to be loaded with remaining pipes and tools by half the crew whilst the other half go on their bicycles to the new site to rig up.

c) Tractor returns to collect trailer and remainder of crew bicycle to new site.

This complete operation should take no more than half a day. It is not necessary to keep with the rig a full complement of tools (particularly casing and fishing tools) as many of these are heavy and may rarely be used. Table D.3.3 gives a list of tools that should be moved with the rig and those that should be left at either the Project basecamp or the drillers' sub-camp.

3.6.4. *Drilling*

Drilling commences at 200 m diameter, using water from the 500 litre container filled by the village. Temporary casing is rarely required before water is struck, but below this level it is then common for the hole to cave. When temporary casing is required, 200 mm square-threaded, flush-jointed drilling casing (in 3 m or, less often 1.5 m lengths) is used. Casing should *NEVER* be driven, but allowed to fall slowly under its own weight, or, if necessary "wound" down into the hole using chain wrenches. If casing needs to be driven then the hole is tight and should stand without casing. A casing clamp "spider and slips") must always be used. Drill rig operation is outside the scope of this Manual - drill operators are staff with many years of training and experience in machine operation; they do, however, require guidance and supervision in good borehole construction.

Table D.3.3. : Drilling Tools

WITH EACH RIG

Drilling Tools

- 2 x 200 mm chisel bits
- 1 x 150 mm chisel bits
- 1 x 175 mm dia. dart valve bailer
- 1 x 175 mm clack valve bailer
- 1 x 125 mm dart valve bailer
- 1 x c.120 mm drilling jar (200 mm stroke)
- 1 x c.115 mm drill stem 4.9 m long
- 1 x c.115 mm drill stem 1.5 m long
- 1 x rope-socket + mandrels
- 1 x wireline saver
- 1 x bar and chain tightener
- 1 x set claw-end tool wrenches

Fishing Tools

- 1 x friction socket
- 1 x solid jar bumper bar
- 1 x latch jack
- 1 x horn socket
- 1 x full-circle slip socket
- 1 x c.120 mm fishing jar (450 mm stroke)

Casing Tools

- 8 x 200 mm drill casing, 3 m long
- 1 x set spider and slips for 200 mm pipe
- 2 x chain tongs for 200 mm pipe
- 1 x 200 mm casing hanger

Blacksmith's Tools

- 1 x 150 mm bit gauge
- 1 x 200 mm bit gauge
- 1 x forge
- 1 x anvil
- 2 x 6 kg sledgehammers
- 1 x hot chisel and handle
- 1 x set blacksmith's tongs

Test Pumping

- 10 x 50 mm x 3 m rising main
- 10 x 16 mm x 3 m pump rods
- 1 x 50 mm T piece
- 1 x 50 mm x 3 m discharge pipe
- 1 x 75 mm x 900 m pump cylinde
- 1 x eye socket (pump rod to drill line)
- 1 x V-notch weir tank

General

- 1 x complete tool box
- 1 vice

Table D.3.3. : Drilling Tools (Continued)

IN CAMP (FOR ALL RIGS)

1 x 250 mm chisel bit	10 x 200 mm drill casing (3 m long)
1 x 250 mm bit gauge	1 x 200 mm drive head
1 x centre rope spear	1 x 200 mm drive clamp
1 x combination socket	2 x hydraulic casing jacks
1 x c.120 mm fishing jar (450 mm stroke)	1 x casing clamp

3.6.5. *Recording*

A record of strata (a sample collected, logged by the drill supervisor and independently logged by one of the Project hydrogeologists) should be taken every metre. A record of borehole depth should be taken every hour. Very careful records of casing installed, including the exact length of each piece, should be noted. This is very important for both bailer testing and gravel pack installation. When first water is struck, this depth is noted as is the height to which the water rises. The record of strata, casing record and hourly drilling log are all recorded on the Daily Drilling Report form [Figure D.3.4], together with depths and water levels before and after drilling. In addition morning and afternoon drilling activities are recorded on the Diary Sheet, which is required for waterpoint costing [see Section 14].

3.6.6. *Bailer Testing*

After water is first struck a bailer test is carried out at 3 metre intervals. For this a 3 m long 175 mm dart-valve bailer is used which has an ID of about 140 mm and capacity of about 40 litres. For the test the bailer is lowered, completely filled, raised and emptied as rapidly as possible for 10 minutes or until the bailer cannot be filled (i.e. there is less than 3 m of water in the hole), whichever is the sooner. The aim is to remove on average one and a half full bailers a minute (i.e. the bailer dropped, filled, removed and emptied in forty seconds) in order to take out 15 full bailers (c. 600 litres) in ten minutes. The water level must be recorded on the Daily Drilling Report [Figure D.3.4] before and after

the test, the latter reading being taken as quickly as possible after the bailer is removed. A record is also made of the depth of the hole and the amount of temporary casing in the hole. The bailer tests thus form a record of the yielding potential of various specific and cumulative zones in the aquifer, depending on the length of temporary casing. If possible the electrical conductivity of at least one bailed sample should be measured each day by the supervisor or hydrogeologist and recorded on the Daily Drilling Report, to ensure that a borehole with unacceptably high conductivity is not completed. If the conductivity exceeds 3,000 µS/cm the borehole should be abandoned and a new site selected.

3.6.7. *Stopping the Drilling*

The question as to when the hydrogeologist should stop the drilling has been discussed at length above [Section 3.5.2]. The three "rules of thumb" are that drilling can stop when:

a) 10 - 15 m of saturated aquifer thickness are achieved, assuming adequate bailer test results. Exceptions to this may be made at the discretion of the hydrogeologist when the aquifer is confined and the piezometric level is 5 m or more above the top of the aquifer.

b) Drilling progress drops to 0.1 m per hour or less for one day, i.e. there is less than 1 m advance in the day, and the rock is fresh (not vein quartz for example). A small amount of extra penetration could be more rapidly achieved with a 150 mm bit, if this is likely to result in acceptable borehole depth and yield. If neither the aquifer thickness nor the bailer test criteria are met the borehole should be abandoned without delay and the rig moved to another site in the village.

c) The bailer test provides a positive guide to stop drilling. This is when any one standard bailer test (as described in Section 3.6.6 above) gives a drawdown of less than 7 m if no temporary casing is below the depth at which water is struck or less than 11 m if temporary casing seals off a potentially productive part of the aquifer. Note that if the drawdown is <u>over</u> 15 m and part of the aquifer is cased out by temporary casing the yield <u>may</u> still be adequate. Experience and common-sense are needed.

Figure D.3.5

DAILY DRILLING REPORT

OFFICE OF THE PRESIDENT AND CABINET
DEPARTMENT OF LANDS, VALUATION AND WATER
(GROUND WATER SECTION)

SAMPLE FORM ONLY

Date 20. 7. 82 Drill Headman Mkandawire Project Livulezi
Borehole Nº GP 42
Location Kamphulusa Rig Number MG 2408 Drill Supervisor CHITAUKALI

1. BEFORE DRILLING Static water level (m) —
 Hole depth (m) 7.0 Hole diam.(mm) 200
 Casing depth — Casing diam.(mm) —

2. OPERATIONS (give times)
 A.M. Drilling: From 0700 To 1200
 Other operations Nature
 From — To —
 P.M. Drilling From 1200 To 1700
 Other operations Nature
 From — To —
 Water struck (m) 10.2 Rising to (m) 7.6

3. AFTER DRILLING Static water level (m) 7.6
 Hole depth (m) 17.3 Hole dia.(m) 200
 Casing depth (mm) 15.6 Casing dia.(mm) 200
 EC of bailed sample 510 µs/cm

4. HOURLY DRILLING LOG

Time	Depth (m)	Notes
0800	9.1	
0900	10.4	
1000	12.0	
1100	13.6	
1200	14.2	a bit hard
1300	14.8	
1400	15.3	
1500	16.0	
1600	16.6	
1700	17.3	

5. BAILER TEST RESULTS

Nº	Hole Depth (m)	Temp Casing (m)	RWL (m)	Number of bailers	Time (min)	WL Immediately after Test (m)
1	13.2	11.5	7.8	8	5	10.0
2	16.5	14.2	7.6	15	10	13.1
3						
4						
5						

6. CASING RECORD

Nº (From bottom)	1	2	3	4	5	6	7	8	TOTAL
Exact length (m)	2.98	2.89	2.94	2.69	2.70				

7. DAILY RECORD OF STRATA

From (m)	To (m)	Description
	8.0	Brown clay
	9.0	"
	10.0	Sandy clay
	11.0	Sandy some clay
	12.0	Coarse Sand
	13.0	"
	14.0	Sand some white quartz
	15.0	Coarse sand with clay
	16.0	Sand with some rock fragments
	17.0	Soft brown rock (gneiss)

8. DRILL SUPERVISOR'S SIGNATURE

G. Chitaukali

3.6.8. *Borehole Design and Ordering of Materials*

When the decision has been taken to stop drilling, the borehole must be "designed" by the hydrogeologist without delay so that materials can be ordered from the stores. Empirical rules [developed in Section 3.5.] to be observed for borehole design in basement rocks, unless there is good reason not to, are as follows:

(Note: Empirical rules will be developed and inserted into the Manual for alluvial aquifers, in due course)

a) 110 mm Class 10 PVC screen should be installed from or just below the point at which water was first struck, but not above that, to the bottom of the hole (a 1 m blank casing sump can be used if available)

b) At least 9 m but not more than 15 m of screen should be installed

c) If the depth from where water was first struck in a confined aquifer to the bottom of the hole is more than 15 m some screen should be installed near the top of the aquifer and the remainder (totalling 15 m) at the bottom of the hole, with blank casing in between

d) Screen should not be set at a depth of less than 3 m below the ground surface

e) 3 centralisers are required to be tied in the mid point of each length of slotted pipe

f) plain 110 mm Class 10 PVC casing is installed in 3 m lengths from the uppermost slotted section to about 0.5 m above ground level. Any surplus pipe will be cut off (and could possibly be used as a sump in a subsequent borehole)

g) A bottom cap is required, as is solvent cement (generally about half of a 500 ml tin) and cleaning fluid or aceton (generally about one 500 ml tin)

h) Gravel pack volume is also estimated [see Section 3.6.10].

A requisition for the correct amount of the following materials is passed to the stores at the Project basecamp.

plain casing	slotted casing	bottom cap
centralisers	solvent cement	cleaning fluid
gravel pack		

All items received must be checked and their quantities recorded on the Borehole Construction Report [see Section 3.6.13].

3.6.9. *Pipe Installation*

Installation of PVC casing and screen is simple and foolproof if the following points are observed:

a) for all solvent cement joints the outside of the spigot (male) and inside of the socket (female) are wiped carefully with a rag dipped in cleaning fluid (acetone), which etches the PVC surface to give a better bonding surface for the solvent cement. (Note that acetone is extremely volatile so the tin should only be uncovered for very short periods of time). It then helps to hold the spigot alongside the socket, and mark the spigot (e.g. with a pencil or even clay) with a line to indicate how far it should seat into the socket. Solvent cement is then painted carefully on the inside of the socket and outside of the spigot to the line. The spigot is then pushed into the socket firmly right up to the line in a single smooth action (the fit is so tight that it is only possible as a result of the lubricating action of the cement) and a firm twist is then given to the spigot pipe to spread the cement (although movement rarely occurs). A five minute delay must then be allowed before any weight is put on the joint, to allow the cement to harden.

b) The 3 m lengths of screen and casing should be laid out above the ground (e.g. on steel drilling casing) in the order in which they are to go into the borehole. The bottom cap is cemented to the spigot of the lowest length of pipe. Three centralisers are tied with string across the arms of the T, equally spaced round the circumference of the screen at the midpoint of each length (after ensuring that the centraliser height is no more than 40 mm; if so they must be cut with a hacksaw).

c) The lowest length of pipe is inserted end cap and spigot first in the borehole and held under the socket with which should not be overtightened. The spigot of the next length of pipe is then cleaned with acetone, marked, painted with solvent cement and pushed firmly into the protruding socket of the first length [as in a) above]. After a five minute wait, the pipe string is lifted by 20 cm to check the

solvent cement joint, the clamp is removed and the pipe is lowered carefully into the borehole, to prevent snagging of the centralisers.

d) This process is continued until the lowest length of pipe touches the bottom of the borehole. The pipe string is then lifted 20 cm off the bottom of the hole, to ensure that it is hanging vertically under gravity, the pipe is clamped in position and then cut so that about 0.5 m protrudes above ground. The borehole is then ready for gravel packing, which should be carried out immediately (delays may result in formation collapse against the screen).

3.6.10. *Gravel Pack Installation*

a) Gravel pack material will need to be collected regularly from the lakeshore. Whilst for both the Upper Livulezi and Dowa West Integrated Projects, gravel is collected from Grand Beach, Salima, new Projects may need to investigate alternative sources. For a Project with four rigs completing about five boreholes a week, a 7 ton truck load of gravel will be needed every 7 - 10 days. Gravel grain size should be visually checked [see Section 3.5.4]. Where possible community volunteers should be taken to the Lake to load gravel; experience has shown that this is a very popular outing. Gravel should be stored at the basecamp in a bay with three 1 m high walls and a concrete floor.

b) Gravel pack is delivered with the borehole casing. Although calculation indicates that 22 litres (ie just over one bucket full) of gravel is required per metre of hole annulus (ie 110 mm pipe in a 200 mm hole), experience has shown that two or even two and a half times this is generally required (ie two buckets of gravel per metre of borehole). To avoid extra vehicle journeys to provide small amounts of additional gravel, the figure of 2½ times should be used to order gravel from the stores. For example, a 20 m borehole will require 50 buckets of gravel, a 30 m borehole 75 buckets of gravel. Any surplus should be carefully heaped and moved to the next site.

c) The gravel should be kept on a tarpaulin or canvas sheet and, if possible, protected from heavy rain. When the installation of production casing is complete, gravelling should commence without delay. It is important to feed the gravel continuously at a constant rate to avoid segregation during fall. In practice this means using two buckets, one to pour from slowly whilst another is being filled in readiness to take over immediately.

d) Gravel should be placed from the bottom of the borehole up to 2.5 m inside the lowest length of temporary casing (which emphasises the importance of keeping careful casing records). The casing (if in 3 m lengths) is then pulled (or if necessary jacked) out by 1.5 m only. A 1.5 m length of 110 mm PVC casing is inserted, socket down, over the protruding piece of borehole casing, and gravel is again poured to 2.5 m up inside the temporary casing. The casing is then pulled (or jacked) by another 1.5 m and the top piece unscrewed and removed. The PVC pipe extension is removed, gravel topped up again to 2.5 m inside the casing and the whole process repeated. In this way the gravel is brought up to 3 m below ground level without risking formation collapse against the screen.

e) Gravel is maintained at this level of 3 m below ground during development, and after test-pumping this remaining annulus is filled with clay to 1 m below ground. The remaining 1 m is filled with concrete during handpump installation.

f) All stages of gravel pack installation must be supervised by one of the Project hydrogeologists.

3.6.11. *Borehole Development*

The procedure for development by rawhiding is as follows:

a) A 900 mm long 75 mm ID test-pumping cylinder is carefully installed 1 - 2 m above the bottom of the borehole with 50 mm rising main, 16 mm pump rods and a 3 m long discharge outlet attached to a 50 mm T piece.

b) The discharge pipe should point downslope and, if necessary, a drain should be dug to ensure that pumped discharge is taken well away from the borehole. Pumping is initiated slowly at 15 strokes per minute (representing about 0.7 l/sec with the middle stroke setting of 660 mm on the RB 22 RW) increasing

slowly over 15 minutes to 35 strokes/minute (representing 1.7 l/sec) or until pump suction is reached. After 15 minutes pumping or when pump suction is reached, whichever is sooner, pumping is stopped and recovery allowed for five minutes. At all times, but particularly during the early stages of development, the level of the gravel pack in the annulus around the casing should be maintained at 3 m below ground surface.

c) Pumping is then recommenced at 35 strokes/minute for 15 minutes or until pump suction is reached when pumping should cease and recovery for five minutes allowed, as above.

d) This process should continue until the discharge water is clear and visually sand-free, which generally takes two to three hours and rarely exceeds four to five hours.

e) Development which is required beyond five hours is likely to be a result of poor gravel-packing. Development should continue into a second day only at the discretion of the hydrogeologist.

3.6.12. *Test Pumping*

Test pumping procedure is as follows:

a) Full recovery is not necessary prior to test commencement, as this could take several hours and the test is not designed to give aquifer or well properties, but only to confirm yield adequacy.

b) Using the pumping equipment exactly as set up for development, the borehole discharge is pumped into a weir tank marked at 1.0, 0.75, 0.5 and 0.25 l/sec. The borehole is pumped continuously for four hours at the highest possible of these rates (a clear indication of potential will have been obtained from the development operation). Adequate drainage away from the borehole must be ensured.

c) Water levels should be recorded as follows:

0 - 20 minutes	every 2 minutes
20 - 30 minutes	every 5 minutes
30 mins.- 2 hours	every 15 minutes
2 hours - 4 hours	every 30 minutes

d) During the final hour of the test, the electrical conductivity should be recorded and a water sample collected [Section 16].

e) After four hours the pumping should be stopped and recovery measurements should be taken for one hour as follows:

0 - 20 minutes	every 2 minutes
20 - 30 minutes	every 5 minutes
30 mins. - 1 hour	every 15 minutes

f) During the recovery, the pipes and rods should be removed carefully from the borehole. The hole depth is then plumbed to determine the amount of infill during development. The annulus around the casing is backfilled to ground level with clay that is tamped down. The borehole casing is given a temporary cap and the rig and crew are then ready to move to a new site. The first load (temporary casing and drilling tools) will have been moved during the development and testing stage.

3.6.13. *Borehole Construction Report*

Section 3.6.5 describes the regular recording of information on the Daily Drilling Report. At the end of borehole construction the Borehole Construction Report should be immediately and carefully filled out. This report includes much of the information required for costing the borehole and all the information for the cardex hydrogeological archive. Completed examples of the form are given in Section 13.

4. BOREHOLE REHABILITATION

4.1. AIMS

One of the essential components of the Integrated Projects is the rehabilitation of existing boreholes and the protection of existing dug wells where possible and appropriate. The latter is briefly described in Section 6. From the description of groundwater development in Malawi [Chapter A] it is clear that there has been a very considerable investment in boreholes already. The aim of the rehabilitation component is to ensure that this investment is not written off but effectively utilised by incorporating existing boreholes into the Integrated Projects wherever possible so that the community-based maintenance system [Chapter E] can be extended to cover them. In the discussion of alternative-supply options [Chapter B] the example of the Zomba South area was quoted. Rehabilitated in an Integrated Project, the 109 existing boreholes represent a service to meet the design principles for 20% of the 1990 population.

4.2. SOLUTIONS

4.2.1. If the existing boreholes are to be incorporated into the maintenance structure which is to be established by the Integrated Project [Chapter E] then the pumps must be replaced. None of the existing handpumps [Section 7] can be maintained at the village level. They should therefore be replaced by the Malawi (deep) pumpheads so that maintenance requirements of new and existing boreholes are unified.

4.2.2. Simply replacing the handpump is not, however, sufficient to ensure that the existing borehole does play a full part in the Project by providing an adequate and reliable supply that is of an equal standard to that of the new waterpoints. The design and construction defects of the existing boreholes

have been referred to in Section 3. The poor screen and inadequate gravel pack mean that many of the existing boreholes continue to pump sand throughout their lives. Unless this problem is rectified, the new pump may require much more frequent maintenance than the pumps installed on the new Project waterpoints. A procedure for cleaning out the existing boreholes and, where appropriate, installing an inner lining and gravel pack is, therefore, an important component of the rehabilitation work. The costs of the rehabilitation procedure outlined in Section 4.3 have to be carefully monitored, in the same way as the costs of construction are monitored. There may be occasions when it is cheaper to re-drill a new Project borehole rather than go to great expense cleaning out and relining a particularly difficult existing borehole. Each rehabilitation attempt is, therefore, an individual exercise requiring the judgement of the Project hydrogeologist.

4.2.3. To bring the existing boreholes fully into the Project also requires the involvement of the community. The people living around the existing borehole may have had poor service in the past from a pump which breaks down frequently and is out of action for long periods. The rehabilitation will have to be explained to them in exactly the same way as all the other components of the Project, emphasising that rehabilitation will not leave them with an inferior waterpoint. The community will need to bring materials so that an improved apron and washing slab can be constructed. After rehabilitation, therefore, the borehole should be indistinguishable from the newly constructed Project boreholes. It is important to ensure that the community are happy with the location of the old borehole, whose site they will not have chosen. A new pump and apron will not necessarily be sufficient to change people's attitude. If they are unhappy with the location, for example if a graveyard is close by, an alternative site must be chosen and a new waterpoint constructed.

4.3. REHABILITATION PROCEDURE

4.3.1. The number of existing boreholes in the area of an Integrated Project is obtained in the planning phase [Chapter B]. At this stage all that is required is the number of boreholes so that sufficient provision for rehabilitation is made in the Project Submission Document. Thus, in the preliminary cost estimate, an average rehabilitation cost of K750 for each existing borehole is included.

4.3.2. In the preparation phase more detailed information is abstracted about the construction details and maintenance record of each borehole. The important information required from the maintenance records is:

a) depths of borehole measured periodically on maintenance visits

b) water levels measured on maintenance vists

c) frequency and nature of pump repairs.

The boreholes are visited in the course of the initial survey [Section 2] to collect additional information on:

a) the current state of the borehole and surround

b) the site location in relation to pollution hazards

c) the attitude of the village to the borehole

d) the chemical quality of water from the borehole.

4.3.3. *General Rehabilitation Criteria*

All this information is put together by the hydrogeologist and related to the general criteria for deciding whether and how to rehabilitate each borehole.

a) *Water Quality*. If the electrical conductivity of the water is above 3,000 μS/cm the borehole should not be rehabilitated, unless there is little chance of finding a nearby site to drill a borehole or construct a dug well to provide water of more acceptible quality. If there is no alternative site, and the village have been using the borehole and wish to continue using it, a full chemical analysis should be taken. If no constituents are unacceptably high [Section 16] then rehabilitation should be considered.

b) *Yield*. If the original tested yield of the borehole was very low (less than 0.25 l/sec) then rehabilitation is unlikely to be successful. An alternative site for a new waterpoint should selected. If the original tested yield was over 0.25 l/sec the borehole should be included in the rehabilitation programme, where a decision to proceed with rehabilitation is made on the basis of the initial test pumping of the borehole [see below].

c) *Infill*. Many boreholes have infilled to some extent because of the poorly designed gravel packs [Section 3]. It is commonly thought that a very large number of the existing boreholes require immediate cleaning because of the amount of infill. It is, however, the rate of infill in relation to the borehole depth and casing configuration which is important. If a 45 m deep borehole with 25 m of slotted casing at the bottom has infilled by 10 m in 35 years, then the sand pumping problem is not too severe. If, in contrast, a 45 m deep borehole with 20 m of slotted casing at the bottom has infilled by 20 m or more in two years, then water inflow must be greatly restricted and rehabilitation is certainly required. In practice, it has been found that the depths measured by the maintenance crews (each time a handpump is removed) are so unreliable that they cannot be used at this stage as a definitive criterion. No borehole is, therefore, eliminated from the rehabilitation programme on the basis of infill unless it is so blocked by pipes or other material dropped into the borehole that it is technically difficult and costly to clean it out.

d) *Frequency of repairs*. If a borehole has been pumping sand it is likely that the downhole components (cylinder and cup leathers) will have required very frequent replacement [Section 7]. This will present a continuing problem to the new pump, unless it can be resolved by installing an inner liner and new gravel pack. If a borehole has required much less frequent replacement of downhole components and there is little evidence of infill, then the full rehabilitation procedure may not be necessary.

e) *Lithology.* The existing boreholes were completed in the same way [Section 3] whatever the lithology of the aquifer. In an Integrated Project where an alluvial aquifer occurs, sand pumping is likely to be a very significant problem and most of the boreholes will need cleaning and relining. In a Project in a weathered basement area, many of the existing boreholes will have been completed in the fresh bedrock [Chapter A] and the infill and repair frequency will be much lower.

The criteria for selecting boreholes for rehabilitation and the operational procedures for carrying out the work are still being established in rehabilitation activities currently underway. The complex relationship between the infill, the original borehole construction, and the need to relate the technical aspects and cost of the rehabilitation to the alternative of providing a new waterpoint nearby emphasise the need for professional hydrogeological input to the rehabilitation programme. The current (November, 1982) operating procedure is described below.

4.3.4. *Steps in Operational Procedure*

a) Inform the Village Water Committee that the borehole is to be rehabilitated and ask them to clear access and supply the materials for an improved apron [Section 8].

b) Remove the existing pump and, if necessary, break the apron so that the drilling rig can move over the borehole

c) Measure the depth of the borehole and the water level.

d) Begin bailing with 100 mm diameter bailer, measuring the increased depth attained.

e) Continue bailing to original depth or until bailer is producing water only, in which case the infill material is too compacted to be removed by bailer.

f) Run in drill bit to disturb infill material

g) Continue alternate drilling and bailing until original depth is reached

h) If there is an obstruction in the borehole caused by a dropped cylinder, rising main and rods, for example:

- if recent and standing above the infill it may be easy to "fish" for it

- if buried by infill material it cannot be economically retrieved.

j) When original depth is reached or the borehole is blocked, perform test pumping for one or two hours to determine the yield of the borehole to confirm an adequate yield for rehabilitation
   - If the sustained yield is 0.5 l/sec or more the borehole should be relined
   - If the sustained yield is less than 0.25 l/sec and the borehole is blocked at shallow depth, the borehole should be abandoned
   - If the sustained yield is between 0.5 and 0.25 l/sec and the borehole has been cleaned to its original depth, development should be attempted to increase the yield [see Section 3]. In many existing boreholes the pump intakes are set uneccessarily deep and merely raising the cylinder may greatly ease the sand-pumping problem. If development does not result in clear water after 10 hours the borehole should be retested. If the yield is 0.5 l/sec or more the borehole can be relined, if not the borehole must be abandoned and an alternative site chosen
   - if the borehole has been cleaned to its original depth and the sustained yield is less than 0.25 l/sec then the borehole should be abandoned and an alternative site chosen.

k) After testing, measure the depth of the borehole and bail out any infill.

l) Install 110 mm Class 10 PVC casing and screen. Select screen length and position according to depth at which water was struck, water level and location of existing slotted casing (from construction records). This should be a maximum of five or six 3 m lengths of PVC screen [see Section 3 for details of PVC installation]. The PVC for use in rehabilitation has much smaller centralisers to allow gravel to pass in the very small annular space between the PVC and the steel casing.

m) Install gravel pack material [see Section 3] very slowly to allow adequate settling. It is not possible to measure the gravel level in the annulus. Water poured into the annulus may assist in settling the gravel.

n) Measure depth of borehole inside casing.

o) Install test pumping equipment to 1 or 2 m above the bottom of the PVC lining. Develop the borehole by interrupted over-pumping ("rawhiding") as described in Section 3. This should continue for at least three hours or until the water is clear.

p) Carry out test pumping for four hours at a constant rate determined from development results. If the sustained discharge after installation of the PVC and gravel has dropped below 0.25 l/sec an alternative site should be selected and the borehole abandoned.

q) Remove testing equipment. Measure depth of borehole and water level.

r) Use testing results to determine handpump cylinder setting [see Section 7].

s) Install new handpump [see Section 7].

t) Construct new apron and washing slab [see Section 8].

4.3.5. In the investigation of borehole rehabilitation techniques, carried out in 1982 by the UN Borehole Maintenance Project (attached to the Groundwater Section of DLVW), a compressor has been used successfully to clean out infilled boreholes. This is a very quick method of removing the infill if it is fined grained (silt or sand) and not too compacted. Cleaning with the compressor using a flexible air hose may clean out many metres of soft sand infill in a few minutes. Once the borehole is cleaned to total depth, the procedure for installing PVC and placing gravel is as outlined above. The compressor with air line and eductor pipe can then be used as an effective way of developing and testing the rehabilitated borehole, moving the pipes up and down the screen for most effective development. The techniques of rehabilitation are still being evaluated and there may need to be modifications to this Section of the Manual in due course.

5. DUG-WELL DESIGN AND CONSTRUCTION

5.1. INTRODUCTION

Dug wells have always been regarded as a simple, unsophisticated and relatively easily-constructed way of providing rural water supplies. They have, however, also aquired a reputation for unreliability during dry years as so many wells are dug in an ad hoc way "until there is enough water". In Malawi, although over 2,000 protected dug wells with handpumps exist, there are still no firm criteria for well depth or yield to guide the relatively unskilled digging crews and their village helpers in digging a well which will be a good and reliable source of groundwater. The Integrated Projects set out to provide waterpoints which are well protected against both drought and contamination, achieving this at no greater level of skill or cost than necessary. For that reason, if dug-wells are to continue to play a major role in the Integrated Projects, as is hoped and planned, design criteria for dug wells deserving of the title "Integrated Project waterpoints" must be tested and established as soon as possible. This Section is written as an interim measure to give the problems, some possible answers and stop-gap procedures Almost two years development of the "low-cost borehole" has been carried out, mostly in the Upper Livulezi Valley and much success has been achieved. It is now the turn of the dug well, and the Dowa West Integrated Project has become (November, 1982) the location for testing appropriate designs and construction techniques for the dug well. This Section will be rewritten when acceptable solutions to the many outstanding problems of dug wells have been found.

5.2. DUG WELLS IN MALAWI

5.2.1. Dug wells have been constructed, in one way or another, for very many years in Malawi. The broad, shallow valleys("dambo") of the plateau areas of Malawi have always been the focus of population settlement, partly due to the proximity of water to the surface right through the dry season. Traditional water holes in a dambo margin are generally shallow, large in diameter and stepped on one side to allow women to walk down to the water to fill their pots. There are not, however, the traditional skills of dug-well construction which exist in much of the Middle East and Asia.

5.2.2. A major well-digging programme was carried out in various parts of the Central and Southern Regions during the 1930s by the Colonial Development Corporation. Little is known of the construction details or even the locations of some of the wells. Many of the wells are still in use. They are lined with concrete and are walled but otherwise open, with a windlass and chain to lower individual villager's buckets. Some of the wells are extremely deep - exceeding 30 m total depth in alluvium in some cases - and represent a major construction exercise. It is assumed that the wells were constructed by well-equipped and skilled teams and were probably expensive at the time. It is certain that the cost of dug wells of that depth and construction would compare unfavourably with the cost of drilling a borehole at the same site today.

5.2.3. The "Community Protected-Wells Programme" started within the Ministry of Community Development in 1975 as an offshoot of their Rural Piped-Water Programme. The policy of maximised community participation had been well demonstrated in the piped-water projects. The aim of the dug-well programme was to utilise the same community spirit to dig wells in the flat "dambo" areas of Malawi where gravity piped-water supply was not feasible and people were accustomed to using water-holes in the dambos. A big step taken was to protect the dug well with a top slab and install a handpump. Section 7 describes the handpump development, which was initiated to produce a simple, cheap, easily assembled and locally-maintained unit. Dug well construction between 1975 and 1980 was carried out as follows:

a) Government supplied eight bags of cement, a pump and a 1.7 m diameter top slab with flange-fitting for the pump

b) The village supplied sand, 1,000 bricks and selected the site

c) The villagers carried all the materials to the site (using ox-carts if necessary) and dug a 2.5 m diameter hole through the top soil to the underlying dambo clay

d) With the help of a Project Assistant a brick foundation wall (OD 1.7 m, ID 1.2 m) was built with cement mortar inside the hole

e) Villagers dug the well inside the foundation (at a diameter of about 1 m) into the clay soils to the required depth (said to be usually 3 m below the brick foundation); this part of the well was left unlined

f) The brickwork was plastered, the concrete slab positioned and a surrounding drainage apron constructed

g) The pump was installed by the Project Assistant who then held an opening ceremony.

5.2.4. In early 1980 the dug-well programme of the Ministry of Community Development came into the new Groundwater Section of DLVW. New dug-well designs were tried and during 1981 and 1982 two main designs were utilised in the national (dispersed) dug-well programme.

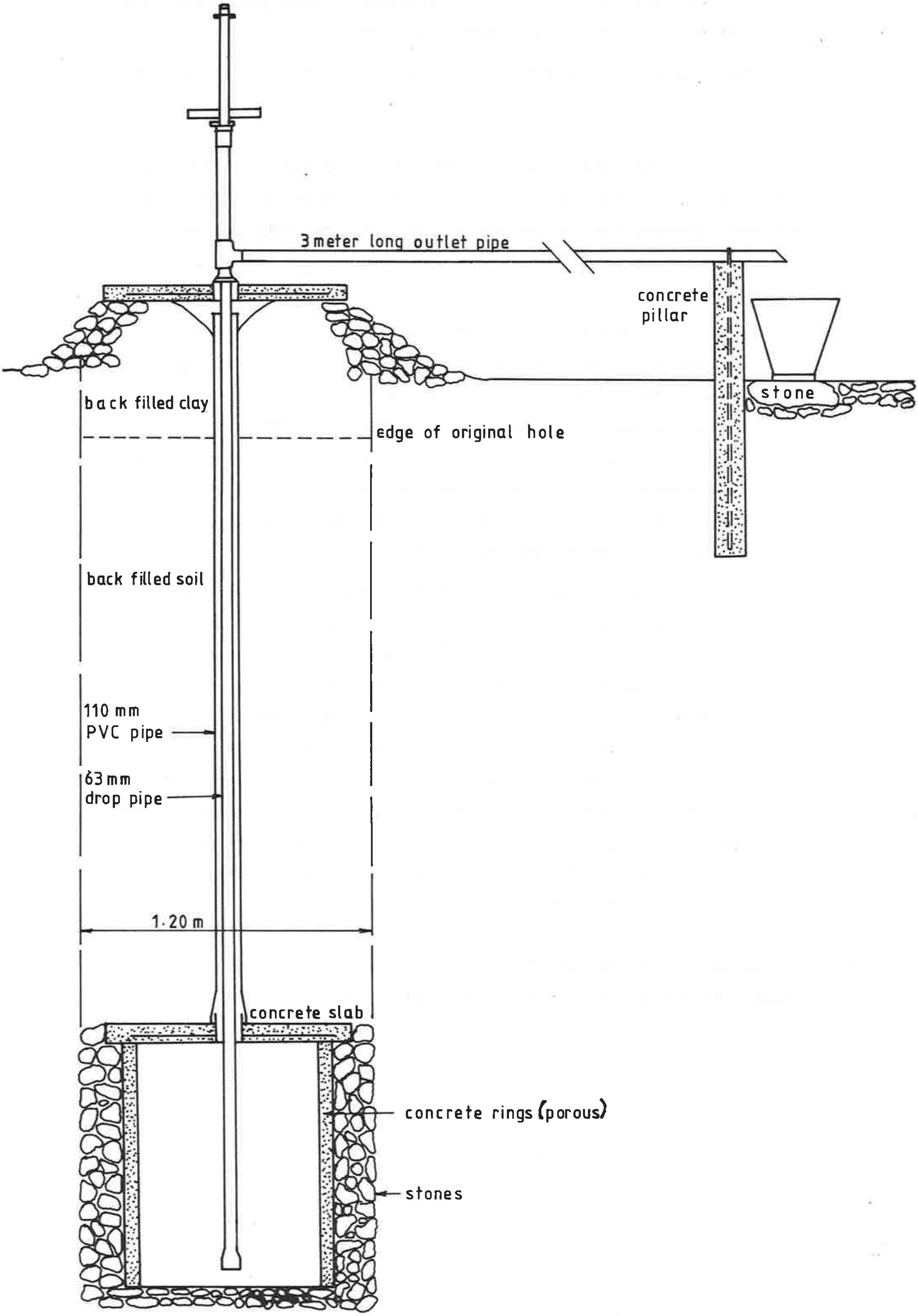
a) Where only limited Government support is available from a Project Assistant a 1.5 m diameter hole is dug by the villagers as far below water as possible. The hole is lined with bricks and mortar throughout its depth, reducing in diameter towards the top to accommodate a 1 m diameter concrete slab. The brickwork is done by a specially-trained local builder who is paid a fixed rate per metre of lining. A pump is installed by the Project Assistant.

b) Where digging teams are available a hole is dug several metres below water level, two or three 1 m high, 0.8 to 1 m diameter concrete rings are installed and covered with a bottom slab. A PVC pipe passes from ground level through a hole in the bottom slab into the concrete-ring chamber. The well is then backfilled from the bottom slab, around the PVC pipe, to just above ground level. A top slab with an 80 mm socket cast into the centre is positioned over the well, with the socket centred over the PVC pipe [see Figure D.5.1]. This is the construction method employed in the Upper Livulezi Project and is described in detail under Procedure [Section D.5.6]

5.2.5. It is estimated that about 2,000 protected dug wells with handpumps have been constructed to date (November, 1982).

Figure D. 5.1. TYPICAL DUG WELL WITH BACKFILL

Scale: 1: 20



5.3. DUG-WELLS IN INTEGRATED PROJECTS

5.3.1. For the first time in Malawi, the Integrated Projects have brought dug wells and boreholes together into one programme. In the past both have been entirely separate and often in direct competition, each claiming to be better than the other. It is clear that both have advantages - and disadvantages - relative to the other and that the benefits of both can be combined by integration of the two together into a single programme [see design principles in Chapter B]. Groundwater is the resource that the Integrated Project seeks to develop and the method of abstraction of groundwater is then selected in a rational way. If the groundwater level is shallow (3 - 4 m), and the formation soft enough, a well is dug; if the groundwater level is deep (below 6 m) a borehole is drilled. Either a borehole or a dug well is equally appropriate for intermediate groundwater levels of 4 to 6 m. There are only few areas in Malawi where a mixture of dug wells and boreholes would not be appropriate. Locally, deep water levels may rule out the use of dug wells and, also locally, an incised landscape with fresh bedrock at or near surface may only readily permit groundwater abstraction from dug wells in the thin colluvial soils adjacent to the drainage lines.

5.3.2. By far the most important advantage of the dug well is that the community is directly involved through their own physical effort in its construction. There is undoubtedly no better way of ensuring their commitment to proper care and maintenance. Furthermore the dug well requires unsophisticated equipment for its construction and because of the large component of unpaid labour, it is relatively cheap to construct. A final important factor is that a dug well can be a successful source of water supply in a very thin low-permeability aquifer (as may be found in some of the dissected areas of Malawi) whereas successful borehole construction would be difficult and perhaps costly.

5.3.3. There are, however, disadvantages. Firstly, a reliable dug well is not actually easy to construct. Many rural water supply projects in various parts of the world have started with dug wells lined simply with brick or concrete rings and have progressed to more sophisticated construction practices because of the shortcomings

of the simple dug well. Selection of suitable lining materials and construction methods is not easy and has many complicating factors (e.g. local availability, transport costs, material life, aquifer blocking, rehabilitation requirements etc.). The dug well is susceptible both to drought, unless aquifer penetration is considerable (greatly complicating construction),and also to pollution, unless special care is taken with well-top sealing, pump installation and apron construction.

5.3.4. During almost a year of digging wells in the Upper Livulezi Integrated Project it became clear that the principles of dug-well construction have not been clearly defined in Malawi, and a number of problems of both design and construction of dug wells have emerged. In the way that the Upper Livulezi has been a test project for low-cost borehole design and construction practices, so it is planned that the Dowa West Integrated Project will be the same for dug wells.

5.3.5. Perhaps the most important point to be made about dug wells in an Integrated Project is that they must complement the boreholes and must be equally well-designed and constructed so that the community has equal confidence in them. There are two criticisms of the current practice of "dig and backfill" that have resulted in a search for alternative designs:

a) A large diameter hole has a major advantage in times of drought; as water levels fall a man can get into the well and dig down to maintain satisfactory inflow. If the well is backfilled, this would be a major operation, probably requiring skilled personnel and equipment to excavate down to and lift the bottom slab. However, with a fully-lined hole the procedure would be much simpler; the pump needs to be removed and the top slab lifted aside, giving rapid access to the hole, into which a man can climb or be lowered. For this reason the benefits of better protection from contamination, by using the backfill, should be relinquished in order that a well can be kept productive through a dry year - or even several dry years.

b) A second point is that when a borehole pump breaks down and cannot be immediately repaired (perhaps because of lack of spare parts) it is almost impossible to obtain water from the hole due to its small diameter. With a dug well, diameter is

not a constraint to getting water out but the top slab with the pump fitted is a constraint. There is always a possibility that, for any number of reasons, pump spares may suddenly become unavailable (eg no transport or fuel for delivery to the district) resulting in long delays before pumps are repaired. With boreholes nothing can be done, but with dug wells it seems sensible to design for this eventuality so that even if all the pumps break down, most villages will have access to a protected well into which they can lower a bucket. For this reason a pump design is being tried in which the pump base flange actually conceals a hole large enough for a bucket, so that, if the pump is not immediately or easily repairable, it can be removed to reveal an access hole.

5.3.6. The aim of the Integrated Project is to provide a waterpoint - borehole or dug well - that is safe and reliable and also as well designed and constructed as possible within the constraints of the Project. In this way it is hoped that all of the rural population will, eventually, be served either with piped surface water or handpumped groundwater. In the interim, however, there is a need for a more immediate provision of at least partially protected water supplies to as many people as possible as soon as possible. Because of the relatively slow rate at which the Integrated Projects will spread across the country a two-tier programme of dug-well construction is proposed:

a) A nationwide programme of construction of partially-protected dug wells. This programme should be encouraged by Ministry of Health extension staff throughout the country and supported at district level by a member of the Groundwater Section of DLVW. The aim would be to get every village where a dug well is feasible, to dig a well to a standard diameter as deep as possible, line it to above ground level (probably with bricks and mortar) and construct a simple apron. The skilled part of the construction would be carried out by specially-trained local builders, paid per well. A simple standard windlass with a chain and bucket would be installed over each dug well. The target cost of each well should be between K100 and K150 and perhaps 5,000 of these should be constructed as soon as possible.

b) In due course an Integrated Project would be implemented in an area where a considerable number of "standard dug-wells" exist. A survey of the wells would be carried out and all suitably sited ones earmarked for upgrading to an Integrated Project waterpoint. The windlass would be removed, the well substantially deepened using dewatering equipment and the deepened section lined. This upgrading would be greatly facilitated by having a standardised diameter for the upper section. The well would be sealed with a top slab, a hand pump would be installed and a full apron constructed. This would bring the cost of the dug well up towards the Integrated Project target figure of K750 and would replace the partially-protected, shallow and unreliable open well with a well-protected, deep and reliable waterpoint.

5.4. FUTURE DEVELOPMENT

5.4.1. Construction practices for dug wells are well described in numerous books specifically devoted to the subject of dug wells for rural water supplies. However the literature generally avoids discussion of the principles of dug-well design, so it would seem that wells are just dug some distance below water and completed, in the hope that the well will be a reliable source of water. This is perhaps because the theory of large diameter well hydraulics is complex and has been little described. By contrast, very little has been written about borehole construction practices appropriate for rural water supplies, although borehole design principles are much more widely described (although not commonly adhered to in rural water-supply programmes).

5.4.2. It is clear that if dug wells are to play a major part in future Integrated Projects (as we hope they shall) a major review of their design is necessary. One starting point is that the back-filling procedure should be stopped, so that advantage can be taken of two features of the large diameter well: it can easily be deepened in times of falling water levels and if a pump cannot be repaired water can be abstracted using a bucket and a rope.

5.4.3. At present (November, 1982) considerable effort is being put into testing alternative ways of lining a well, and various prototypes are being tried in the Dowa West Integrated Project. Concrete ring production presents an example of the many questions to be resolved:

- Should concrete rings be moulded at the basecamp, well-site or even in situ in the well?
- What should the ring-moulds be made of, eg steel, glass fibre, wood?
- What ring diameter should used in order that a man can work comfortably inside it to deepen the hole?
- Should porous rings or perforated, non-porous rings be used?
- Should concrete rings be used only below water and a brick lining to the surface, or should rings be used for the full well depth?
- Can alternative materials - such as sisal cement shuttering slotted into concrete pillars - replace the traditional concrete rings?

5.5. SOME PRINCIPLES OF DUG-WELL DESIGN

5.5.1. All of the Section on hydrogeology and some of that on borehole design and construction principles in Section 3 are also relevant to dug wells.

5.5.2. In essence the dug well forms a resevoir of groundwater and provides water, via the pump, from its own storage. If continuous pumping is planned, the rate of inflow to the well should be equal to the rate of the pumping, but with intermittent hand-pumping it is only necessary that inflow equals aggregate outflow over a period of time (sensibly taken to be one day). The well storage acts as a "buffer" in providing water at peak pumping periods (such as early morning and late afternoon) when pump discharge can therefore be very much higher than the rate of inflow to the well. For that reason a dug well can be employed successfully in aquifers of very low permeability, which is the case for the "dambo" wells of Malawi. In the discussion below the "worst case" (and possibly the most common) of a low permeability aquifer is assumed.

5.5.3. In contrast to the dug well, a borehole has negligible storage due to its small diameter and therefore the rate of inflow to the borehole from the aquifer "reservoir" needs to be equal to the average pumping rate at peak periods. Remember also that the rate of groundwater flow is a function of "head", so the greater drawdowns possible in a deeper borehole will induce higher inflow rates from the aquifer than could be obtained with a shallower dug well in the same formation. Furthermore, the formula given in Section 3.5.3 (a) shows that the actual diameter of the well has only a small effect on its yield, which in a uniform formation would only be a slightly greater than a borehole of equal depth (although the latter would have negligible storage).

5.5.4. A dug well in an Integrated Project should be capable of providing 125 people with 27 litres per head per day [Chapter B] , giving a total daily requirement of 3375 litres. If all the water were to be pumped out at one time in the day, well storage of about this volume would be required and a total 24 hour inflow of this same volume would also be necessary. However, it is more realistic to consider pumping to be spread out over a 12 hour day (from 6 am to 6 pm) with peak periods in the morning and evening, so the well storage requirements could be reduced (although the total inflow in 24 hours would still need to be the same). It would not, however, be correct to specify a storage requirement of only half the daily pumping requirement, as the inflow to the well during the day will be irregular, depending on drawdown which is itself dependent on the pumping schedule, which could be variable. Whilst storage of the full daily requirement is not necessary, the minimum storage should be over half the daily pumping requirement and an arbitrary figure of two-thirds of it should allow an adequate safety margin. Inflow into the drained well over 12 hours should fully replenish the storage capacity (ie if the reservoir is drained by the end of the evening pumping period it must be full again by the early morning). Again, remember that rate of inflow is a function of "head" or drawdown, not dug-well diameter, unless the formation is fissured, in which case the chance of fracture intersection will increase with diameter. Therefore, rate of inflow will be greatest when the well is drained and very low when the water level has almost recovered. For that reason, it will help

to have the lowest expected static water level perhaps 1 m above the minimum level in the well required to give the necessary storage. So the height of water in the well in relation to static water level is the factor which largely governs rate of inflow to the well (disregarding the properties of the aquifer).

5.5.5. Dug well diameter, whilst not greatly affecting rate of inflow, does directly affect its storage. Assuming an internal diameter of 1 m after lining, each metre of the well will store 785 litres. In order to have a storage capacity of two thirds of the daily pumping requirement of 3,375 litres, the well reservoir should be at least 2.9 m deep (disregarding the storage capacity of any back-fill behind the well lining). With 1 m high concrete rings, at least three porous concrete rings should be installed if possible, with the top of the highest one at least 1 m below the static water level. The inflow into the drained hole over 12 hours should be adequate to fill at least to the top of the third ring (ie a height of 3 m of water). If the pump suction is to be significantly above the bottom of the well, additional depth must be added accordingly.

5.5.6. The susceptibility of the well to small changes in water level must be recognised. A fall in static water level could result in a major drop in both storage capacity and rates of inflow. This emphasises the need to:

a) construct wells in the dry season when water levels are at their lowest

b) be aware of longer-term water-level fluctuations, if data is available, and dig to appropriate depths

c) be able to deepen the well fairly easily after completion (ie the well cover should be removable and the well-lining diameter sufficient to allow a man to dig inside the well).

5.5.7. In all the above it should be remembered that problems may not be perceived immediately after construction, as it is clear that at present people only use about half of the design daily consumption volume. However it is hoped that, with a greater density of water-points, more extensive health education and a general raising of living standards, people will use more and more water. It would be a poor time to discover that the dug wells cannot perform to their design.

5.6. OPERATIONAL PROCEDURE

5.6.1. The operational procedure given here is for the current construction practice using a backfilled well and small diameter rings and slabs [Figure D.5.1]. When changes in the organisation of the programme, or dug-well design or the method of their construction occur, the procedure will be modified and this Section of the Manual will need to be completely rewritten. In the meantime, some notes on possible procedural modifications are given at the end of the Section.

5.6.2. *Siting*

This is discussed in detail in Section 2. The following summary notes are given:

a) The dug-well site will generally be in a valley (dambo margin) where water levels are in the range 1 - 4 m below ground level and certainly no more than 6 m below ground level.

b) Areas where groundwater levels are likely to be less than 1 m below ground level and particularly areas prone to flooding should be avoided.

c) Villagers will often choose a dug-well site close to a traditional open well, as they know that the source is perennial. However these sites may be a considerable distance from the village. The ability to dig to greater depth with the Project staff and equipment should enable sites to be selected as close to the village as possible, to maximise water usage. A distant well is likely to be used only as a dry season source of water.

d) Particular care should be taken to avoid potential sources of pollution such as pit latrines, cattle kraals, and rubbish pits [see Section 16].

e) All the above points should be communicated to the villagers, who select their own site which is then approved by the hydro-geologist [as detailed in Section 2].

f) Construction should only be completed during the dry season, as water levels will be low and a greater depth can be achieved, providing greater security against drought.

5.6.3. *Community Tasks*

The community tasks are as follows:

a) Ensure reasonable access to the site.

b) Men of the village commence digging the well using their own hoes and buckets. If relatively hard material is encountered a pick-axe is loaned from the Project stores. The men are given a guide rod of 1.2 m length and dig the well as deep as possible ensuring that the well is 1.2 m diameter throughout by rotating the guide rod horizontally. Digging should continue below water until either the water cannot be removed fast enough (a rate of inflow of over 1 bucket [20 l] per minute) or wall collapse starts to occur.

c) Women of the village collect rocks, stones or coarse sand for the gravel infill to be put outside the concrete rings. If rocks are collected, a hammer is provided for the villagers to crush the rock and transport is also provided if the rock source is far from the village, although use of an ox-cart should be encouraged. Between six and eight buckets of crushed stone or coarse sand are required to backfill behind each metre of concrete ring, and additional stone to backfill above the bottom slab.

d) About seven men from the village are taken to a source of fresh rock to collect 30 buckets of crushed stone to be taken back to the basecamp, where the ring moulding team is situated. The stone is used to make three concrete rings, two slabs and a pillar for the pump extension pipe.

e) Other materials are provided for the apron, as described in Section 8.

5.6.4. *Ring-Moulding Team*

The ring-moulding team comprises three builders and three locally employed labourers stationed at the Project basecamp. They make the concrete rings and the top and bottom slabs for well construction, and the concrete pillars required for both well and borehole completion. The following are points of both information and procedure:

a) Materials required include crushed stone supplied as described above, river sand brought in from the nearest suitable site and cement (stored under cover at the Project basecamp).

b) All concrete structures should be made under cover as both heat and rain can affect both the cement and the curing process (and thus the strength of the concrete).

c) Concrete is mixed in a concrete mixer using a 1:2:4 (cement: sand:aggregate) mix for the slabs and pillars and a 1:2:6 mix for the porous rings. If possible the aggregate should be cooled with water before mixing and the concrete mixing should be done early in the morning when temperatures are lower. Care must be taken when mixing, as ordinary Portland cement manufactured in Malawi may be up to 30% weaker than the standard specifications. In all cases (rings, slabs and pillars) the concrete is placed in a mould and compacted using a poker.

d) The porous rings are strengthened by using the normal 1:2:4 mix for the top and bottom 15 cm and the 1:2:6 mix for the centre section [Figure D.5.2]. Particular care must be taken during the handling and transportation of the porous rings as they are brittle and will break relatively easily.

e) The top and bottom slabs are reinforced with 8 mm steel rod at 200 mm spacing in two directions at right angles [Figures D.5.3 and D.5.4 respectively]. The bottom slab is cast with four 8 mm rod loops on its upper side (to assist in lowering it into the well) and with a central 110 mm hole (using a short piece of 110 mm PVC pipe). The top slab is cast with an 80 mm socket in its centre, (welded to the reinforcing mesh) to be used to fix the pump.

f) The pillar [Figure D.5.5] is cast with a hoop of 12 mm rod at one end, to be used to retain the 3 m pump discharge extension pipe.

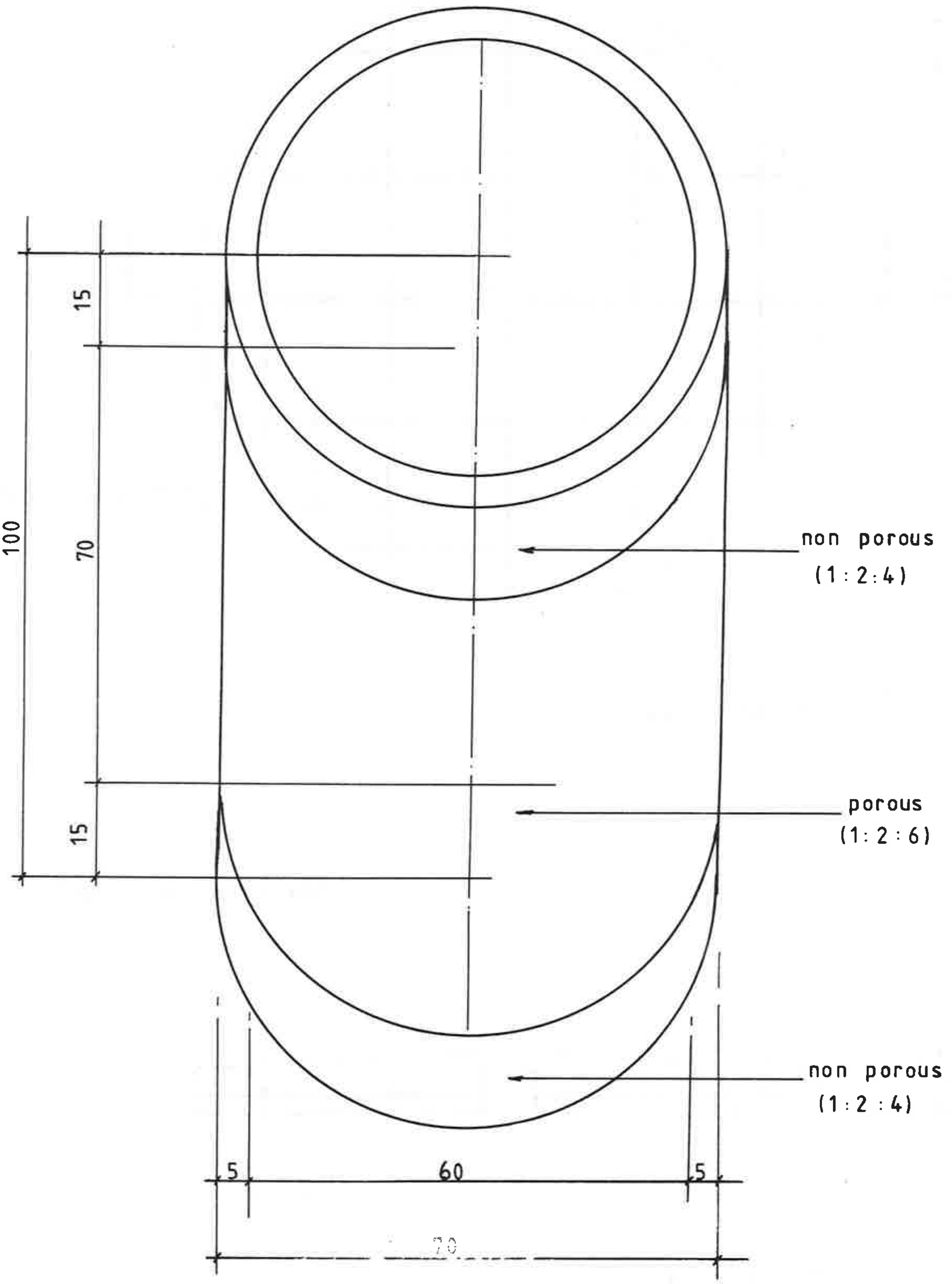
g) The moulds are removed after 24 hours and the structures are watered three times per day for the next seven days, before transportation to the site of the well.

5.6.5. *Well-digging Team*

The well digging team moves to the dug-well site when the villagers have dug as deep as they can. The team comprises two men, with a skilled dug-well foreman for every two teams. The team will stay at the site for a period of between two days and one week (very rarely up to two weeks) depending on the hardness of the strata.

Figure D.5.2. POROUS CONCRETE RING

(all dimensions in cm.)



Elevation

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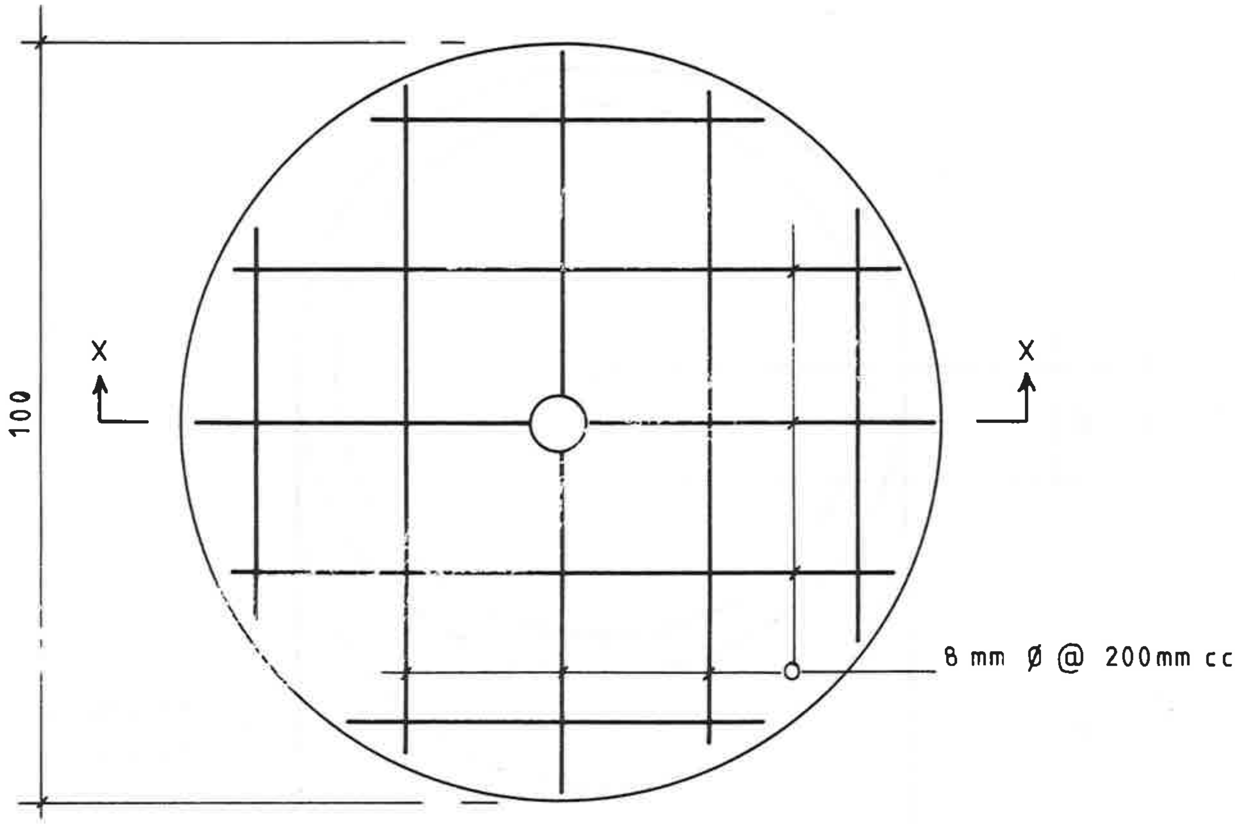
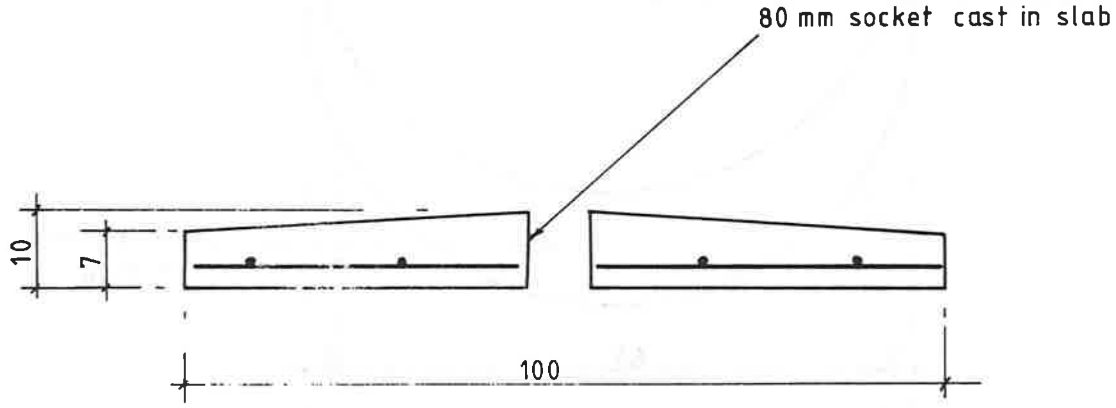
Figure D.5.3. TOP SLAB

(all dimensions in cm)



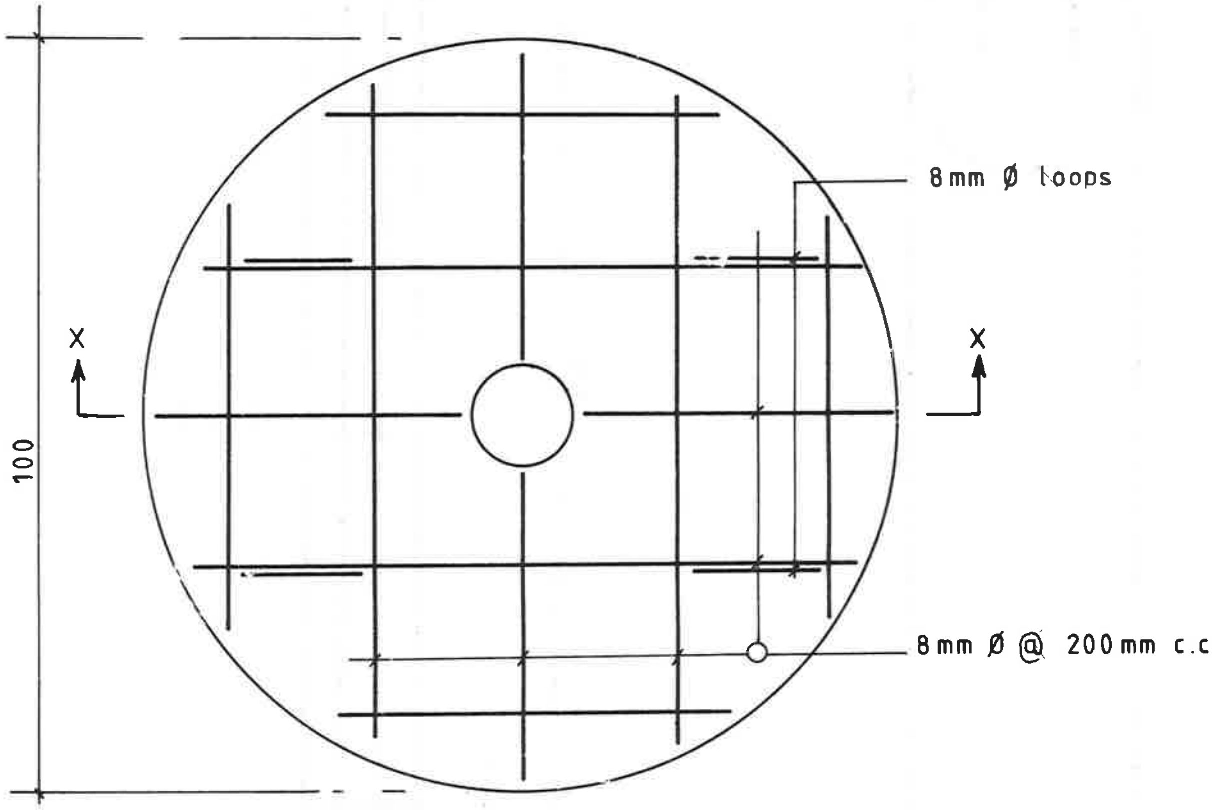
Plan view



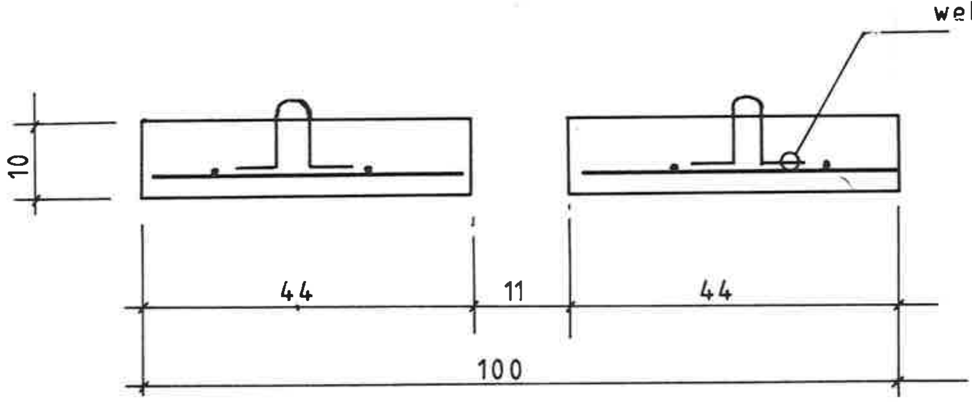
Section X X

scale 1:10

Figure D. 5. 4 BOTTOM SLAB
(all dimensions in cm)



Plan view



Section X X
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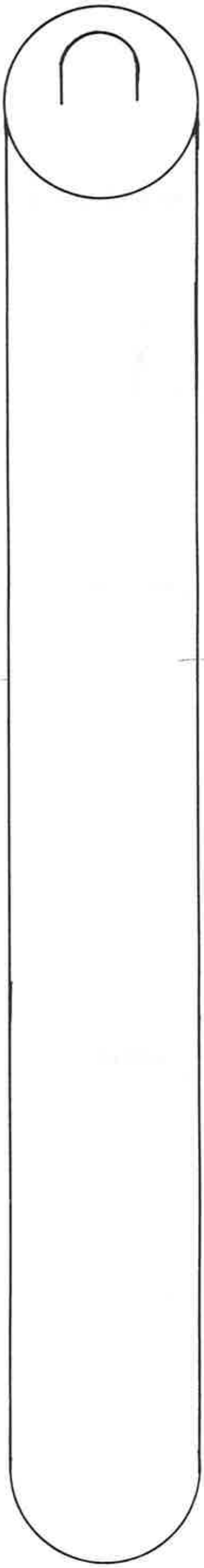
Figure D.5.5 CONCRETE PILLAR



Elevation
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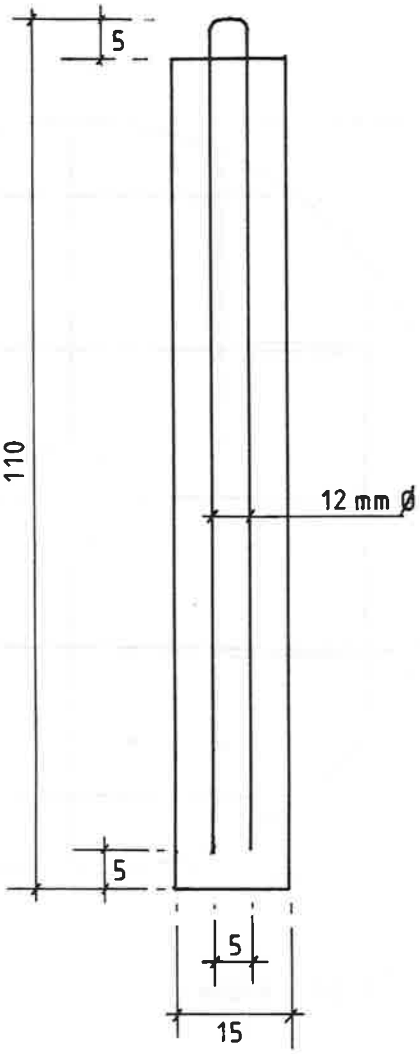


Section
scale: 1 : 10

5.6.5 (2) Transport will be required for the team to set up a sub-camp, preferably so that they can get to several dug-well sites on their bicycles. The following points illustrate the team's role:

a) Over the hole is erected a tripod, comprising four 3.5 m long steel pipes of 100 mm diameter with a pulley fixed at the tripod apex. A wooden beam tied between two tripod legs is used to anchor one end of a length of strong sisal rope which passes over the pulley and is attached to a strong bucket or kibble. The bucket is used to remove spoil and to lower men into and take them out of the well.

b) With the aid of men from the village, digging is continued using a small petrol-driven water pump to dewater the well. Great care must be taken to prevent exhaust fumes (which are heavier than air) from settling in the well as these are asphyxiating and could be extremely dangerous. An 8 m suction pipe with a foot valve is used initially and if the depth goes beyond 6 m it will be necessary to lower the pump into the well and use an exhaust extension pipe.

c) Dug-well depth is discussed above. It is preferable that three 1 m high concrete rings are installed to provide adequate storage, unless the aquifer is very permeable (eg an alluvial sand). If the well is to be backfilled, the top slab should preferably be at least 1 m below static water level, and even more if the well is not dug in the later part of the dry season. Overnight recovery in the drained well should be at least 3 m of water.

d) When the required depth has been reached and approved by the Project hydrogeologist the well is logged and then the porous concrete rings can be inserted. The rings are carefully lowered into the well and centred. Crushed stone is then lowered in a bucket to a man standing on the concrete ring who backfills the annulus around the ring to form a gravel conduit and to add structural strength and stability. The procedure is repeated for the next two concrete rings, ensuring that they are all well centred.

e) The bottom slab is carefully lowered into the well using a rope passed through the loops, and fixed firmly in position with crushed stone around and over it.

f) 110 mm PVC pipe is inserted through the hole in the top slab towards the bottom of the hole and held vertically whilst crushed stone is used to backfill the well to the static water level, or 2 m below ground level, whichever is the deeper, and then clay is used to backfill to the surface and above it to form a half metre high mound.

g) A stone wall with rocks and concrete mortar is built around the clay mound to support the top slab. The PVC pipe is cut and the slab put over the mound with the pump socket centred over the PVC pipe. The slab is cemented to the stone wall to give stability and protection against pollution.

h) The final duty performed by the well digging team is disinfection of the well. One teaspoon of sodium hypochlorite per metre of depth of the well below water is added through the PVC pipe. The socket in the top slab is then capped to await pump installation.

5.6.6. *Notes on How Operational Procedure may Change*

It is quite clear that if a major change in well design and construction practice occurs as a result of the experimental work currently in progress (November, 1982) the procedure for well construction will change completely. It is planned that this Section will then be rewritten. The following notes cover some procedural changes that may occur in the interim period.

a) If the well is not to be backfilled, then 1,000 to 2,000 bricks will need to be supplied by the village to line the upper portion of the well. Hole diameter will need to increase (so a longer guide rod will be needed for the volunteer diggers). The brick lining would be carried out by a builder prior to the arrival of the well digging team.

b) If concrete rings are made at the well site, there will be various changes :

(i) rings may be used to line the full depth of the well so additional materials will be required. Rings above the water level, or for at least 2 m below ground, whichever is deeper, would be non-porous to prevent contamination

(ii) a ring-moulding team will be required at each site, together with moulds and materials. However, only one builder would be needed,

with village helpers as only one set of concrete structures are required

(iii) steel ring moulds are extremely expensive, prohibitively so if a large number are required. Timber and plywood moulds are being tried, as these would be cheap and easy to move from site to site

(iv) aggregate should be stored under a tree and cement in a house or tent. The mixing and curing of concrete should take place in a position protected from the sun and wind - if necessary shade and windbreaks should be organised the villagers.

c) If the concrete rings were to be cast in situ in the well only an inner mould would be required and the ring insertion process would be avoided.

5.6.7. *Equipment for Construction*

a) Ring moulding team (supplying four well digging teams):
- 3 metal ring moulds (100 cm height, 70 cm OD, 65 cm ID)
- 2 metal bottom slab moulds (100 cm diam., 8 cm thickness)
- 2 metal top slab moulds (100 cm diam., 6 cm thickness)
- 2 metal pillar moulds (100 cm height, 15 cm diam.)
- 2 wooden floats
- 2 trowels
- 2 shovels
- 2 metal or wooden pokers
- 1 wheelbarrow
- 1 concrete mixer
- 2 metal pails

b) Each well-digging crew:
- 1 tripod (4 metal legs - 4 m height, 100 mm diam.)
- 1 fixed pulley
- 1 movable pulley
- 2 new sisal ropes
- 2 old sisal ropes
- 1 well bucket
- 1 hard hat
- 1 6 kg hammer
- 1 3 kg hammer

- 1 crowbar
- 1 small petrol driven water-pump (eg Honda) (8 m suction hose)
- 2 pick axes
- 2 hoes
- 2 shovels
- 1 pair of goggles
- 1 tin of sodium hypochlorite
- Petrol
- Oil
- 1 first aid box
- 1 measuring tape (5 m)

6. DUG WELL PROTECTION AND REHABILITATION

6.1. Wherever it is possible and appropriate, existing dug wells in a Project area should be protected from surface pollution by the addition of a top slab and deepened to give protection from drought. The wells can then be disinfected, handpumps can be installed [see Section 7] and aprons constructed [see Section 8]; these protected wells would then be no different from any newly constructed dug wells on an Integrated Project.

6.2. Unfortunately, few existing open wells are suitable for improvement. Many are too wide for a protecting slab to be erected over the surface, and most are highly polluted. Some of the older, well-constructed dug wells built in the 1930s [see Section 5] may be suitable for protection; most of these would not require deepening, but only the addition of a top slab, handpump and an improved drainage apron. In most other cases, it would be better to dig a completely new well rather than attempt to protect an unsuitable existing one. The labour can be provided by the villagers and a better constructed and perhaps safer waterpoint would result.

6.3. If the proposed "two-tier" programme of dug well construction is adopted [see Section 5], simple wells can be constructed all over the country and fully protected at a later stage, within an Integrated Project which will eventually provide complete coverage of the area with protected waterpoints. It is important that the first stage of partially-protected dug well construction is carried out to a standard diameter so that the upgrading can be achieved as easily as possible. All suitably "standard dug wells" would be substantially deepened [see Section 5] using dewatering equipment, and involving the community as much as possible in the digging under the supervision of Project staff. The deepened section would then be lined, the well sealed with a top slab, a handpump installed (to replace the windlass and bucket) and an apron constructed. Any subsequent deepening required (which may become apparent in a particularly prolonged dry season) can be carried out simply by removing the handpump and the top slab. This will, however, require dewatering equipment again. Detailed procedure for the "two-tier" programme will need to be evolved if the principle of the programme is adopted by DLVW.

6.4. The practice of backfilling dug wells (as is currently the case in the Upper Livulezi Project) makes any deepening of wells (required due to falling water levels) difficult and time consuming to carry out. Existing backfilled wells,in a new Integrated Project area, which require deepening are possibly best opened, deepened, and lined to the surface.

6.5. A more detailed discussion of dug well design and construction practice is given in Section 5, where it is made clear that much work needs to be done to improve existing methods.

7. HANDPUMPS

7.1. INTRODUCTION

7.1.1. The borehole or dug well is constructed. The problem remains of how to lift water from depth to the surface. This apparently simple issue has long been, and continues to be, a cause of much argument and research and, most important of all, is probably the commonest cause of failure of rural groundwater supply projects.

7.1.2. In Malawi we have chosen to use the handpump to provide water directly on demand at the source. This is known as a "primary" water supply, where the protected water is collected at source and not reticulated. The reasons for this are given below [Section 7.2].

7.1.3. The handpump is perhaps the major focal point of the Integrated Project, linking the construction phase to the operation phase as the actual device producing water from the carefully designed and constructed waterpoint. The selection of appropriate handpumps, a seemingly simple exercise, has, in rural water supply projects all over the world, proved to be a crucial question which rarely seems to be adequately answered. It is essential that we find an acceptable answer if the Integrated Projects are to succeed in their objectives of providing a reliable water supply to much of the rural population of Malawi.

7.2. WHY HANDPUMPS?

7.2.1. Many countries implementing rural groundwater supply projects choose a system of motorised pumping from a borehole into storage tanks. These supply standpoints situated in different parts of the village each of which serve relatively few people (five families, or 25 people, for example). This is commonly known as a "secondary" water supply. Why are we not doing this in Malawi?

7.2.2. There are several reasons for this, perhaps the most obvious (but not necessarily the most important) one is cost. An example of a typical scheme for a village of 1,000 people in a neighbouring country clearly illustrates the difference in cost. The "secondary" scheme of one borehole supplying 40 taps is estimated to cost K225,000 to construct and at least K15,000 per year to operate and maintain. A "primary" scheme in Malawi may have three boreholes and 2 dug wells, all with handpumps, and cost K6,000 to construct and a target figure of about K150 per year to maintain (operation, by hand, costs nothing). The "primary" scheme only has 12.5% of the number of waterpoints, but its capital cost is only 2.6% and recurrent cost only 1% of the "secondary" scheme. Who would meet the operation and maintenance costs of a "secondary" scheme in Malawi? The level of income in rural areas is clearly too low to meet a per capita annual recurrent cost of K15. Furthermore, breakdown of the single motorised pump (or shortage of fuel) will affect the whole village whereas breakdown of one handpump will have little effect in a village which has several.

7.2.3. In addition to breakdown another important issue is maintenance. A motor pump requires considerably more skill to maintain than a handpump. We already have a major problem with providing an adequate handpump maintenance organisation [Chapter E]; the problems of maintaining a large number of motors and pumps will be much more difficult to resolve.

7.2.4. The question of speed of implementation of the rural water supply programme is linked to cost. As donor funds are limited, the rate at which "secondary" supplies are provided is likely to be controlled by availability of funds. With "primary" supply programmes, in which eight times the number of people can be served for the same cost as a "secondary" programme, the limitation is more likely to be construction capacity than funds. It is surely better to provide a basic service of protected water supplies to as many of the rural population as soon as possible than to provide a superior service to a few.

7.2.5. An eventually upgraded service is by no means ruled out by a "primary" scheme. In the future, water demand will hopefully increase to well above the present very low level of consumption per capita. Small motorised

pumps could be installed in many of the boreholes which previously had handpumps, supplying individual connections.

7.2.6. The discussion outlined above points to the need for an initial programme of relatively simple, low-cost handpumped (primary) water supplies which may grow by phased development to "secondary" piped supplies together with the aspirations of the recipients.

7.3. A HANDPUMP EXPLAINED

7.3.1. For those readers unfamiliar with handpumps a brief description is given here. By far the majority of borehole handpumps used in Malawi, and elsewhere, are of the deep-well reciprocating pump type. The basic principle of this type of handpump has been used for a very long time (certainly since classical times). There are many other handpump types (eg rotary action, "Archimedes screw" Mono pumps); however these are not described here.

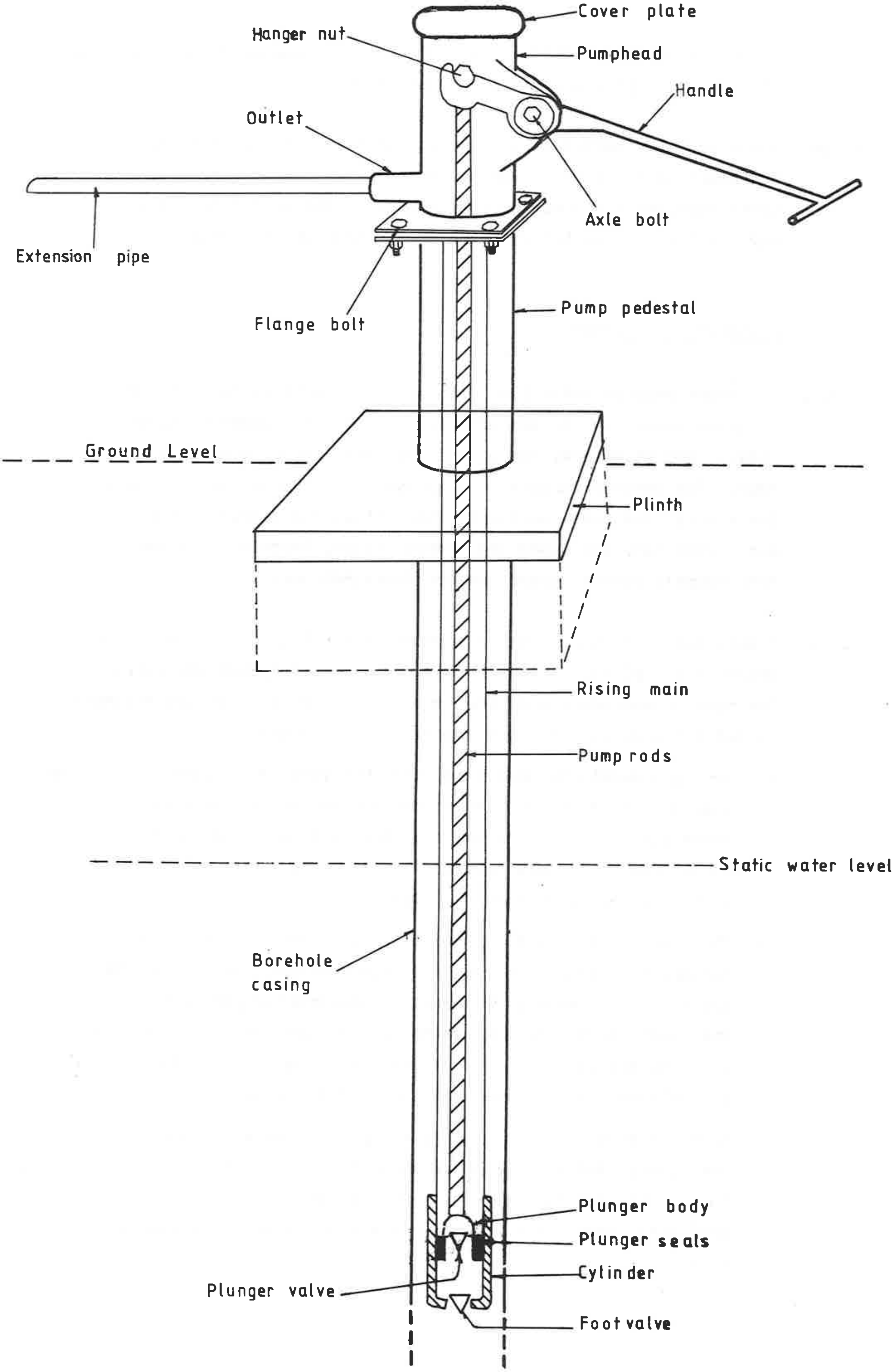
7.3.2. Figure D.7.1 shows a schematic section of the Malawi Handpump (deep) which is a typical lever-operated, deep-well reciprocating pump. The main characteristic of the "deep-well" type is that the cylinder is set below water. The pump operates as follows:

a) When the handle is depressed, the pump rods are raised by a distance which is related to the handle movement by the "mechanical advantage" (the ratio of the distance from the T piece on the handle to the axle bolt, and the distance from the axle bolt to the hanger [see Figure D.7.1]).

b) The plunger, attached to the rods, is lifted and its valve closes, reducing the pressure in the cylinder (as the plunger seals against the cylinder wall). Atmospheric pressure on the water in the borehole pushes water past the open footvalve and into the cylinder, and at the same time water above the plunger is displaced upwards in the rising main.

c) As the handle is lifted, the rods and plunger are lowered. The plunger valve opens allowing water to pass through it and at the same time the footvalve closes under gravity, preventing water from escaping from the cylinder and rising main.

Figure D.7.1. COMPONENTS OF A HANDPUMP (Borehole)



d) On each successive stroke the process is repeated: plunger raised with plunger valve closed and footvalve open, bringing water into the cylinder, then plunger lowered with plunger valve open and footvalve closed, preventing water from escaping back to the borehole. In this way water is pumped on each downstroke of the handle (which is an upstroke of the plunger).

e) The volume of water delivered on each stroke is the swept volume of the cylinder, which is the product of the cross-sectional area of the cylinder and the distance the plunger moves (or stroke length), less any leakage past the plunger seals. A measure of the leakage relative to the theoretical swept volume is a measure of efficiency, though this will change with pumping rate (which affects plunger sealing).

7.3.3. The traditional dug-well handpump is a "shallow-well" reciprocating pump. The main characteristic of this type of pump is that the cylinder is <u>above</u> water (usually at ground level), with a suction pipe from the cylinder to water. The use of this pump is limited to areas where water is within 6m of ground level. However dug-well handpumps used in Malawi are of the "deep-well" type, i.e. the cylinder is set below water as in Figure D.7.1. The principal difference between the borehole and the dug-well handpumps in Malawi is that the latter do not have levers; the effort required to lift water from depths of less than 6 m at an acceptable rate (about 20 - 30 l/min) is such that no mechanical advantage is required. For that reason a direct action T bar handle is used [see Figure D.7.3] although the plunger and footvalve arrangement is similar to the borehole handpump described above.

7.3.4. There are other ways besides levers of providing reciprocating action. An example of this is the flywheel-driven crankshaft which provides up and down motion via a con-rod, in a similar way to an internal combustion engine. This type of pump is in very common use in Malawi.

7.4. HISTORY OF HANDPUMPS IN MALAWI

7.4.1. Handpumps have been extensively used in the borehole programme in Malawi since the 1930s and in the protected dug-well programme which started in the mid-1970s.

7.4.2. Almost 5,000 borehole handpumps are currently in use in the public-sector rural water supply programme. Seven different reciprocating-type handpumps are in common use (together with a few Mono "Archimedes-screw" pumps), of which the commonest are Climax and Godwin single and double flywheel operated pumps. The first Climax and Godwin pumps were installed in 1940 and there are now about 3,300 of them in the Programme. Other pumps in use include two imported from South Africa, the flywheel-operated National pump and the Mono pump. There are also two "bush" pumps which have been made in Malawi, one by Government and one by Brown and Clapperton Ltd. The production version of the Malawi handpump (deep) has been installed during 1982 (with prototypes in late 1981) [see Section 7.7 below]. The numbers and costs (at date of purchase) of borehole handpumps currently in use in Malawi are summarised below.

Table D.7.1.

Borehole Handpumps in Use in Malawi

MAKE	COUNTRY OF MANUFACTURE	NUMBER (Nov.82)	PUMPHEAD COST
Climax	UK	2900	K1,485 (1977)
Godwin	UK	375	K1,485 (1977)
National	RSA	220	K 375 (1979)
Mono	RSA	15	K 161 (1977)
Bush	Malawi	1050	K 330 (1982)
B & C	Malawi	240	K 127 (1977)
Malawi (deep)	Malawi	c. 100	K 130 (1982)

7.4.3. A focal point of the protected dug-well programme has been the installation of a simple, cheap, locally-produced handpump. This handpump has been developing since 1975 through a number of "Marks" and is discussed in detail below [Section 7.8].

7.5. PROBLEMS

7.5.1. There are numerous problems associated with the use of the handpumps that have been imported to Malawi and installed on most of the boreholes to date. Many, but not all of these problems have been overcome with the dug-well handpump.

7.5.2. Most borehole handpumps available on the world market were designed a long time ago, primarily for single family use in the USA or Europe. Their use in rural water supply programmes in developing countries has not, on the whole, been successful. This is not surprising, as a backyard pump that gives trouble-free operation for five years to one family, with spares available in the local hardware store, would not give the same performance to 50 families in a village in Malawi where spares are not easily available. It is therefore true to say that few handpumps in use for village water supplies in developing countries were actually designed for the task, until very recently.

7.5.3. The capital cost of handpumps (and their spares) and their transport cost has always placed a major foreign exchange burden on the rural borehole programme in Malawi. For example, the Climax and Godwin flywheel pumps are manufactured in the United Kingdom and their latest landed cost (1978) was over K1,400 for the pumphead alone. Thus the 3,400 pumpheads of this type in villages in Malawi represent a capital investment of K3.5 million at todays prices. Spare parts are extremely expensive, for example each con-rod costs K125 and the pump requires two.

7.5.4. Problems associated with the supply of handpumps are numerous. Pumps ordered from the UK may take over a year from issuing the requisition to the Controller of Stores to receipt in Malawi. A further example illustrates delivery problems: about 500 National pumps were ordered in 1978 from South Africa. They were trucked up through Botswana but were not able to cross into Zambia as the Kasangula ferry was not operating. The pumps were delayed for several months before being re-routed through Zimbabwe and Mocambique. On arrival over half were damaged and a total of 143 pumps had to be written off as irreparable.

7.5.5. Pumphead installation and maintenance share many of the same problems, and these problems are described in the next paragraph. Damage in transit is not uncommon; pumps are sometimes well packed for export then unpacked into stores in Malawi and damaged when being transported to the field. Cracked castings are particularly common; brittleness is an indication of poor casting quality. Some pumpheads are very heavy (e.g. the double-wheel Climax weighs about 400 kg) and most pumpheads in current use need to be lifted for removal and replacement of the down-hole components.

7.5.6. By far the greatest problem with handpumps, not only in Malawi but in rural groundwater supply programmes everywhere, is the operation and cost of an effective maintenance programme. The recurrent costs and administrative burden of maintaining the existing handpumps in Malawi are already very considerable, and there is little chance of the centralised Government maintenance organisation effectively shouldering the four- or five-fold increase in the maintenance burden which will be necessary if the rural population of Malawi is to be served with adequate water supplies. The only acceptable and realistic solution is to shift much of the responsibility of maintenance onto the user community. This is not only financially and administratively attractive but also has the social benefit of increasing the feeling of ownership of the waterpoint, which is so important in ensuring the success of the programme. This is discussed in full in Chapter E. However, a major technical problem remains. There are very few, if any, robust, low-cost handpumps available which are designed specifically for easy maintenance. Most of the handpumps in use in Malawi need the existing maintenance teams with their heavy trucks and winches.

7.5.7. An example of the spare parts cost of pumphead maintenance is given by an analysis of the spare parts needed for the Climax pumphead. Although it is difficult to get wholly accurate figures, this analysis is likely to be broadly realistic. There are about 2,900 Climax handpumps in use in Malawi (with a further 375 Godwin handpumps), installed since 1940 and now being replaced at a rate of about 100 units per year by bush pumps because of the cost of spare parts. The Climax (and Godwin) handpumps are, however, considered to be the

7.5.7. (2) most reliable pumps in use in Malawi. The following problems, more or less common to both pumps, are noted (all prices are CIF Malawi, 1982):

a) Regular lubrication is essential if the pumps are to have a reasonable life. Three to four visits are made annually to most pumps and it is common to add half a litre of oil at each visit. Theft of oil from the crankcase (by removing a drain plug) is not uncommon (for lubricating bicycles, for example).

b) Ball bearings, which are the crankshaft and handle "main bearings", last on average five years, possibly longer if the pump is well lubricated, but very much less if the pump is operated dry. The bearings cost K77.00 per pair.

c) Con-rod breakage occurs on average every five years, again if the pump is well lubricated. If not, breakage can occur in only a year or so. An associated problem is that new con-rods are often fitted to old crankshafts, which greatly accelerates con-road wear. It is estimated that about 1,000 of the pumps in use require con-rod replacement at this moment. Con-rods cost K266.42 per pair.

d) The crankshaft itself is replaced on average every 10 years and costs K75.

e) The cross-head wears slowly and requires replacement in about 10 years. Con-rods can be damaged if the cross head is very worn. The cost of the cross-head is K123.70.

f) Differential cup leathers on the distance piece require replacement at least once a year. In fact water pouring out of the drain hole in the upper chamber is so common that it is considered to be a "design feature" of the Climax pump (and is used by small children to fill tins while pumping is in progress). Differential cup leathers cost K3.12 per pair.

g) The pedestal (base) column casting is said to break at intervals of about 10 years. Whether this is the result of continuous stress or occasional impact is not known. This may be very serious as the pumphead can fall, which may result in flywheel breakage. This latter problem also occurs occasionally due to careless handling during transport or

even during maintenance. A wheel life of about 10 years is estimated as a result. The base column costs K125 and the flywheel K186.31.

h) As is common to all pumps, cylinder cup leather failure is the most common cause of breakdown, and cup leather replacement is often necessary two or three times per year and sometimes more often. Suction and check valve discs and springs are also regularly replaced (perhaps once per year on average).

j) In summary, typical spare parts requirements for 10 years of pumphead operation (not including any down-hole components - rising main, rods, cylinders, cylinder parts) are as follows (approximate 1982 prices):

		KWACHA	
17 litres of oil	c.	40	
2 sets of bearings		145	
2 sets of con-rods		530	
1 crankshaft		75	
1 cross-head		124	
10 sets of differential leathers		30	
1 pedestal column casting		125	
1 flywheel		186	
TOTAL		1,255	over 10 years
or		125	per year

It can be seen that for the pumphead the 1982 cost of spares for 10 years operation, at K1,255 is not dissimilar to the 1977 purchase cost of K1,485. Whilst the pump is said to be reliable, it is clear that a 20 year old unit will have few original components. The annual repair cost of K125 is not being spent, as 100 pumps are now being taken out of service per year (mostly with broken con-rods) and are being stripped for spare parts. It is likely that this number of 100 pumps replaced per year will increase fairly rapidly.

7.5.8. The above discussion clearly illustrated the cost of pumphead maintenance. A similar story can be told of the cost of maintaining the downhole components. In 1980-81, 21,000 cup leathers were installed by maintenance units, who were maintaining about 4,700

borehole handpumps. On average this means that every cylinder has its cup leathers (2) replaced every six months. Bearing in mind that it takes an average of at least a month between the breakdown and the repair visit, this implies an average cup leather life of only five months. Also during 1980-81 5,700 3 m long 50 mm diameter steel rising main pipes and 3,800 16 mm pump rods were replaced, largely as a result of corrosion.

7.5.9. Lack of standardisation of handpumps in the borehole programme and the consequent diversity of spare parts pose obvious problems. Almost all spares have to be ordered from abroad and the whole procedure is greatly complicated by the number of different pumps in use.

7.5.10. From the above it is clear that there is a serious "handpump problem". The Integrated Projects undertake to provide well-designed and well-constructed waterpoints with a high level of community involvement both in construction and in operation and maintenance. However, the handpump - the actual device giving the water - is not suitable for maintenance at village level. This is certainly true of the borehole handpumps in use, and also to some extent of the dug well handpump.

7.6. SOLUTIONS

7.6.1. *Borehole Design*

Evidence is growing that the single biggest cause of handpump breakdown in Malawi is borehole (not handpump) design. It has long been thought that no attention need be given to the design of boreholes for handpump supplies, as the yield is too low to warrant any care. It has been stated above that the "average cup-leather life" in Malawi is only six months. From March to June 1981, twenty of the new "low-cost boreholes" (well-designed and carefully constructed in the feasibility study phase of the Upper Livulezi Project), were completed and equipped with National flywheel pumps with conventional down-hole components. The location of the boreholes is typical of the "plateau areas" of Malawi. To date (November, 1982) all of the pumps are working at or near peak efficiency and not one cup leather has been replaced,

after 17 to 20 months of operation, which gives a cup-leather life of at least three times the average. During this period all the pumpheads have required lubrication and many have needed repair, but no down-hole components have been lifted. This implies that even the "best" pumps will have a poor maintenance record in "bad" boreholes whilst even "poor" pumps may operate for a considerable time in "good" boreholes. This, of course, applies largely to the down-hole components of the pump. Borehole design and construction practice is discussed fully in Section 3.

7.6.2. *Handpump Design*

In addition to good borehole design, to solve the "handpump problem" we need to find a handpump, or design one from scratch, to meet the requirements of our Integrated Projects. In early 1981 the Groundwater Project devoted much of its time to a literature search for suitable handpumps. A considerable amount has been written about handpumps, particularly in the last 10 years, and it quickly became clear that Malawi's problems were identical to those of most other developing countries. One major success story was apparent and that was the India Mark II handpump developed in India during the 1970s and now in mass production. However the India Mark II was still rather too complex for village-level maintenance. Valuable information was obtained from reports of handpump testing work done on behalf of ODA by Consumer Association Testing and Research, an independent company in the UK. It became clear that there was no handpump on the market which was wholly suitable for the Integrated Project programme, and in April, 1981 serious work started on the design of a Malawi borehole handpump. Although success was not expected it was felt that the risks of failure were more than balanced by the benefits in the event of a suitable design being found. Added incentive was provided by the UNDP funded World Bank implemented Global Handpump Project, whose objectives were at an international level. In designing the handpump, the following major features were sought, in the following order of importance:

a) ease of maintenance
b) local manufacture
c) sturdiness and reliability
d) relatively low cost.

7.6.2. Taking the points in order:

(2)

a) *Ease of maintenance* is undoubtedly the key to the solution of the"handpump problem". All handpumps will need maintenance eventually, even the most reliable, and if maintenance is difficult this poses problems that may eventually lead to the failure of a project. However, if maintenance is easy (and relatively cheap) a lower level of reliability can be tolerated. An "ease of maintenance" target was established such that foot-valve and plunger could be removed and replaced, by one trained man with an unskilled helper if necessary, from 30 m, in about half an hour, without in any way interfering with the major linkages (ie wearing parts) of the pumphead. It was clear from the start that this would require the use of"extractable" footvalves and plungers. A further target was that essential tools should be kept to a minimum and should fit in a tool box that could be carried on a bicycle.

b) *Local manufacture* is preferable for many reasons. Firstly the obvious problems of ordering, delays in delivery and foreign exchange requirements are overcome. Secondly, and much more important, if there is the ability to manufacture the handpump, then there should not be the same psychological barrier to carrying out maintenance that often occurs with an imported unit. Spares availability, pump reconditioning, minor or major design improvement and modification to suit specific conditions are all facilitated by local manufacture. Finally, there is the question of pride; if Malawi produces her own handpumps that are reliable and efficient, this is a source of pride to the designers, the manufactuers, the Project staff and the village users.

c) *Sturdiness and reliability* are obvious virtues of a handpump, although, as stated above, less important than ease of maintenance. The rigours of life in a village for a handpump supplying 25 to 50 families are very much more extreme than would be expected. It is therefore important that the above-ground body or frame of the handpump should be very sturdy indeed, to withstand many years of service which will include misuse as well as normal use, and also occasional impact. So whilst the moving (ie, wearing) parts should be easy to replace, even at the expense of strength if necessary, the fixed parts of the pump can be considerably "over-designed" in terms of material

specifications and dimensions. Reliability is a less easy virtue to quantify. It is sometimes argued that, for maintenance by village volunteers, very long maintenance intervals could be detrimental as the people trained to repair the pump will lose incentive and even possibly forget what they have been taught. Furthermore a very long-lived wear component is likely to be expensive; it is perhaps easier for the villagers to collect small sums of money relatively often rather than large sums at longer intervals. Clearly a compromise solution is necessary. Notional targets that were adopted were a one year life between replacement of any down-hole components and a two year life before repairs are needed for the pumphead (assuming simple monthly preventive maintenance by the villagers). A target cost for spares of K10 per year was set. Because of the uncontrollable nature of the attack on steel pipe and rods by corrosive groundwater, the use of relatively inert materials for pump rods and rising mains became a pre-requisite.

d) *Relatively low cost,* whilst being a rather loose target design feature without quoting a standard, is obviously a consideration that must be remembered in all the above design criteria, but takes precedence over none of them. The target adopted in April, 1981 was K250 for a handpump complete with downhole components to a depth of 20 m. This was considerably cheaper than any of the imported alternatives [see Table D.7.1 above]

7.7. THE MALAWI BOREHOLE HANDPUMP

7.7.1. *Pumphead Design and Development*

a) Work started on the design of a new borehole pumphead to meet the design criteria given above [Section 7.6] in April, 1981. In the early stage of the design work considerable benefit was gained from studying the better design features of various commercial handpumps, a task assisted by the report on comparative testing by the Consumer Association (CA). Two designs that were studied carefully were the India Mark II and the Consallen handpumps, both of which were rated highly by the CA. Several design decisions were made very early on:

(i) We had large stocks of 165 mm OD steel borehole casing which were likely to become redundant with the change to PVC casing and screen, so it was

7.7.1. (2) decided to use this pipe as the main pumphead body due to the very considerable strength resulting from its round section and 7.5 mm wall thickness.

(ii) Due to the limited manufacturing capabilities in Malawi, all designs were to use off-the-shelf components, standard bar, plate and rod sizes and minimal precision machining. Cast components were ruled out as no suitable facilities exist in Malawi unlike in Asia where most handpumps comprise cast rather than fabricated components.

(iii) The excellent system pioneered by the India Mark II pump, of "spragging" the pump pedestal into concrete, was adopted, as this provides a very firm anchor and prevents entry of dirty water into the borehole under a bolted-down pedestal flange plate.

b) A simple lever-operated handpump was designed, taking considerable care to make it easy to maintain, in particular to allow the operating parts of the pump to pull out through a cover plate on the pumphead, and to use sealed-for-life bearings, to avoid the need for lubrication. The first set of drawings were completed in July, 1981, the first pumps made in August, 1981 and these were installed in villages in September, 1981.

c) Between September, 1981 and January, 1982 feedback from the field led to change in design through three significant steps; handpumps were built and installed at each stage. The major changes were due to actual or predicted bearing wear because:- initially bearings in the main fulcrum were too close together and lateral movement in the handle became apparent. Also each time rods were removed (and this was often, as prototype down-hole components were also being tested), bolts had to be removed and replaced through bearings. Clumsy replacement in the field (often using sharp blows) was inevitable and would quickly lead to bearing failure. It was important, therefore, to modify the design.

(i) The first alteration to be made was that all bearings should be carefully pressed into position in the factory and then, when nipped up on installation, they are not touched again until actual bearing wear necessitates replacement.

7.7.1. (3) (ii) The design was also altered so that the main fulcrum bearings were widely spaced (the bearing centres are 82 mm apart)

(iii) Furthermore a "T" bar was added to the end of the handle to encourage people to operate the pump behind (ie in line with) the handle and not to one side, as the latter results in movement in an arc with a detrimental sideways component as the handle is pulled towards the body. As the bearings are the only major wearing parts in the pumphead, maximising their life is of the greatest importance.

d) A full set of drawings showing the pumphead designs, essentially as established by February, 1982, but with minor geometry and detail modifications introduced between then and June, 1982, is given in Figure D.7.1. A few of the pumphead design details are worth discussing in some detail.

e) The "tuning fork" handle is undoubtedly a key feature, giving space to lift a 63 mm plunger and foot valve through the lever arms without disturbing the rod hanger bearings or the main axle bearings. Initial worries that the larger nut would come loose have proved unfounded after nine months operation so far, and occasional tightening of these nuts is to be a preventive maintenance task of the village caretaker [see Chapter E].

f) The pumphead and pedestal flange bolt centres are positioned identically to those of the India Mark II pump and the bolt sizes are the same, to allow pumphead interchange. At present both the pedestal and pumphead flanges are "open" and there is no provision for hanging rising main. This is achieved by inserting an appropriate plate, or plates. To hang 50 mm steel pipe a plate with a welded socket is used, and for 75 mm PVC pipe two plates compressing a rubber cone are used [Figure D.7.2 WRB/3M). These plate(s) are clamped between pumphead and pedestal, together with a rubber gasket to prevent leakage. There is, therefore, a considerable degree of flexibility for use of various types of rising main. It must be remembered that a 16 mm pump rod requires a 50 mm space to allow for lateral movement (of 34 mm) resulting from the arc travelled by the lever.

FIGURE D.7.2

DEPARTMENT OF LANDS VALUATION AND WATER WATER RESOURCES BRANCH	
MALAWI HAND PUMP (deep) 'AFRIDEV PUMP'	
DESIGNED BY: O.D.A. GROUND WATER PROJECT 28/6/82. U.N.D.P. BOREHOLE MAINTENANCE PROJECT	
DRAWN BY: K. GUNDASI DESIGN DEPARTMENT MINISTRY OF WORKS AND SUPPLIES	APPROVED BY: 28/6/82 CONTROLLER OF LANDS VALUATION AND WATER
SCALES: 1:2 1:1	
DATE JUNE 1982	DRAWING Nº W.R.B./3/11.

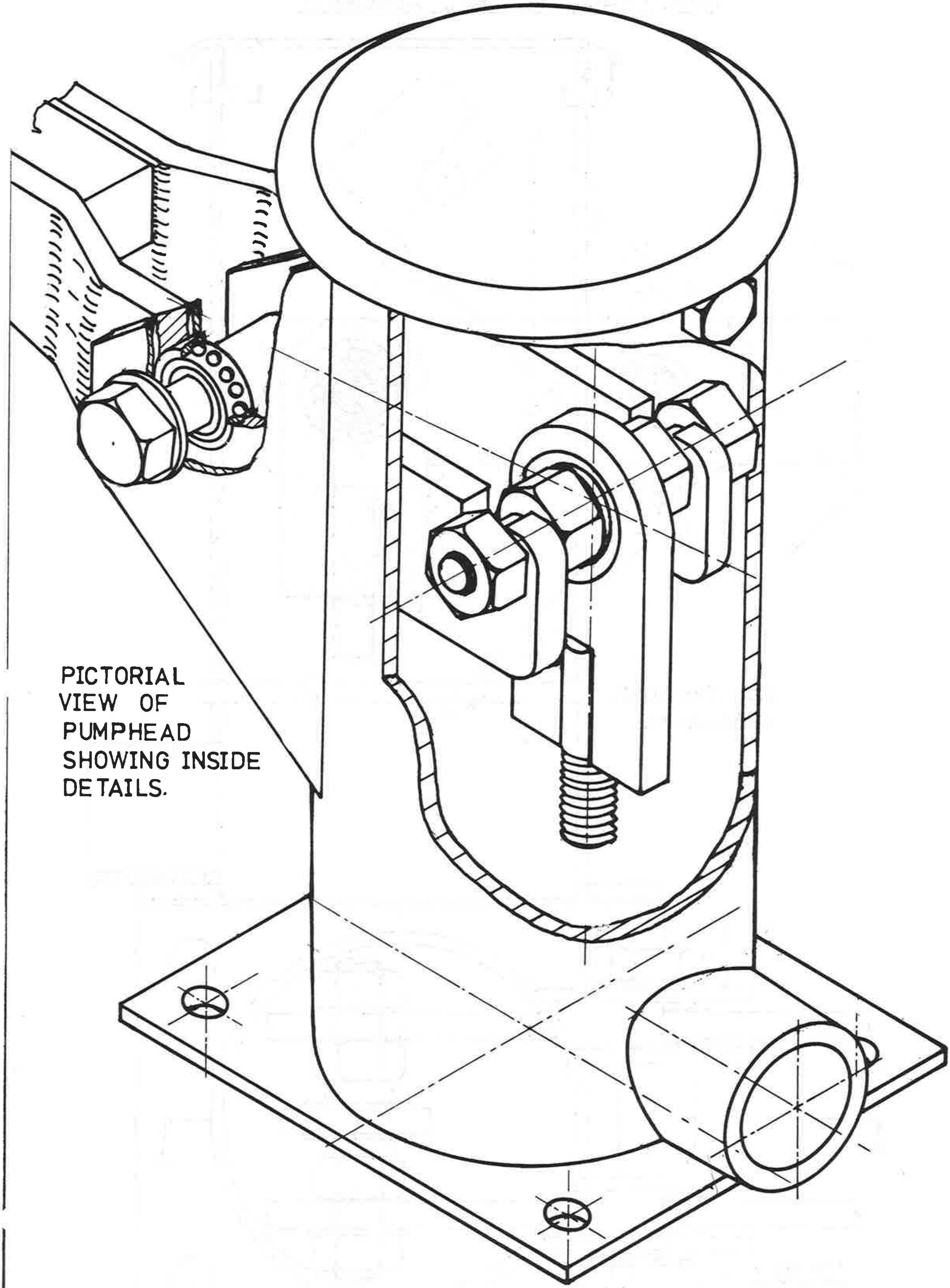
MALAWI HAND PUMP (deep)
'AFRIDEV PUMP'

LIST OF DRAWINGS

ALL SIZES ARE GIVEN IN MILLIMETRES

ALL MATERIALS MILD STEEL UNLESS OTHERWISE SPECIFIED

DEPT OF LANDS VALUATION AND WATER MALAWI HAND PUMP.

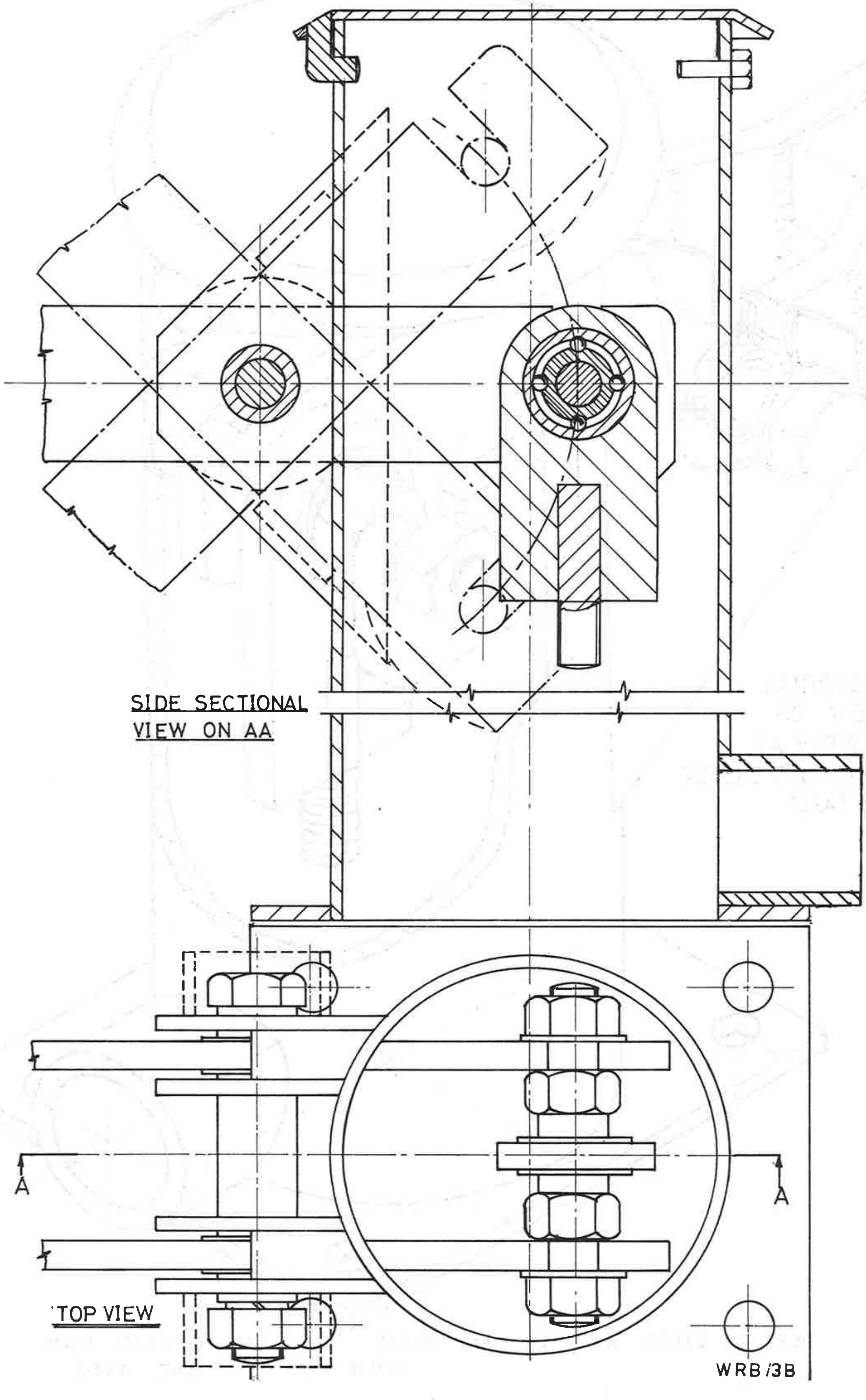


PICTORIAL VIEW OF PUMPHEAD SHOWING INSIDE DETAILS.

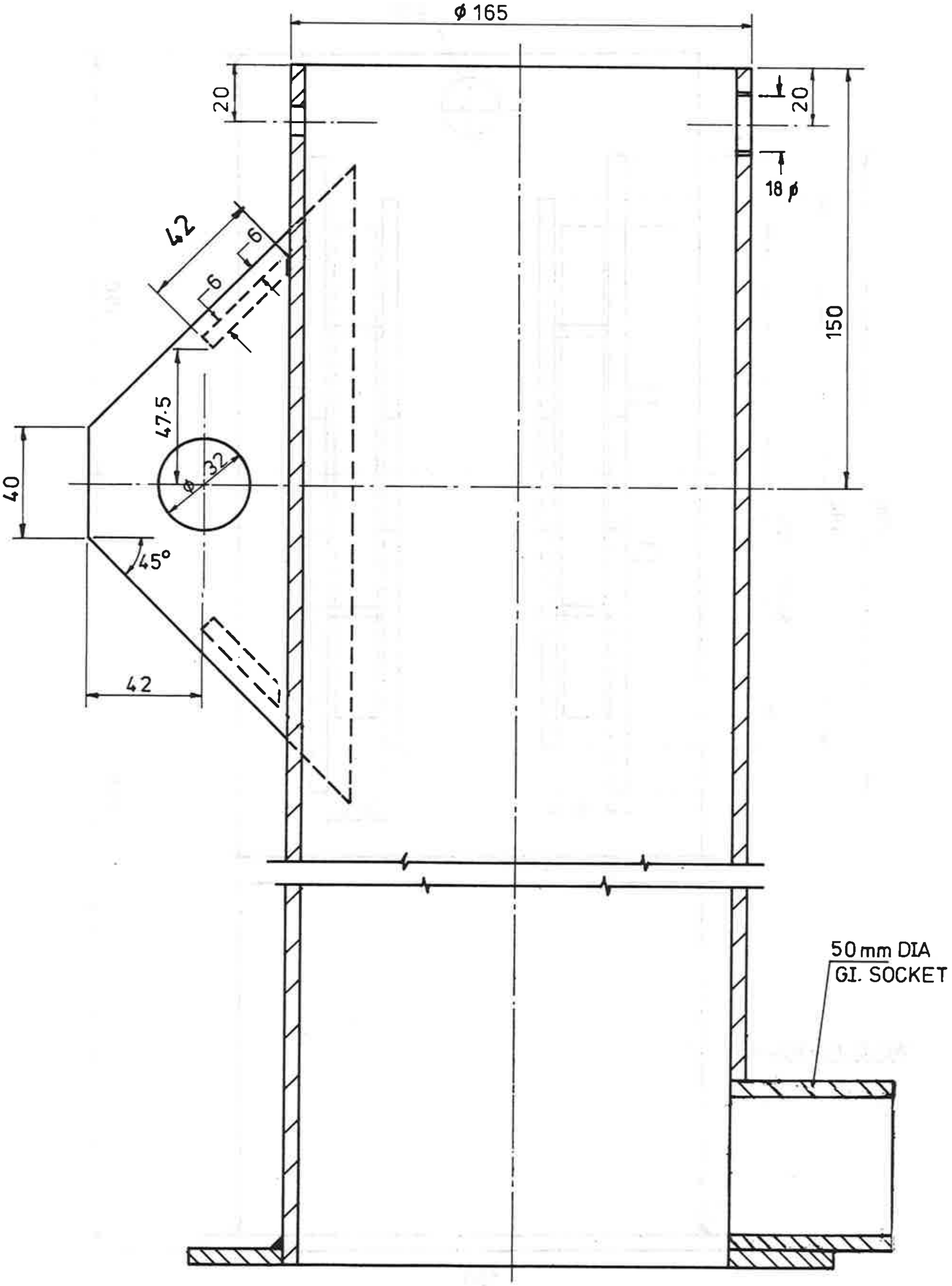
DEPT OF LANDS VALUATION AND WATER. MALAWI HAND PUMP.

W.R.B./3 A JUNE 1982

PUMP HEAD GENERAL ASSEMBLY



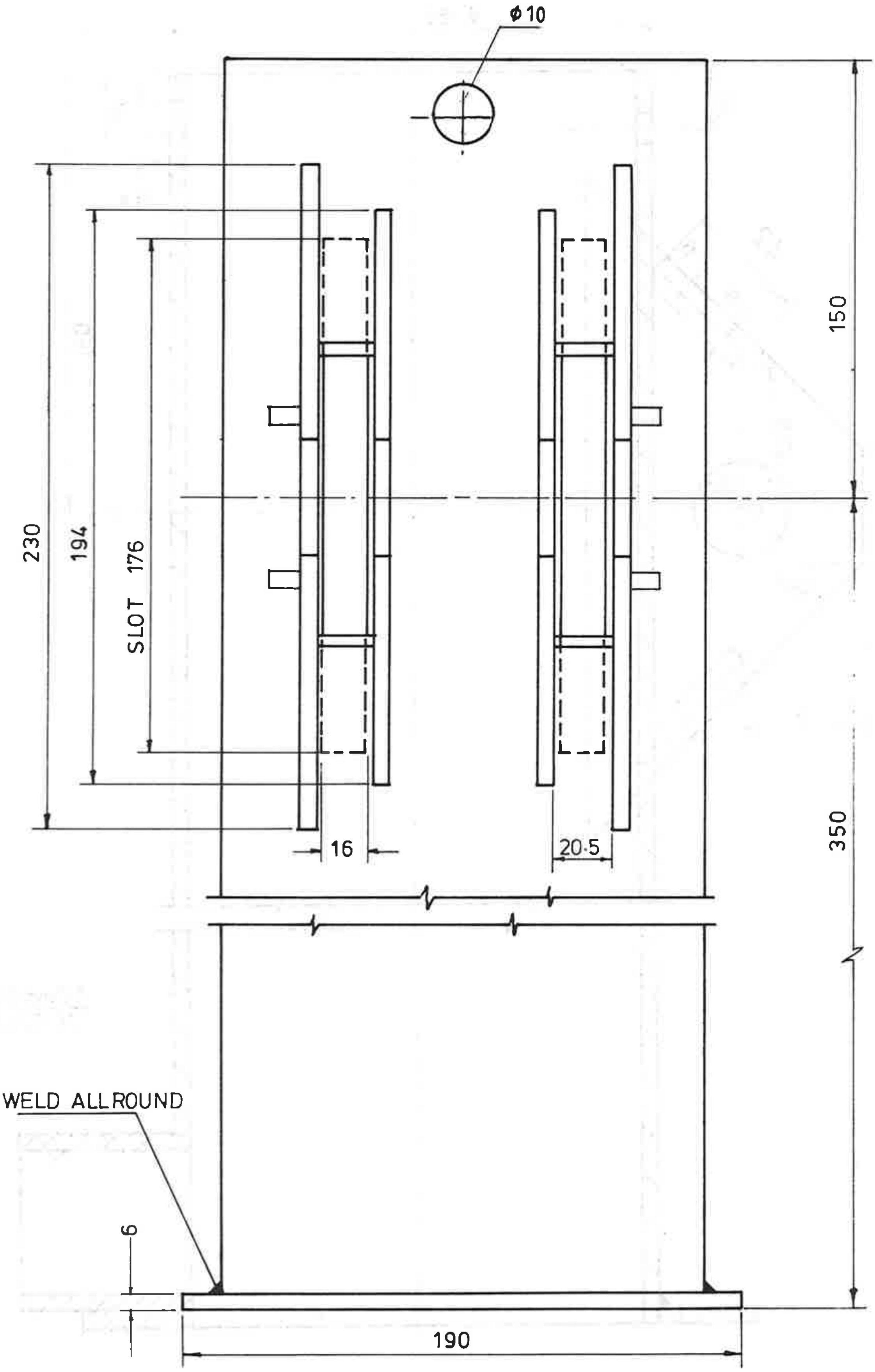
PUMP HEAD



SECTIONAL SIDE VIEW

DEPT OF LANDS VALUATION AND WATER. MALAWI HAND PUMP
W R B / 3 C JUNE 1982

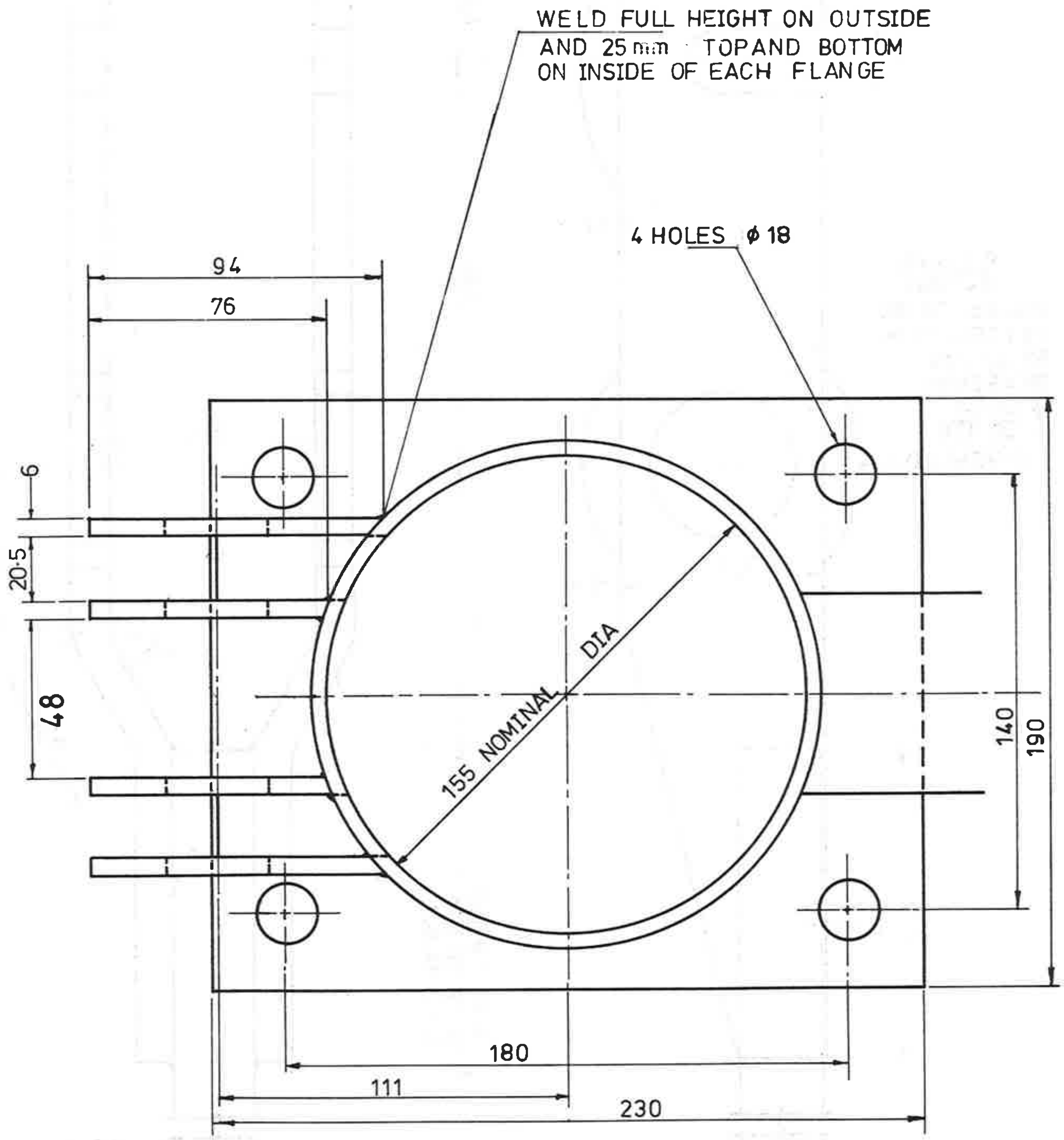
PUMPHEAD



REAR VIEW

DEPT OF LANDS VALUATION AND WATER. MALAWI HAND PUMP
WRB / 3 D JUNE 1982

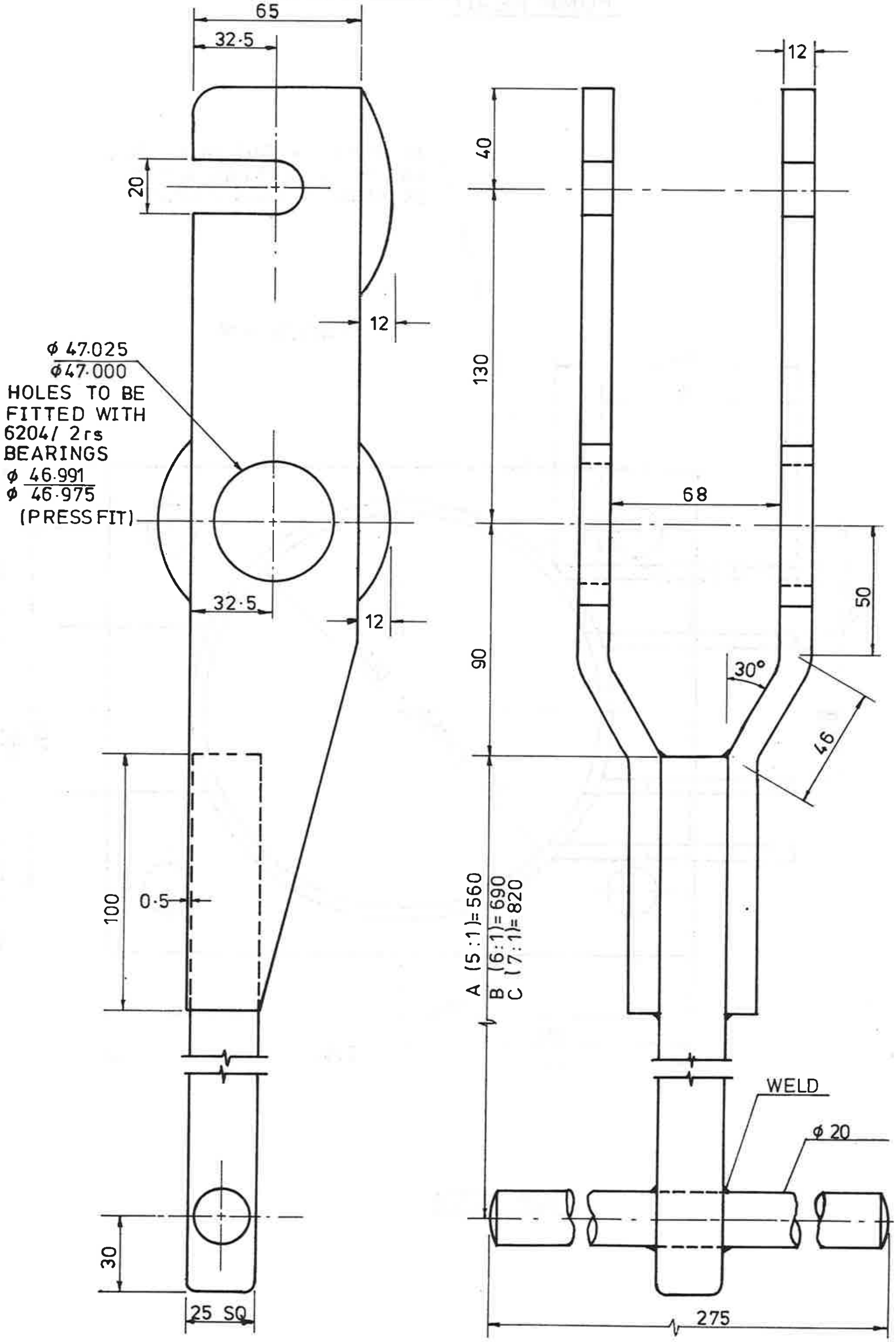
PUMP HEAD



TOP VIEW

DEPT. OF LANDS VALUATION AND WATER. MALAWI HAND PUMP
WRB/3 E JUNE 1982

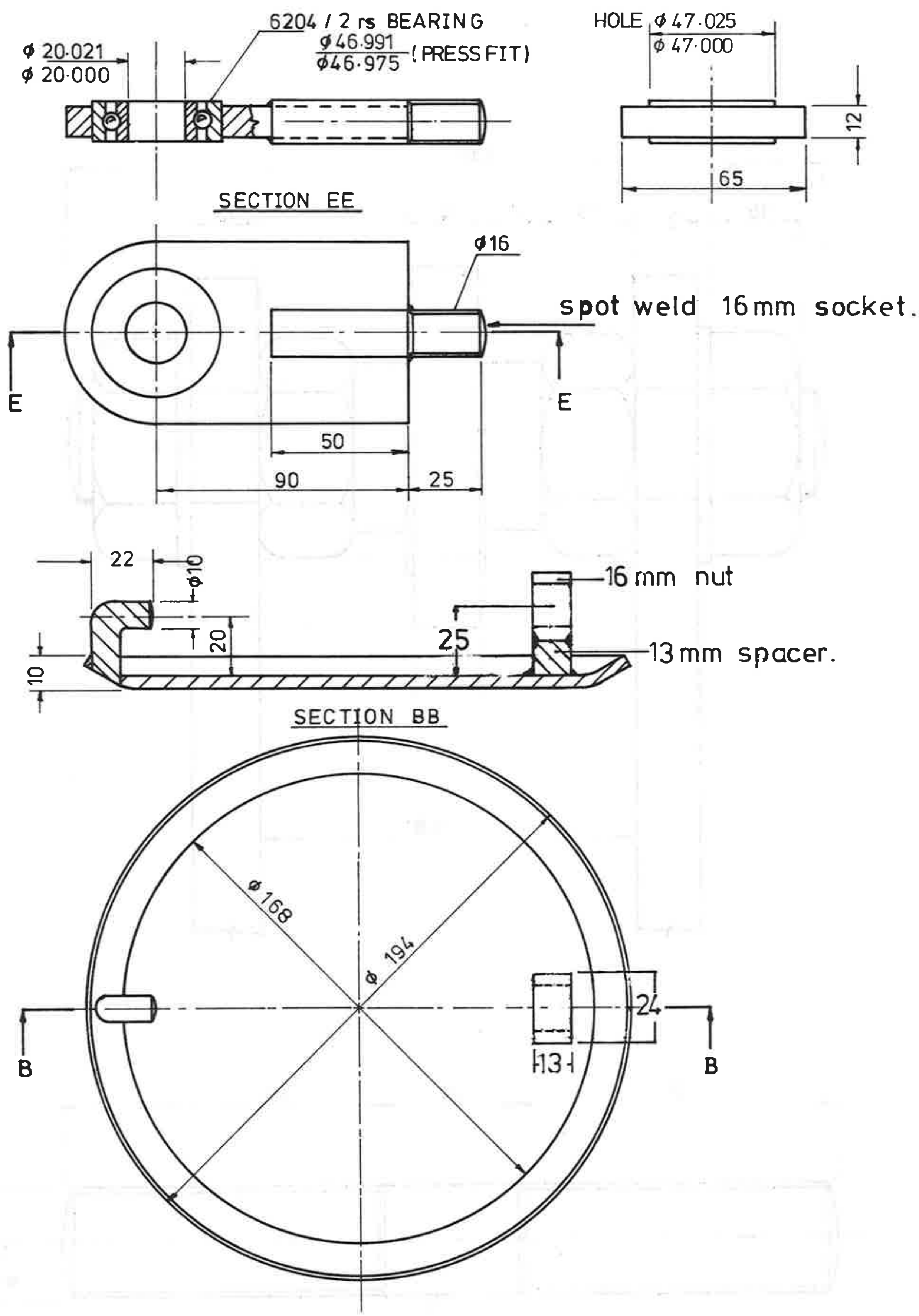
LEVER ARM



DEPT OF LANDS VALUATION AND WATER

MALAWI HAND PUMP
WRB/3 F JUNE 1982

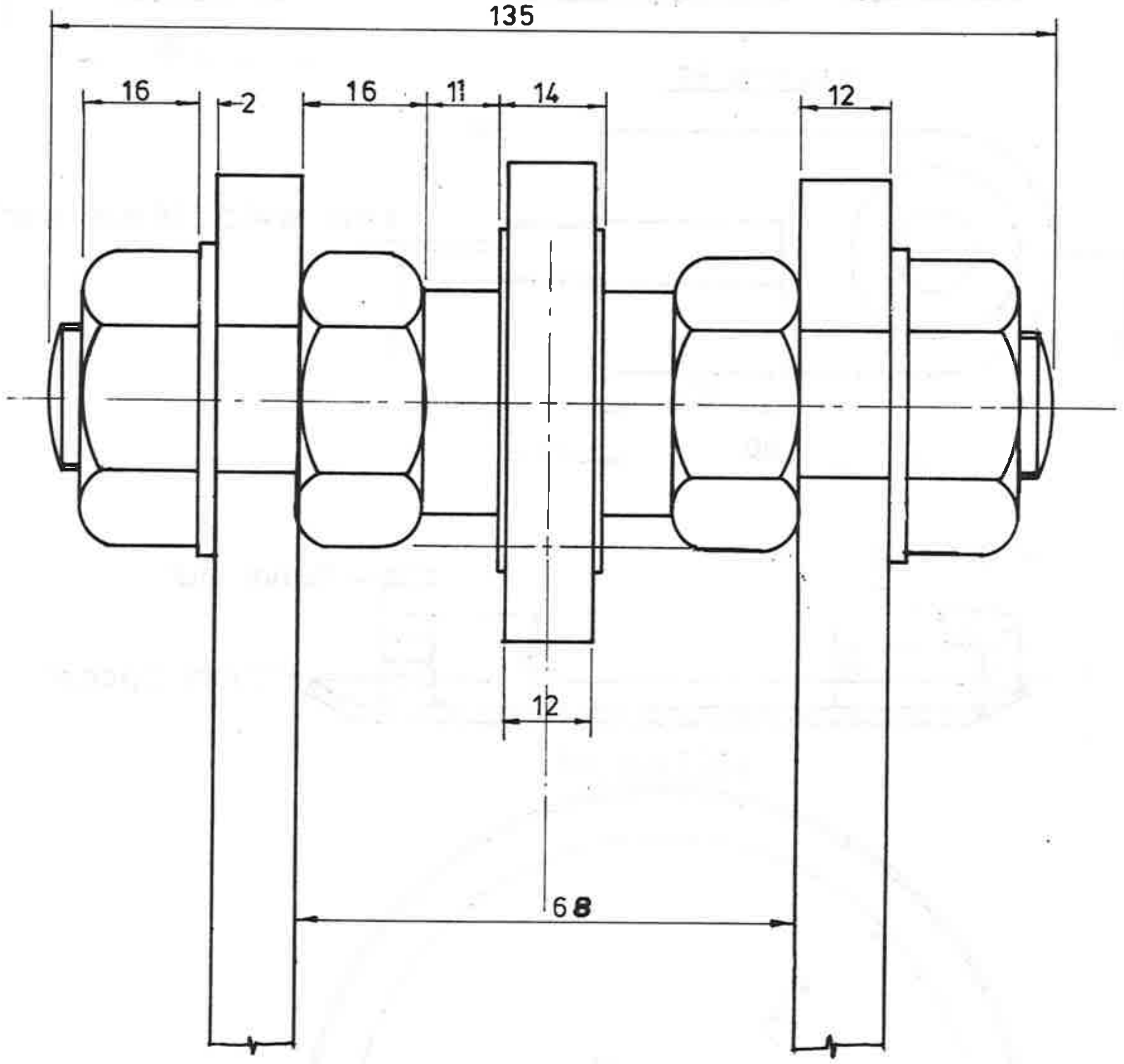
HANGER AND TOP COVER

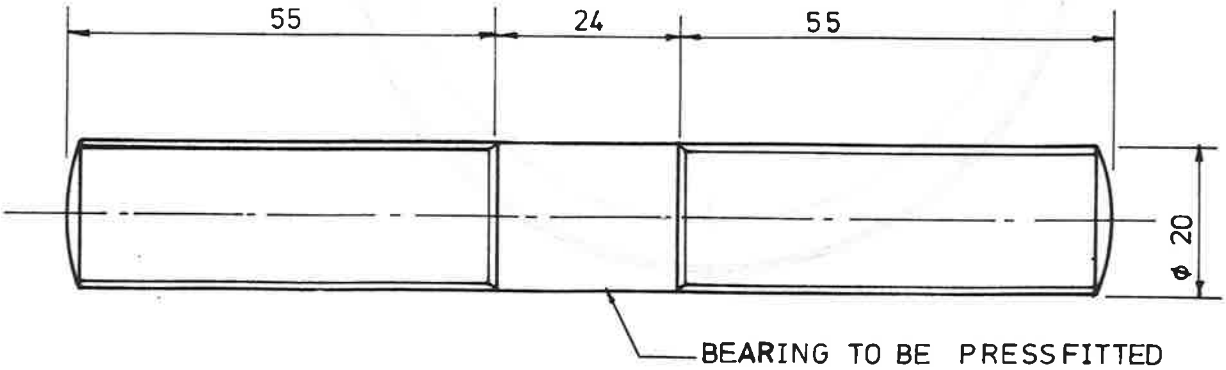


DEPT OF LANDS VALUATION AND WATER.

MALAWI HAND PUMP
WRB/3G JUNE 1982

PARTS FOR AXLE





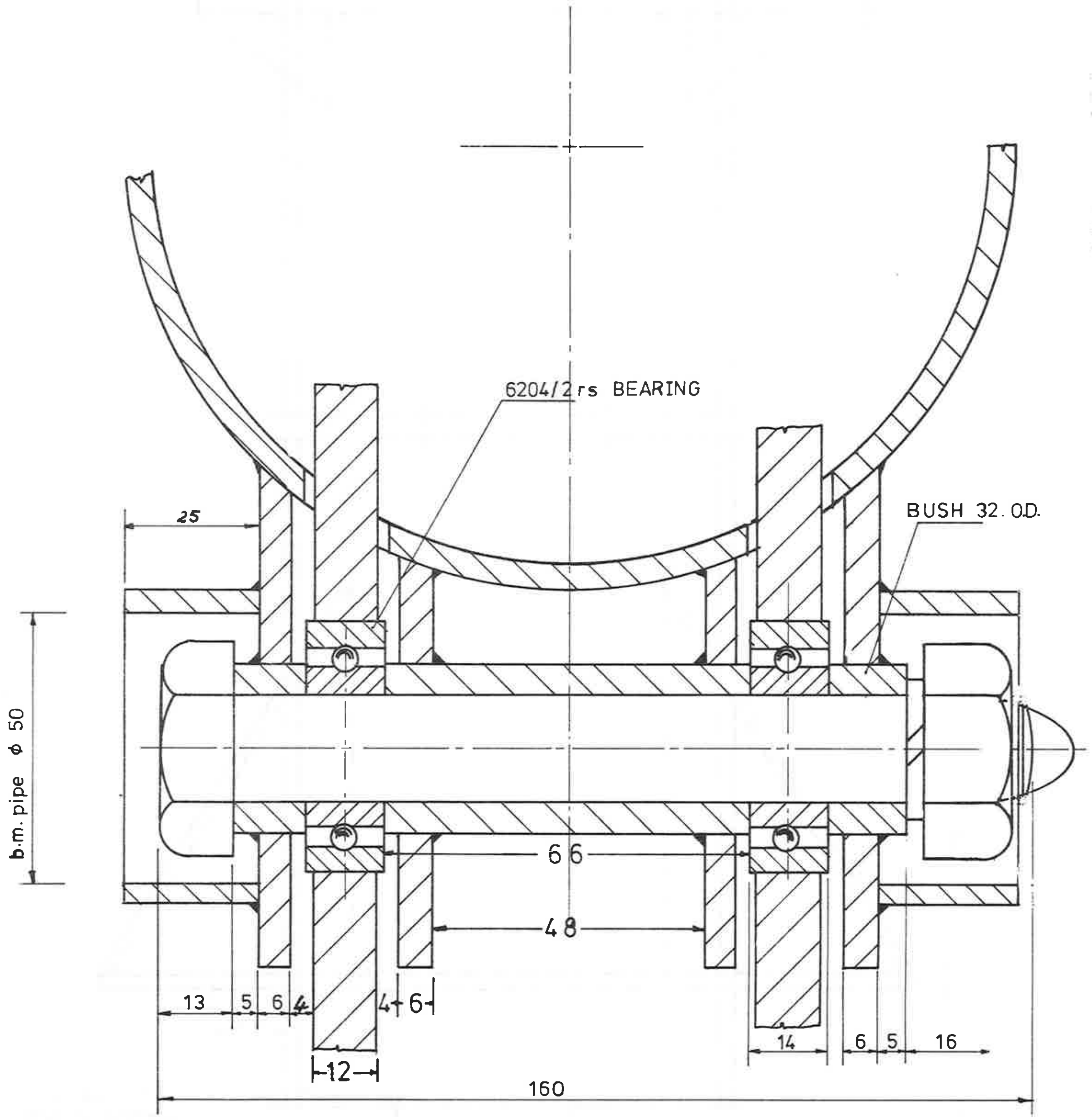
SECTIONAL PLAN

SCALE: FULL SIZE

DEPT OF LANDS VALUATION AND WATER. MALAŴI HAND PUMP

WRB/3 H JUNE 1982

DETAILS OF FULCRUM



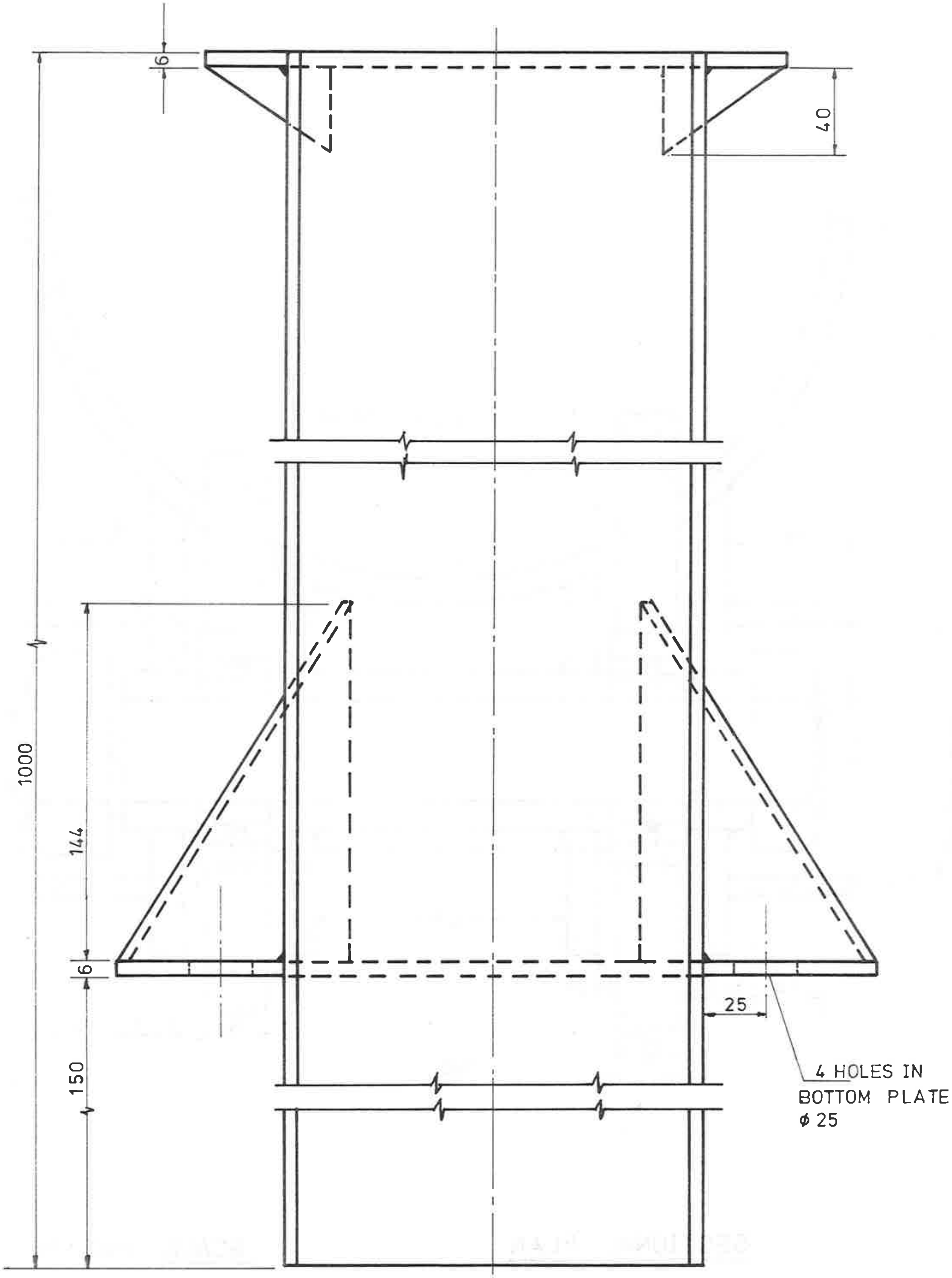
SECTIONAL PLAN

SCALE: FULL SIZE

DEPT OF LANDS VALUATION AND WATER. MALAWI HAND PUMP

WRB/3 I JUNE 1982

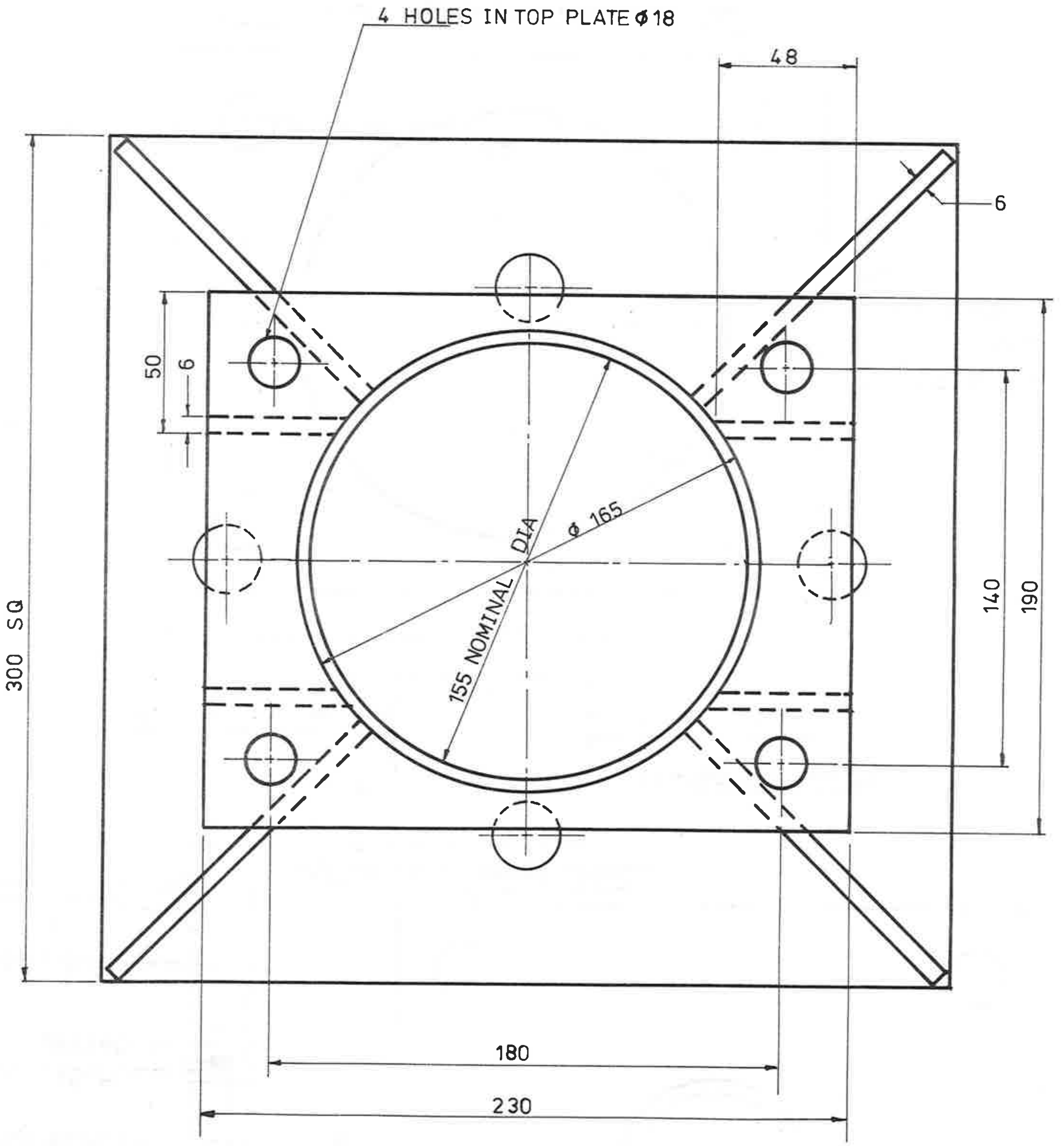
PUMP PEDESTAL



SIDE SECTIONAL ELEVATION SCALE 1:2

DEPT OF LANDS VALUATION AND WATER MALAWI HAND PUMP

WRB/3 J JUNE 1982



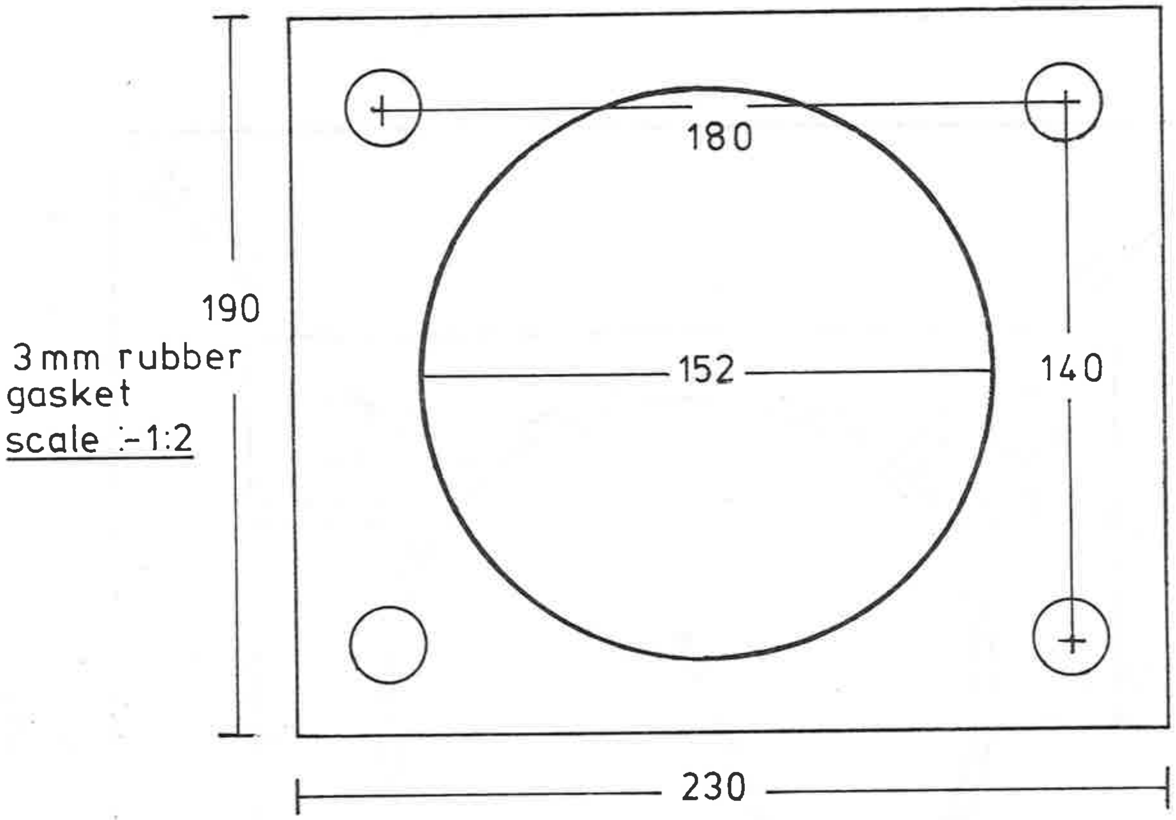
DEPT OF LANDS VALUATION AND WATER

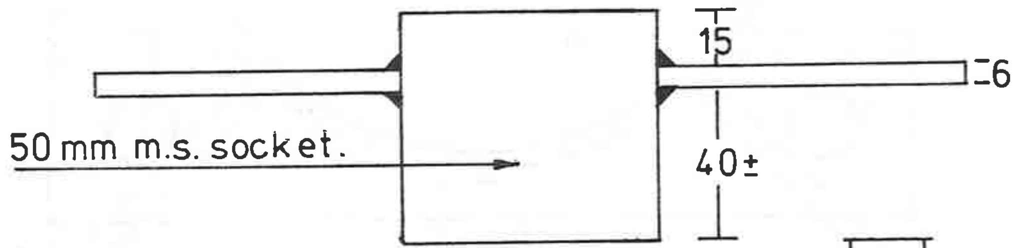
MALAWI HAND PUMP

W R B /3 K JUNE 1982

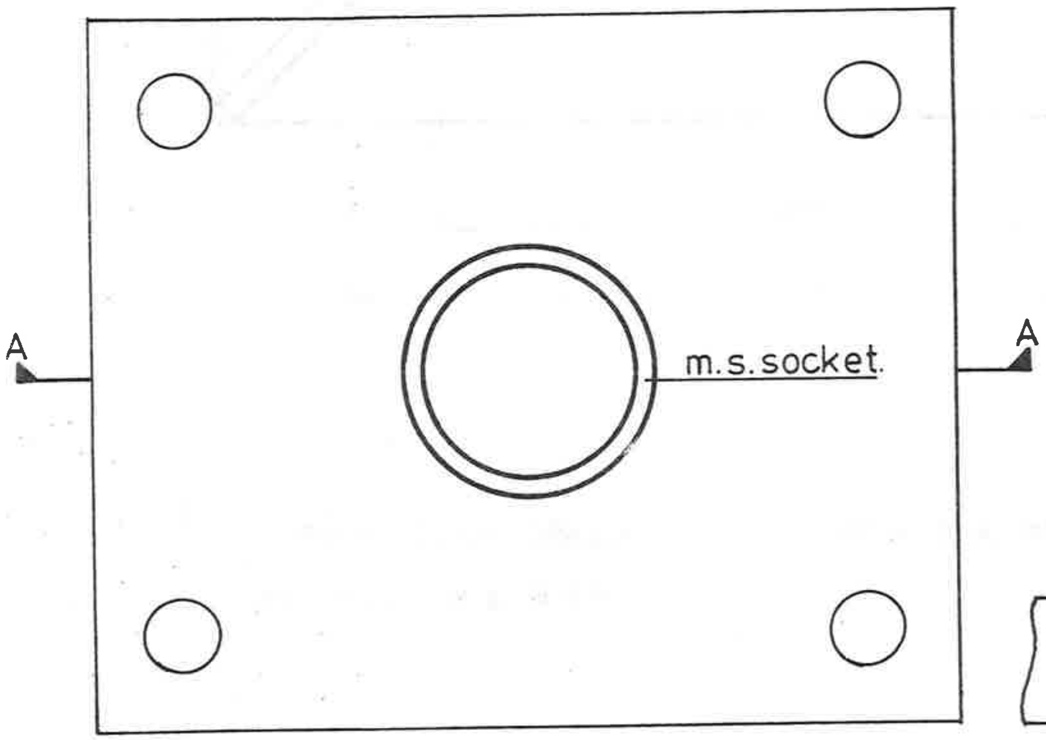
OPTIONAL ADAPTOR PLATE

(to hang 50mm g.i. rising main, hanger for pvc pipe under design.)

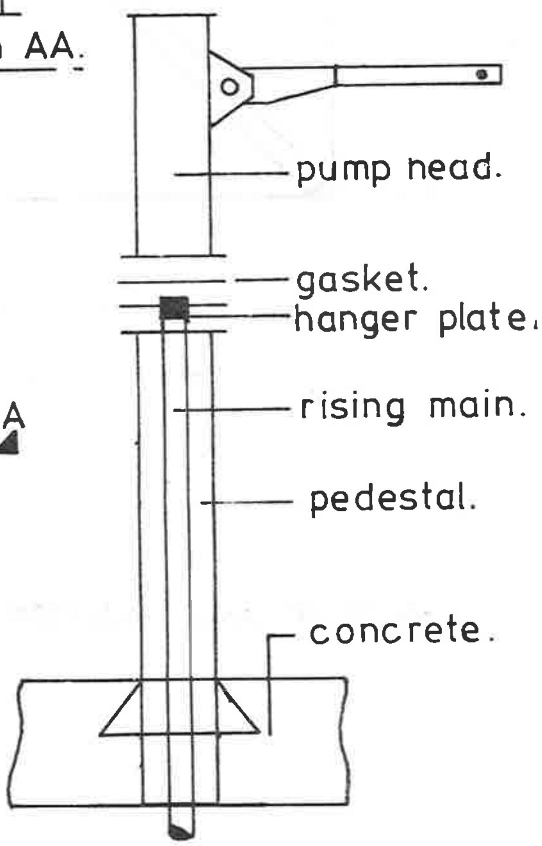




hanger plate - section AA.



6mm hanger plate. scale :-1: 2



not to scale.

WRB/3L.

7.7.1. (4) Another advantage of the "open" flanges is that pumphead installation is very easy. First of all, rising main and rods are fitted through the pedestal, the top rising main pipe is screwed to the adaptor plate then the top rod is cut exactly level with the top of the adaptor plate (with the plunger at the bottom of the cylinder) and the rod hanger assembly is fitted. Then the pumphead is bolted on (with the handle fitted before or after this), the hanger lifted through the "tuning fork" arms of the handle, turned through 90°, dropped into the slots and locked in place by tightening the hanger nuts [Figure D.7.2 WRB 3A].

g) The arc of travel of the handle has been set at 90° (from 45° above the horizontal to 45° below the horizontal) which is considerably greater than with most lever pumps. This is for two reasons, firstly to enable "stop" plates to be fitted to the pumphead that are so far apart that they are rarely likely to be struck by the handle (and certainly not during normal pumping) and secondly to simplify manufacture and minimise material wastage as all four fulcrum flange plates are cut at 45°. The handle stops are fitted in such a way as to avoid finger traps; there are no places on the pumphead where even a small child's finger could be trapped during pump operation.

h) The bushing in all four of the pumphead fulcrum flange plates (see Figure D.7.1, drawing WRB/3I)ensures correct and easy location of the bearings in the handle. This means that handles can easily be fitted in the field and any handle will fit any pumphead. As a result we are able to stock a variety of different handle lengths, to provide an appropriate mechanical advantage for different pumping water levels. Factors other than pumping water level (PWL) are also important here, for example,rod diameter (and hence weight) and plunger seal and cylinder wall materials (and hence frictional resistance). Handles with mechanical advantages of 5:1, 6:1 and 7:1 are currently being employed and criteria for their use are being developed. Possible criteria are 5:1 with a PWL < 10 m, 6:1 with $10\text{ m} < PWL < 20\text{ m}$ and 7:1 with PWL > 20 m.

j) The existence of four fulcrum flange plates has been criticised as unnecessary as two flange plates will suffice. Our opinion is that the greatly increased rigidity and strength given by the extra plates amply justify the additional cost and complexity. The pumphead frame is immensely strong.

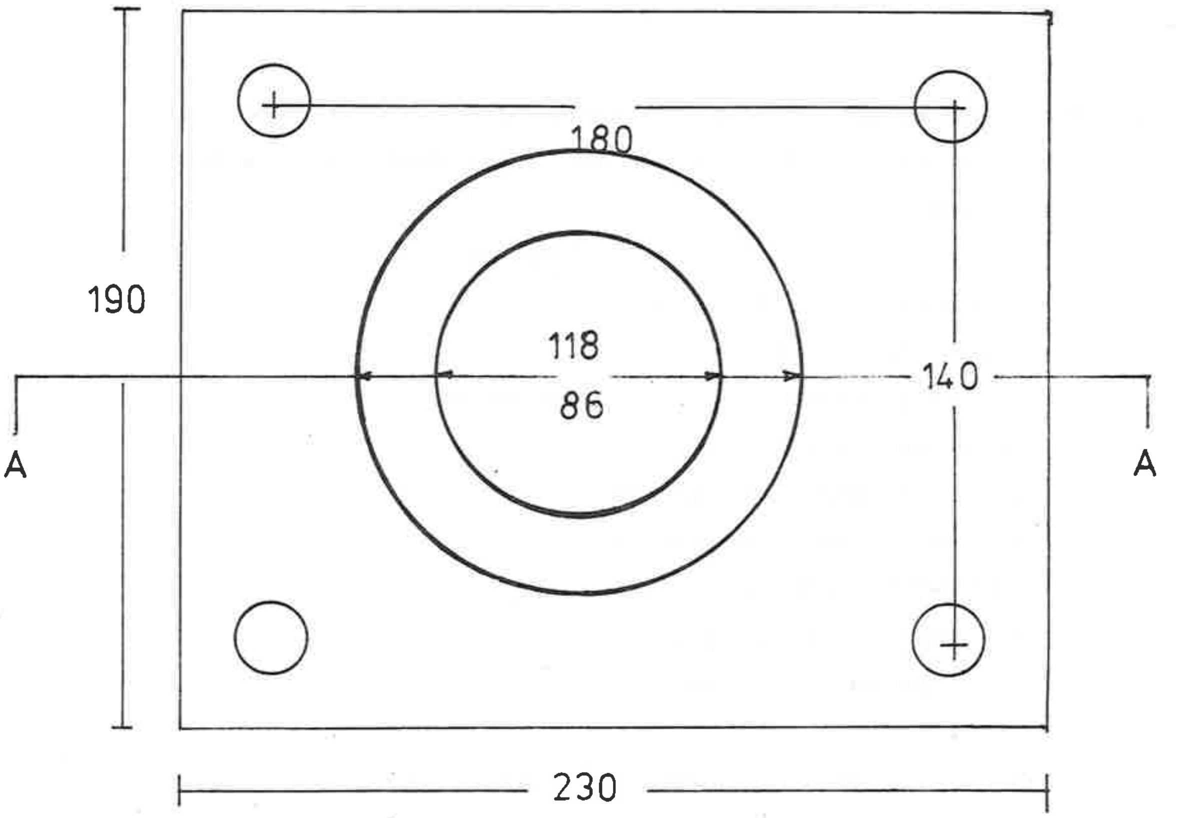
k) A final point relates to pumphead servicing. A single universal spanner has been designed and two of these are sufficient for all the nuts and bolts on the pumphead. The spanner is shown in Figure E.4.1, although a very recent modification to the pumphead (changing the cover plate bolt from 17 mm to 24 mm across the flats, to be the same as the pedestal flange bolts) obviates the need for the central 17 mm socket.

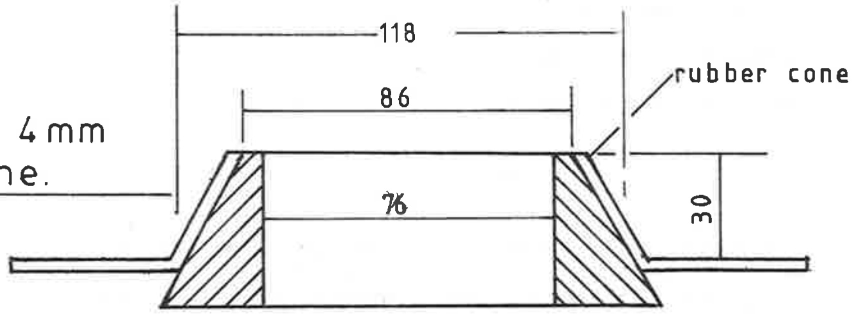
7.7.2. *Pumphead Manufacture*

The current design for the pumphead is given in Figure D.7.2 [drawings WRB/3A to WRB/3M]. Twenty-five pumpheads to this design were made in March and April, 1982 and the first production run of 150 pumpheads commenced in July, 1982. A further run of 200 pumpheads has just commenced (November, 1982). It is hoped to step up production to a target figure of about 1,000 units per year. Several companies in Malawi were involved in prototype manufacture and were assessed for full production capability. The pump is currently (November, 1982) being manufactured by Petroleum Services Ltd. in Blantyre who have invested in assembly and quality-control jigs and are producing pumps to a high standard. The current cost of the complete pumphead is between K120 - K130, depending on the type of borehole casing used. A full production manual is planned, together with detailed Malawi Bureau of Standards specifications for the pumphead. This will facilitate the awarding of annual contracts to approved companies in Malawi for the manufacture of the pumphead. It is important that at least two companies are able to manufacture the pumphead, in order to control prices and quality, through competition. The plant and equipment required to manufacture the pumphead are given in Table D.7.1.

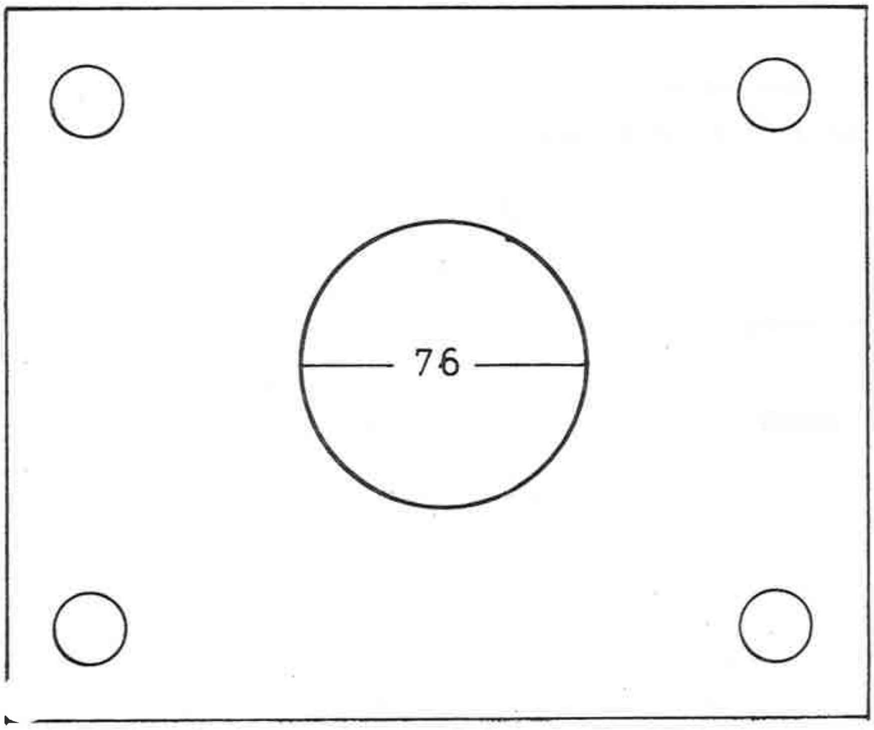
ADAPTOR PLATE (Optional)

to hang 75 mm pvc pipe.

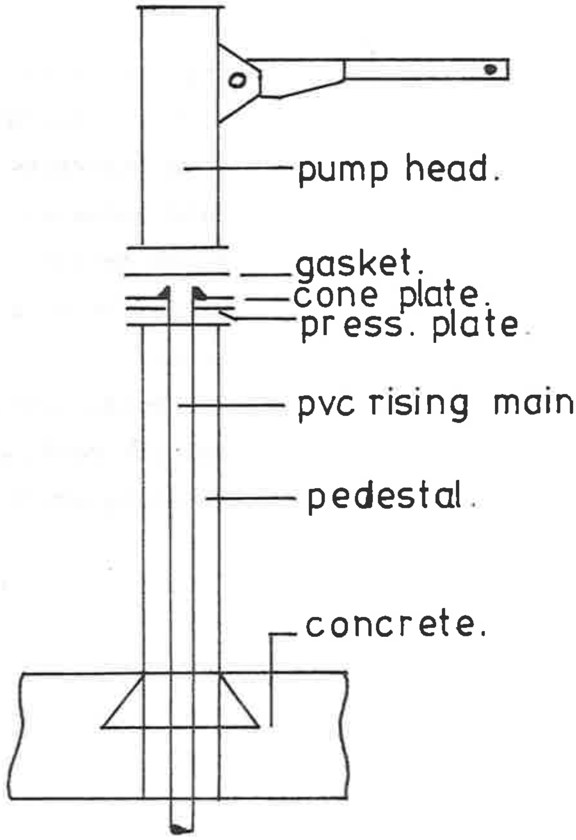




section A-A 4mm mild steel cone.



4 mm mild steel pressure plate.



not to scale.

WRB/3M

Table D.7.1.

a) Plant and equipment required for producing the pumphead in quantity (say 1,000 per year) to a high standard of assembly and finish:

- 2.4 m x 6 mm hydraulic guillotine
- oxy-acetylene profile cutter
- 150 tonnepress brake
- cropping, punching and shearing machine
- universal milling machine
- lathes (centre and capstan)
- hand-held bevelling machine
- heavy-duty pedestal grinder
- pedestal or pillar drill
- 10 tonne hydraulic press
- reamers
- power hacksaw or 150 mm pipe-cutting machine
- welding machines
- sand-blasting equipment
- paint-spraying equipment

b) Minimum equipment required to enable a workshop to produce a limited production of the pumphead to an acceptable standard (with care):

- Oxy-acetylene cutting equipment
- Bench or pedestal drill of 40 mm capacity
- Power hacksaws
- Hand hacksaws
- Bench grinder
- Files, reamers, wire brushes
- Lathe
- 100 tonne hydraulic press
- Welding machines
- Painting equipment

7.7.3. *Down-hole Components*

a) When work started in early 1981 to design a new handpump, it was clear that the problem was twofold. Firstly we wanted to design a pumphead to replace the various inappropriate types in current use. Secondly we wanted to replace existing down-hole components (rising main, rods, plungers and foot-valves) with low-cost alternatives that facilitated easy and rapid removal and replacement of the footvalve and plunger through the pumphead, using materials that overcame the considerable problems of corrosion.

b) PVC pipe was selected immediately to be tested as a replacement for 50 mm galvanised steel pipe as a rising main material, with a diameter large enough to extract a plunger and footvalve. The reasons for this choice were its local manufacture and ready availability, its light weight, its corrosion resistance and its low cost.

c) An early decision had to be made to adopt a standard cylinder diameter. Although 2½ inch (63.5 mm) and 2¾ inch (70 mm) cylinders have sometimes been used in Malawi, 3 inch (76 mm) cylinders have been standard for many years. However these were considered inappropriate and a 63.5 mm (2½ inch) cylinder size has been chosen for many reasons:

(i) A cylinder of 76 mm diameter with a 190 mm pump stroke will give 0.84 litres per stroke (assuming no slip). A pumping rate of 40 strokes per minute (which is a fairly average rate) represents a discharge of 0.56 l/sec. Sustained pumping at this rate is too high for a large proportion of the boreholes in Malawi and is more than double the minimum acceptable yield of boreholes in an Integrated Project (0.25 l/sec) A 63.5 mm cylinder with the same stroke will give 0.61 litres per stroke which is 0.41 l/sec at 40 strokes per minute. This is still 60% higher than the minimum acceptable borehole yield, but is more acceptable as this discharge will rarely be sustained for more than a few minutes at a time.

7.7.3. (2)

(ii) If a 76 mm extractable plunger is employed the rising main diameter will have to have an ID several millimetres greater than this. Although 90 mm Class 10 PVC pipe has an ID of 80.8 mm which would be appropriate, the OD over the sockets is 99.2 mm which will not fit into the 110 mm Class 10 PVC casing whose ID is 98.2 mm. If a 63.5 mm plunger is used, 75 mm Class 10 PVC pipe with an ID of 67.2 mm and an OD over the sockets of 82.8 mm is suitable and gives an adequate annulus for water flow between the borehole casing and the rising main.

(iii) The 63.5 mm (2½ inch) cylinder diameter is becoming an unofficial international standard for handpumps. The India Mark II pump, of which over 100,000 have been installed in the world, uses this size, as do most of the "new generation" of handpumps.

d) 16 mm galvanised pump rods are used in Malawi. These are over specified for their use and therefore both too heavy and too expensive. Rod diameter can therefore be reduced to 12 mm or even 10 mm. The problem of corrosion is a very important one, and use of stainless steel is an expensive solution. A further problem is the danger of damage to pump rod and socket threads during removal from the borehole and replacement, particularly if being undertaken by volunteer village repair teams. If there was a way of removing rods without undoing threads it would be a very significant breakthrough, because maintenance time would be reduced further and, even more important, the level of skill required of the repair person would be considerably lowered. Several possibilities have been considered:

- the use of bayonet couplings
- the use of spring steel rods (or even a flexible but strong synthetic material such as fibreglass) so that the rods can be removed in one piece
- the use of hinged sockets allowing rod removal without unscrewing sockets
- the use of some kind of "snap-on" rod connector.

e) The question of cylinder, plunger and footvalve design has proved to be an extremely complex one, on which a great deal of thought and effort has been expended. PVC, HDPE (high density polyethylene) and ru ber plungers, and extractable

7.7.3. footvalves of many designs have been tried in PVC cylinders
(3) and conventional brass ones. Also conventional brass plungers with leather seals have been tried in PVC cylinders. The change from conventional cup leather plunger seals was considered preferable because of their increasingly high cost, very variable quality and the need to import them (with increasing difficulty).

f) By early 1982 no acceptable solution to the cylinder/plunger/ footvalve problem had been found and it was clear that the necessary expertise in either plastic materials or plastics design did not exist in the Groundwater Section of DLVW or anywhere else in Malawi. Assistance was then sought and granted from the UK ODA and the World Bank for a handpump design project with the following objectives:

(i) design and development of the down-hole components of a handpump using plastic materials which are suitable for local manufacture and for village-level maintenance

(ii) testing of the Malawi borehole pumphead by the Consumer Association.

g) the Malawi borehole pumphead is currently (November, 1982) under test at the Gosfield Laboratory of Consumer Association Testing and Research (CATR) in the UK. No problems have arisen yet and engineering assessments appear encouraging (when completed, the full test report will be inserted in the Manual). The down-hole component design work is still underway, co-ordinated by CATR with help from several large specialist companies. It is hoped to have prototype rod-connectors, cylinders, plungers and footvalves in Malawi for extensive field testing early in 1983. Results so far appear very promising and Malawi could be the first location for the introduction of some very exciting new concepts in handpump design. The targets of easy maintenance and simplicity, local manufacture and low cost are still very much in mind and they become more achievable when coupled with up-to-date techniques and knowledge of design and engineering with plastics and rubbers.

7.8. THE DUG-WELL HANDPUMP

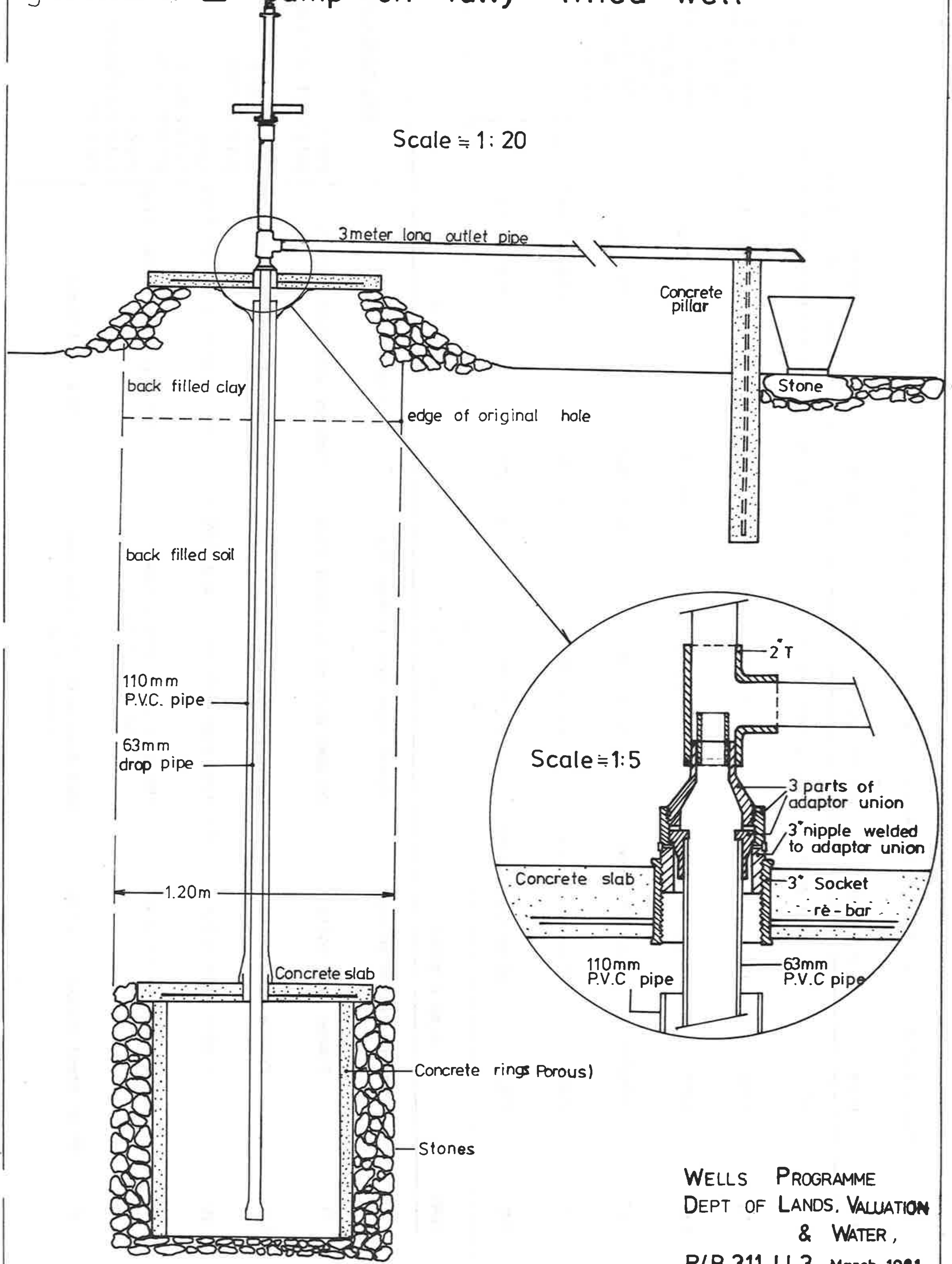
7.8.1. *The Marks I to VI Malawi dug-well pumps*

a) The introduction of a simple, cheap and easily assembled handpump was a focal part of the "Community Protected-Wells Programme" which started in 1975. Since that time six "Marks" have been developed with Marks II, III, IV and V each being an improvement on the earlier version and the Mark VI being specifically developed for greater pumping heads (6 - 10 m with a 45 mm ID cylinder) to complement the Mark V (up to 6 m with a 56 mm ID cylinder). An underlying principle of the pumps is that no lever or other force-reducing mechanism is used due to the pump's shallow application. The absence of a lever eliminates any wear related to bushes or bearings in a fulcrum and the direct-lift action greatly simplifies manufacture. A further advantage is that high plunger speeds (up to 1 m/sec) are achieved which allow the use of plungers without seals. Even badly worn plungers will work satisfactorily if operated at high pumping rates. Pump efficiency (ie the ratio of actual discharge to swept volume) is not too important at shallow depth, so slip past the plunger can be tolerated and can even be positively beneficial as water will provide lubrication and reduce plunger and cylinder wear.

b) Table D.7.2 gives details of the development of the six different Malawi dug-well pumps. Figure D.7.3 shows, in six drawings, details of the Mark V and Mark VI pumps. Over 1,500 Mark V pumps have been manufactured in a DLVW workshop since July, 1980 with the only major modifications being to the steel "Tee" handle and guide bush. The handle has been modified many times over the years. Damage by abuse and even being eaten by hyenas led to abandoning the PVC "Tee" and adopting an all-steel handle, which now has a stroke-limiting guide. Bushes made from imported nylon guide the pumphandle at two places and also act as stops.

c) The handpump has several good design features and has a reasonably good performance record. There is, however, still room for improvements and the performance of about 40 of the handpumps is currently being closely monitored in the Upper Livulezi Integrated Project.

Fig D.7.3. Mark V pump on fully lined well



WELLS PROGRAMME
DEPT OF LANDS, VALUATION & WATER,
P/B 311, LL3. March, 1981.

Table D.7.2. The "MarK" Series of Malawi Dug-Well Handpumps

MARK	YEAR	PUMPHEAD	RISING MAIN/CYLINDER	PUMP ROD	HANDLE
I	1975	2" steel pipe	2 inch steel	3/8" steel	3/8" steel rod 90° bend
II	1976	1½" steel pipe	63 mm PVC	3/8" steel	3/8" steel rod 90° bend
III	1977	75 mm PVC pipe	63 mm PVC	20 mm PVC	PVC "Tee"
IV	1978/79	75 mm PVC pipe	63 mm PVC	20 mm PVC	PVC "Tee"
V	1980	50 mm steel pipe	63 mm PVC	25 mm PVC	Steel "Tee"
*VI	1982	50 mm steel pipe	50 mm PVC	25 mm PVC	Steel "Tee"

*the Mark VI handpump is a version of the Mark V specifically made for deeper pumping heads (6m to 10m)

MARK	SLAB FIXTURE	PLUNGER	FOOTVALVE
I	Square flange in slab	Steel disc with rubber flap	Standard brass
II	Flange with bolts	Perspex disc with rubber flap	Reducer with rubber ball
III	Flange with bolts	Perspex disc with rubber flap	Reducer with rubber ball
IV	Flange with bolts	PVC disc with HDPE rings and HDPE flap	PVC disc with rubber flap
V	80 mm steel socket in slab	PVC disc with LDPE sleeve and HDPE flap	PVC disc with rubber flap
VI	80 mm steel socket in slab	HDPE disc with PTFE ring and rubber flap	Standard brass

Abbreviations

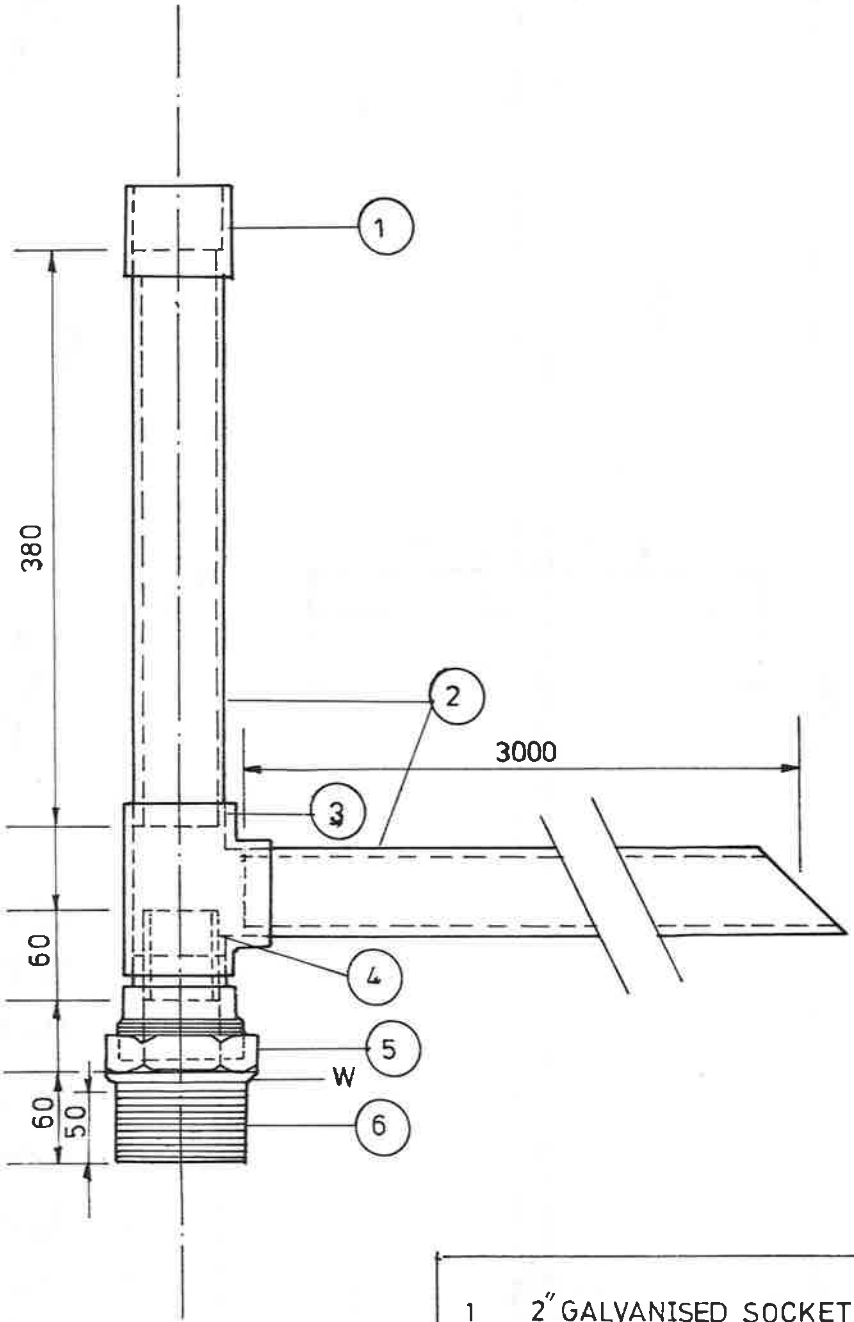
PVC = polyvinyl chloride

HDPE = high density polyethylene

LDPE = low density polyethylene

PTFE = Polytetrafluoroethylene

Pump Head



1	2" GALVANISED SOCKET
2	GALVANISED PIPE 2"
3	2" GALVANISED TEE
4	50 mm P.V.C. PIPE CLASS 16
5	2"-63 mm ADAPTOR UNION
6	3" GALVANISED PIPE END
W	ARC WELDING JOINT

Scale 1:5

DIMENSION IN MM

WELLS PROGRAMME

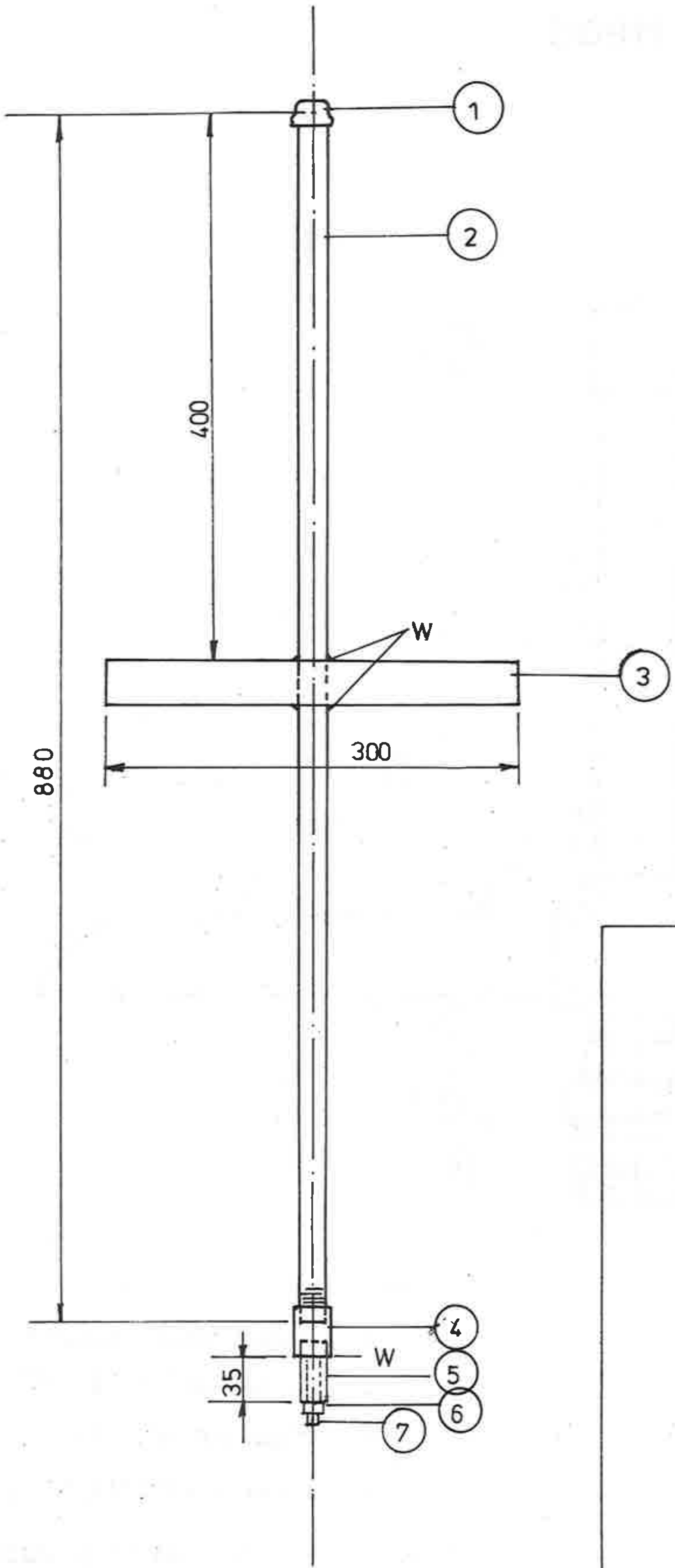
DEPARTMENT OF LANDS VALUATION AND WATER

P/B 311 LILONGWE 3

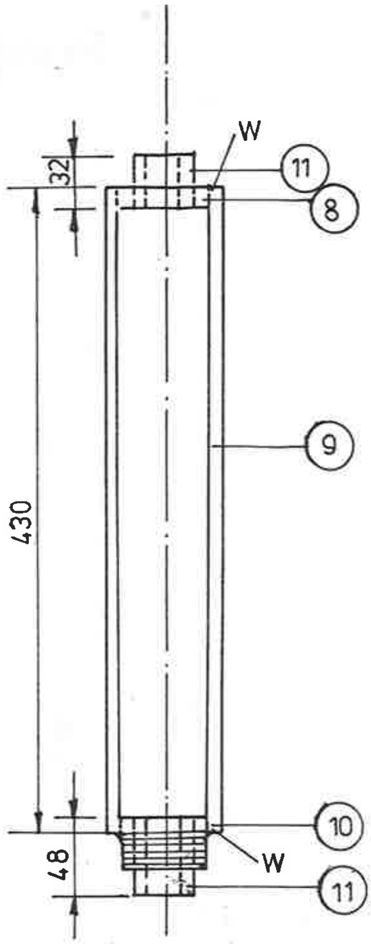
MALAWI.

JUNE 1982

Pump Handle



Pump Handle Guide



1. 1/2" GALVANISED CAP
2. 1/2" GALVANISED PIPE
3. 11/4" FENCING PIPE
4. 1/2" GALVANISED SOCKET
5. 21mm P.V.C ROD WITH 10 mm HOLE
6. 3/8" FLAT WASHER
7. 10 x 60 mm BOLT AND NUT
8. 1 1/4" GALVANISED BACK NUT
9. 1 1/2" x 1/4" FLAT BAR
10. 1 1/4" x 2" GALVANISED REDUCING BUSH
11. 25 x 40 mm THREADED NYLON BUSH

W. ARC WELDING JOINTS

SCALE 1 : 5

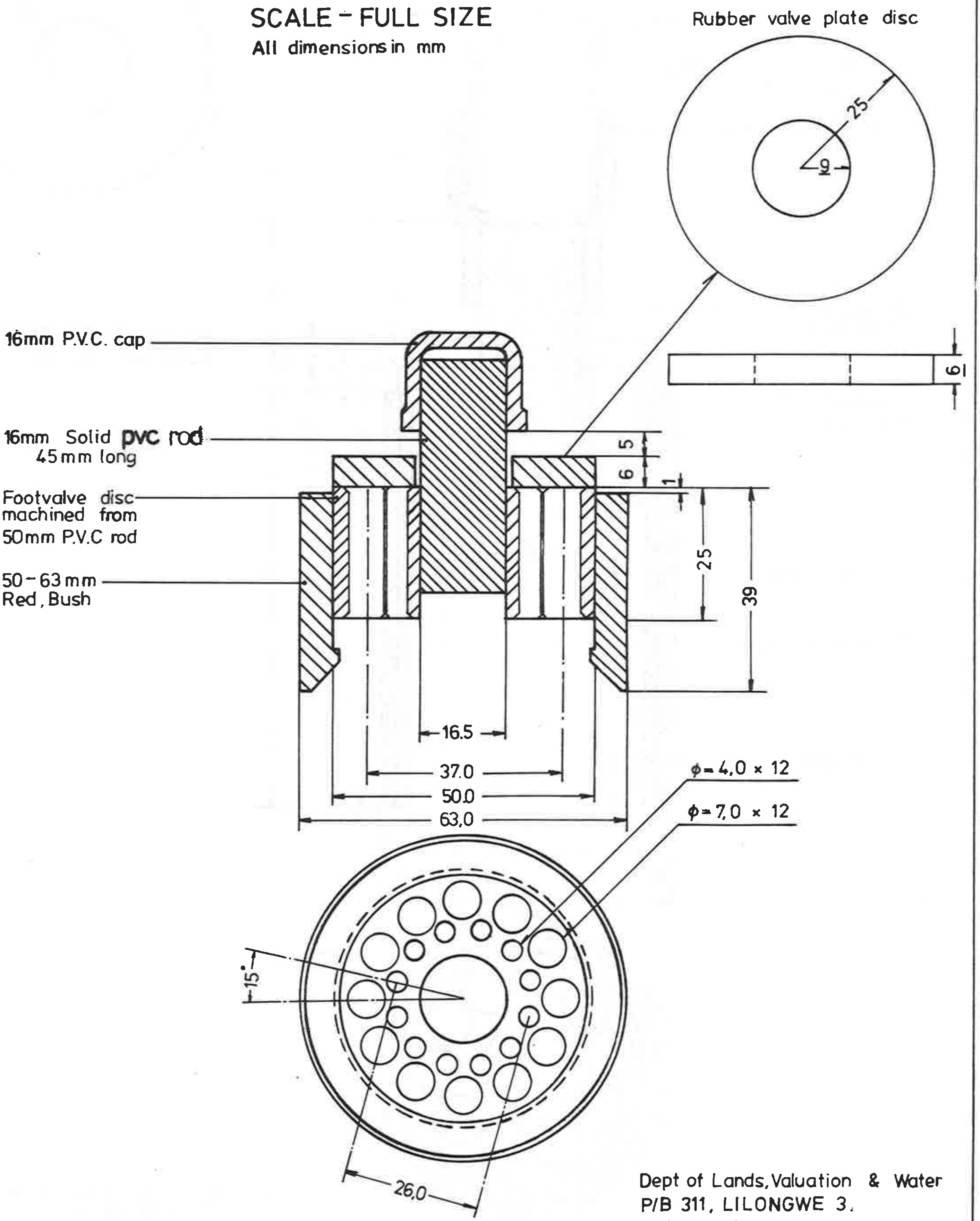
DIMENSIONS IN MM

WELLS PROGRAMME
DEPT. OF LANDS VALUATION AND WATER
P BAG 311
LILONGWE 3
MALAWI

JUNE 1982

Footvalve for 63mm cylinder of MARK V hand pump

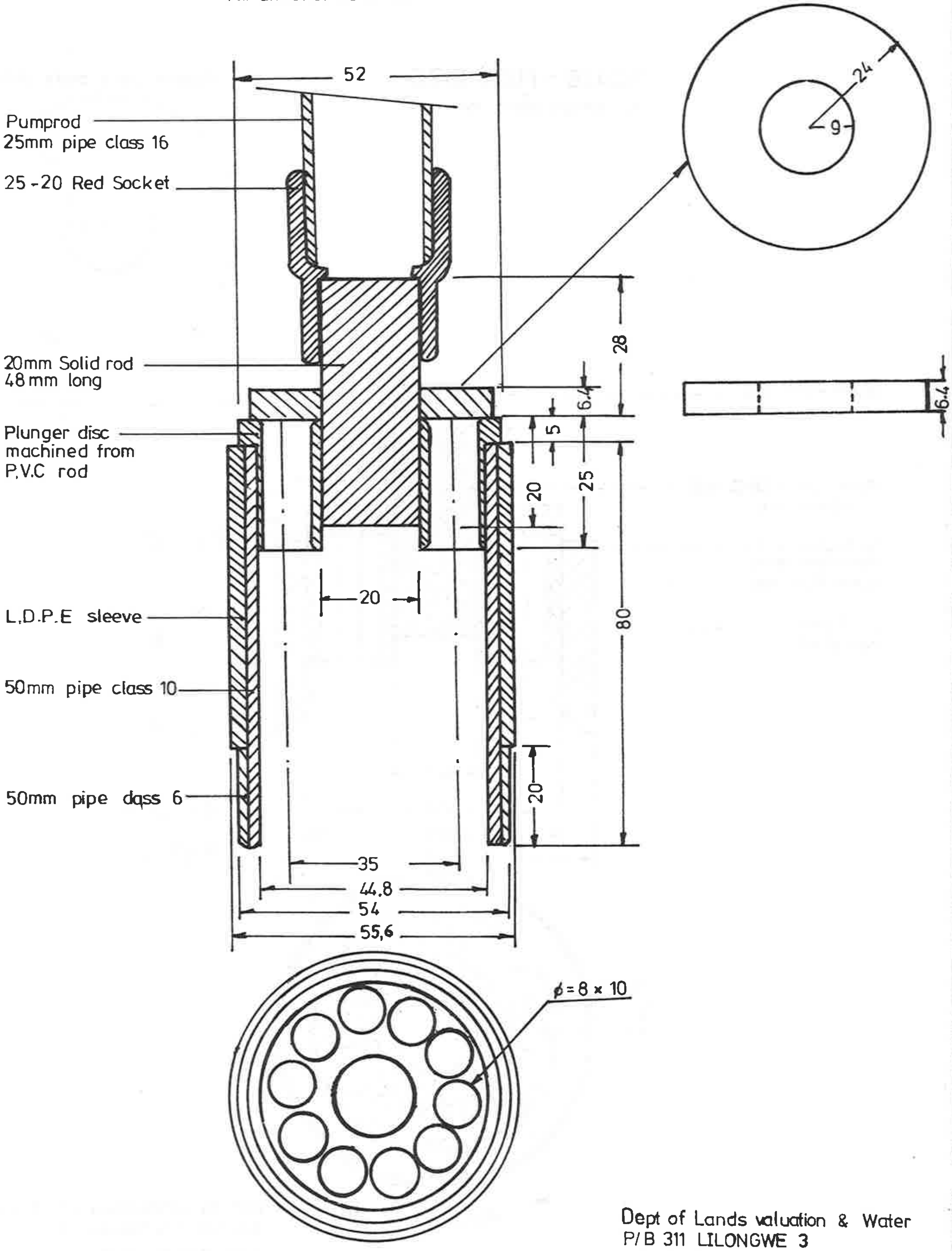
SCALE - FULL SIZE
All dimensions in mm



Dept of Lands, Valuation & Water
P/B 311, LILONGWE 3.
17th March, 1981.

Plunger for 63mm cylinder of MARK V hand pump

SCALE FULL SIZE
All dimensions in mm



Dept of Lands valuation & Water
P/B 311 LILONGWE 3

8 th April 1981

7.8.2. *The Blair or Madzi Pump*

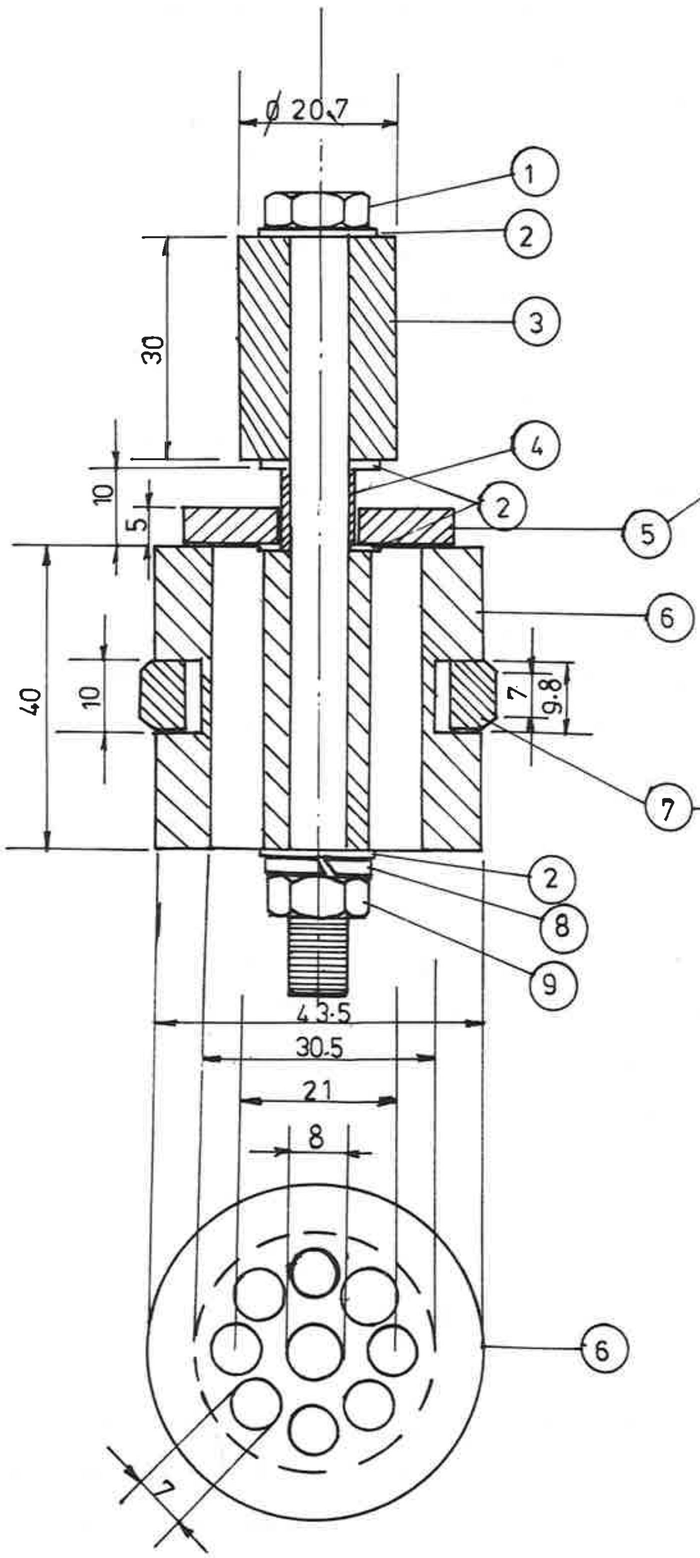
The Madzi pump is a shallow-lift handpump of innovative design which is being manufactured largely of PVC pipe by Pipe Extruders Ltd. in Lilongwe. The pump was designed by the Blair Research Laboratory of the Ministry of Health in Zimbabwe and is being manufactured in Zimbabwe and now in a slightly modified form in Malawi. The major design feature is that the pump rising main also serves as the pump rod, with water discharging from the "walking stick" direct-action handle. In principle, there are two PVC pipes (one inside the other) both with non-return valves at their bases. The outer pipe is fixed and its valve acts as a conventional footvalve. The moving inner pipe is both a hollow plunger and pump rod. The non-return valve in the inner pipe lets water pass on the down-stroke (when the foot-valve is closed) and thus water is forced up the hollow pump rod to the surface. On the up-stroke water enters the cylinder through the open footvalve in the normal way. The Madzi/Blair pump has been installed in the Upper Livulezi Integrated Project and its performance is being monitored. The pump is easy to install, probably easy to maintain and, if it's reliability is proven, is a very interesting design. One reservation is the nature of the discharge pipe. The addition of the 3 m extension pipe fitted to our handpumps has won considerable favour as it ensures that both dirty water and washing activities are kept away from the waterpoint itself. The concrete apron will wear and eventually crack and we have strong reservations about a pump which will only discharge directly over the dug well or borehole.

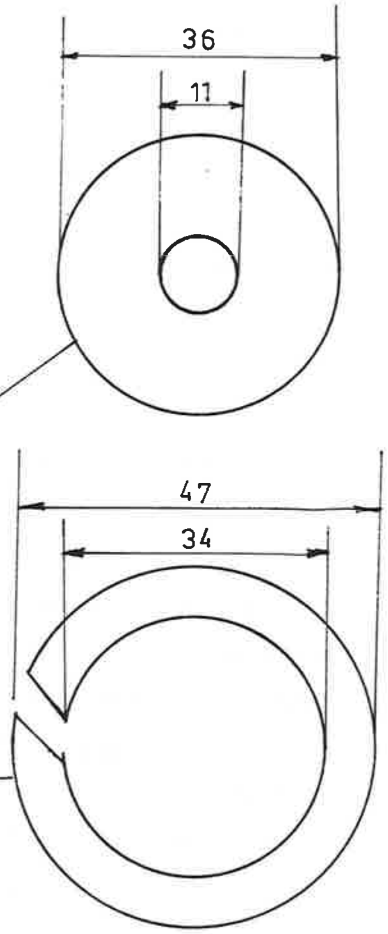
7.8.3. *Further Developments*

There are several areas where further development is needed with dug-well handpumps:

a) It is essential that the design of both the deep and the shallow Malawi handpumps is unified as much as possible so that both can be easily understood, maintained and repaired by the same volunteer caretaker and repair teams. The basic design feature of using lever-assisted pumping for deep lift and direct-action pumping for shallow lift is a sensible division which can be explained to users when the pumps are installed. However, both pumps should be designed to use the same tools and spare parts (where possible) and operate on the sampe principle in order to meet our most important criterion for handpump design, ie ease of maintenance.

Plunger Mark VI Well Hand Pump





SCALE FULL SIZE
DIMENSIONS IN MM

1	M8 BOLT 100 mm LONG
2	5/16" FLAT WASHER
3	20 mm PVC ROD WITH 8 mm HOLE
4	5/16" GALVANIZED FULL PIPE
5	RUBBER PLATE VALVE
6	HDPE PLUNGER DISC
7	P T F E (Teflon) PLUNGER RING
8	5/16" SPRING WASHER
9	M8 NUT

WELLS PROGRAMME
DEPT OF LANDS VALUATION AND WATER
P/BAG 311
LILONGWE 3
MALAWI

JUNE 1982

b) Greater demand is made of a handpump for deep lift than one for shallow lift. When suitable down-hole components have been developed for the borehole handpump [see Section 7.7.3] there is a great deal to be said for using the same (or similar) components for the dug well pump and their life will be greatly extended due to the reduced demand on them. This may, in the end, not prove practicable, but it should be seriously considered as it will greatly assist maintenance and the provision of spare parts.

c) Several features of the current Mark V handpump require careful review. A common cause of failure is breakage of the pump rod, most commonly at the PVC rod to steel handle connection. PVC has a low notch resistance and it is likely that this problem will not be easily overcome. There is another, related, problem with the use of PVC rods. Any rod breakage requires the use of solvent cement for the repair. The problems of storing and using solvent cement probably rule it out for use by village-level repair teams.

d) A final feature that would be of possible value in the dug-well handpump design is the ability to remove the pump to reveal an access hole in the well slab large enough to allow use of a bucket for abstracting water. If for some reason a pump cannot be repaired, perhaps because spare parts are not available, it seems wise to take advantage of the large diameter of a fully-lined dug well so that people can get water from the well in a bucket. A removable cover plate on the slab poses many problems; it would be particularly difficult to prevent dirty water from getting into the well. A handpump design is being tested in which a very low pump "pedestal" comprising 168 mm OD pipe is set into the top slab and the direct-action pumphead is bolted onto the pedestal using flanges, nuts and bolts identical to those of the borehole pumphead. If the pump cannot be repaired the head can be removed together with rods and rising main to reveal a 150 mm ID hole through the pedestal. A 0.75 m long specially made bucket with a capacity of 10 litres can then be used on a rope to abstract water. Even if all the pumps break down in a village which has both boreholes and dug wells, the dug wells can then continue to provide water from a source which is still partially protected.

7.9. TESTING AND MONITORING

7.9.1. Our handpump designs need to be thoroughly tested. This requires careful monitoring of their performance in the field, so that design improvements can be made as appropriate. This programme of handpump testing is not confined only to Malawi, as many other developing countries have similar problems with their own handpump programmes. In recognition of this, UNDP has established an Interregional Project, executed by the World Bank, entitled "Field Testing and Development of Rural Water Supply Handpumps" (project number INT/81/026). Malawi is an active, participating country in this project.

7.9.2. Staff of the Upper Livulezi Project, together with an engineer from the UNDP/World Bank Project are monitoring the performance of several handpumps which have been installed in the Project. The handpumps concerned and their approximate numbers are as follows:

boreholes :	100 Malawi Pumps (deep)
	25 Consallen Pumps (manufactured in UK)
	25 India Mark II Pumps (manufactured in India)
dug wells :	50 Mark V Malawi Pumps (shallow)
	25 Madzi/Blair Pumps

7.9.3. Examples of the provisional monitoring forms (designed in Malawi) that are currently in use in the Upper Livulezi Project are given in Figure D.7.4 to D.7.6. These forms will be replaced when the UNDP/ World Bank Project produces finalised versions of the forms for interregional use.

7.9.4. Handpump performance will be closely monitored for approximately two years during which time further development of the Malawi pumps (both deep and shallow) will hopefully result in handpumps that will, together with good borehole and dug-well design and the full involvement of the villagers in maintenance, solve the "handpump problem" and result in Integrated Projects whose success is assured.

FIGURE D.7.4.

GOVERNMENT OF MALAWI
UNDP/WORLD BANK
GLOBAL HANDPUMP PROJECT

HANDPUMP DATA FORM HDF 1 (INSTALLATION)

Copy 1: field project Copy 2: country HQ Copy 3 UNDP/WB

A. REFERENCE

1 Pump Code	M-8
2 Waterpoint code	GP 62
3 Installation foreman	D.S. NTHARA
4 Recorded by	SAN SHWE AUNG
5 Checked by	

B. LOCATION

1 Country	MALAWI
2 Project	UPPER LIVULEZI
3 District	NTCHEU
4 Village name	M'MANJA
5 Map sheet & grid ref.	XU 768 793

C. WATERPOINT

1 Well type (tick) a) drilled	✓	b) dug	
2 Construction dates a) from	26-4-82	b) to	29-4-82
3 a) Diameter (give units)	200 mm	b) depth	26.38 m
4 Static water level a) below ground	10.25 m	b) date	29-4-82

5 Rock type: Brownish to pale white weathered rock

	diameter (mm) v) inter	w) exter	setting x) from (m)	y) to (m)	z) material
6 Plain lining a)	98.5	110	0	13.58	PVC
b)					
7 Slotted lining a)	98.5	110	13.58	25.38	PVC
b)					

8 Slotted lining a) slot size	0.75 mm	b) open area	9 %
9 Gravel pack a) d_{50}	1.50 mm	b) volume	2.3 m^3
10 Development a) method	OVER PUMPING	b) duration	0.75 hrs
c) sand free discharge (tick)		Yes ✓	No
11 Pump test a) duration	4 hrs	b) yield	1.0 l/sec
c) final pumping water level (below ground)			14.62 m
12 Water quality a) conductivity	μS	b) pH	

D. PUMP

1 Pumphead a) manufacturer	LMD	b) model	MALDEV
2 Installation a) date	17.5.82	b) time taken	2.0 hrs
c) ease (tick) easy	✓ average		difficult

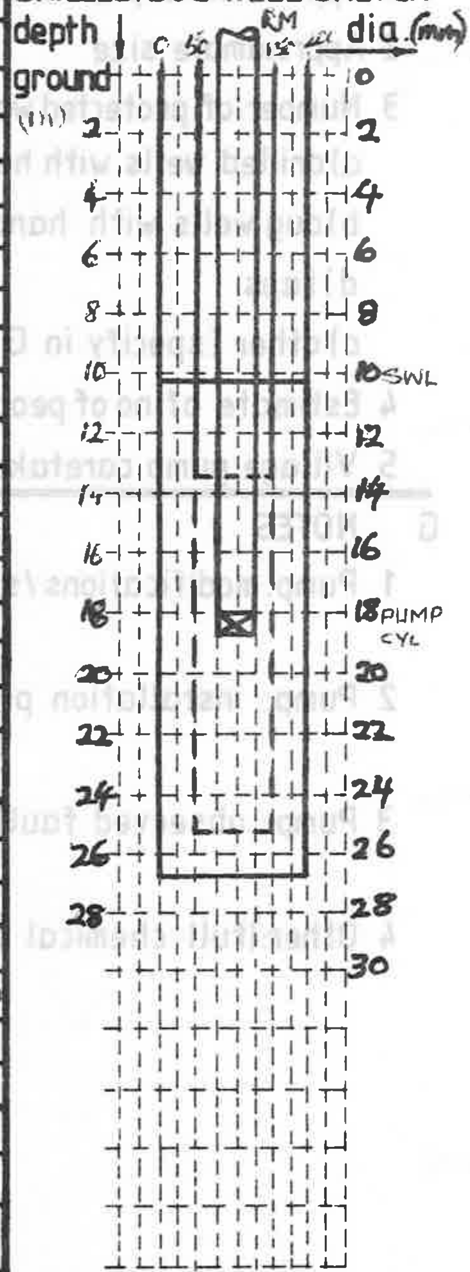
	v) material	diameter (mm) v) inter	w) exter	y) unit length (m)	z) no. of lengths
3 Rising main	GI	54	60	3	6
4 Rods	STEEL		16	3	6
5 Cylinder	BRASS	75	82	0.6	

6 Geometry a) max. stroke 190 mm b) max swept vol 0.84 l

7 'Performance' (no. of full strokes to give 20 l at 30 strokes/min)
a) 'theoretical' 23.81 b) 'actual' 30 c) efficiency a/b 79 %

8 Handle Mechanical Advantage – 5:1
9 Seal Material – Leather

DRILLED/DUG WELL SKETCH



mark a) depth (vertical) scale
b) diameter (horizontal) scale
c) hole depth and diameter
d) lining depth and diameter
e) location of plain & slotted lining
f) rising main depth and diameter
g) rods
h) cylinder location
i) static water level (swl)

REF	B1 MAL	/ HDF 1 /	A1 M-8

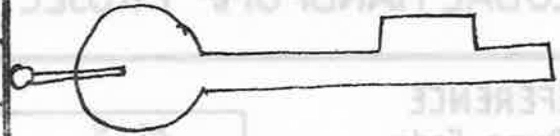
HDF 1 (reverse)

SAMPLE ONLY

E PUMP SURROUND

1 Apron (tick)	Yes	✓	No	
2 Washing slab (tick)	Yes	✓	No	
3 Soakaway pit a)(tick)	Yes		No	✓
b) if no describe drainage	to lower ground			
4 Construction by (tick) Agency		community		
mixture	✓			

APRON SKETCH mark: approx. scale



F VILLAGE

1 Approximate population	660	
2 Approximate size	1 km x 0.2 km	
3 Number of protected water points	existing	planned
a) drilled wells with handpumps	3	
b) dug wells with handpumps	+	
d) taps	–	
c) other (specify in G 4)	–	
4 Estimate of no of people using pump		220
5 Village pump caretaker (s) (tick)	Yes ✓	No

VILLAGE SKETCH mark: approx. scale

o dug well × drilled well

G NOTES

1 Pump: modifications / special features

NONE

2 Pump: installation problems

NONE

3 Pump: observed faults

NONE

4 Other: (full chemical analysis etc)

NONE

REF	MAL	/ HDF 1 /	M-16

GOVERNMENT OF MALAWI
UNDP/WORLD BANK

GLOBAL HANDPUMP PROJECT

HANDPUMP DATA FORM HDF 2 (MONITORING)

Copy 1: field project Copy 2: UNDP/WB

A. REFERENCE 1 Country	MALAWI	3 Pump code	M-8	5 Pump model	MALDEV	7 "Theoretical Performance"	23.21
2 Project	UPPER LIVULEZI	4 Water point code	GR 62	6 Pump install. date	17-5-82	(see HDF 1,D7a)	

B. MONITORING – Record all visits to pump (routine checking, preventive maintenance, minor repair, breakdown repair)

	a) date	b) static water level (m)	c) well depth (m)	d) monitor reading	e) "performance check" +	f) efficiency [% A7/Be]	condition of g) pump	condition of h) surround	i) preventive maintenance	j) repair (details on HDF 3)	k) cause (details on HDF 3)	l) user comments	m) observer
1	Installation	10.25	26.38		30	79%	good	good				Happy with pump	DSN
2	17-9-82				30	79%	"	"				"	SSA
3	26-10-82				30	79%	"	"				"	SSA
4													
5													
6													
7													
8													
9													
10													
11													
12													
13													
14													
16													
17													

+ number of full strokes to give 20l at 30 strokes per minute

REF A1 MAL / HDF 2 / A3 M-8

GOVERNMENT OF MALAWI
UNDP/WORLD BANK
GLOBAL HANDPUMP PROJECT

HANDPUMP DATA FORM HDF 3 (BREAKDOWN / REPAIR)

Copy 1. field project Copy 2 UNDP/WB

[SAMPLE ONLY]

A REFERENCE

1 Country	MALAWI	4 Repair code	R4	7 Pump installation date	13-4-80
2 Project	UPPER LIVULEZI	5 Pump code	X8	8 Original static w. level	11·2 m
3 Pump model	?pump	6 Waterpoint code	GP 74	9 Original well depth	23·6 m

B BREAKDOWN / REPAIR

1 Dates a) breakdown occurred: 16-8-82 c) breakdown inspected: 18-8-82
b) breakdown reported: 17-8-82 d) repair completed: 18-8-82

2 Breakdown reported a) by whom: Village headman b) to whom: Project Officer

3 Breakdown cause: Broken thread of no 7 rising main

4 Parts repaired: None

5 Parts replaced: Replace one new no 7 rising main

6 Tools used: 25mm pipe wrench, 17, 19, 14mm open end and ring spanners, pipe clamp

7 Time taken to carry out actual repairs: 2½ ~~days~~ / hours (delete)

8 Subjective ease of repair (tick) easy [ ] average [✓] difficult [ ]

9 Repair carried out by: J.S. Nthara and crew

10 Assistance from village caretaker(s) (tick) Yes [ ] No [✓]

11 Do you think trained village caretaker(s) could have carried out repair Yes [ ] No [✓]

12 Dug / Drilled well a) static water level: 11·6 m b) depth: 23·5 m

13 Notes (problems, difficulties, observations)

NONE

14 If component(s) corroded, damaged or broken describe in detail and sketch (or photograph) if possible

See B3

15 Recorded by: San Shwe Aung

	A1		A5		A4
REF	MAL	/ HDF 3/	X8	/	R4

7.10. PROCEDURE FOR HANDPUMP INSTALLATION

7.10.1. *The Malawi Pump (deep) installed in a borehole*

On completion of the borehole the drilling team will have covered it with a temporary cap. The next step in the construction process is the installation of the handpump which is followed by the final step of construction of the apron. The procedural steps for hand-pump installation (with conventional steel rods and rising main and brass cylinder) are as follows: (fresh procedures will be given as new down-hole components are developed)

a) Prior to installation of the handpump the construction materials that are required for pump installation and apron construction and which are to be collected by the community should be assembled at the borehole. A full list of materials is given in Section 8.3.5; of this, 12 buckets (assuming 20 litre buckets) of crushed stone, 6 buckets of clean sand, and water as necessary are required for the pump pedestal plinth.

b) The pump installation team together with the supervisor inspect the area round the borehole and determine the orientation of the pump pedestal so that the drain pipe is directed down hill (preferably towards land that is suitable for a small garden which can use the waste water).

c) The pump pedestal can then be installed. A 1 m x 1 m x 0.3 m pit with the borehole casing at the centre is dug. Concrete (1:2:4 mix) using 3 buckets of cement (approximately 2 bags) 6 buckets of sand and 12 of stone is mixed. Concrete is placed in the annulus around the borehole casing (a clay seal should should come to 1 m below ground level) to a depth of 50 mm in the pit. The pedestal is then slipped over the protruding borehole casing to stand upright in the pit. It is essential that the pedestal is centred (by eye) over the casing, that the pedestal flange plate is horizontal (checked with a level) and that a short edge of the pedestal flange faces in the direction selected for the pump discharge outlet. The remainder of the concrete can be poured to the line on the pedestal around the top of the four sprag plate gussets. The top surface of the concrete should be sloped down to ground level to provide drainage away from the pump. A cover plate is bolted onto the pedestal which is then left for a week for the concrete to cure.

The newly-formed pump committee should ensure that the plinth is watered daily during this period.

d) The pump supervisor should now design the depth setting of the pump cylinder. The test pump yield in l/sec (Q), rest water level in metres (RWL) and final drawdown in metres (S) (which is the difference between the rest water level and the pumping water level (PWL) at the end of the test) must be obtained from the drilling supervisor. The estimated "hand-pumping water level", assuming a continuous pumping rate of 0.25 l/sec and also assuming that the test pump drawdown comprises laminar head losses only, is estimated using the following formula:

$$HPWL = \frac{S}{4Q} + RWL$$

HPWL is the estimated maximum depth to water in the borehole during normal pumping. The pump cylinder intake should be set at least 5 m below but not more than 10 m below the HPWL, with the proviso that the cylinder intake must always be at least 1 m above the bottom of the borehole.

e) Having determined the cylinder setting, an appropriate number of lengths of rods and rising main, together with a cylinder, rising main adaptor plate and gasket, pump top-head and 3 m extension pipe can be drawn from the stores. The pump handle can also be selected as follows:

for HPWL < 10 m	the A type (5:1) handle
for 10 m < HPWL < 20 m	the B type (6.1) handle
for HPWL > 20 m	the C type (7.1) handle

All materials are transported to the site for installation seven days after the pump pedestal has been installed.

f) The pump cylinder should be stripped and cleaned and cup leathers checked. The cylinder is then re-assembled and is carefully installed into the borehole along with the appropriate length of rods and rising main (one length of the latter may have to be cut and rethreaded if necessary). The last length of rising main is screwed into the adaptor plate which is then centred over the bolt holes on the pedestal flange. The top pump rods (with the plunger resting on the bottom of the cylinder) is then cut level with the top of the adaptor plate socket and re-threaded with an appropriate die.

g) The rod hanger assembly is attached to the protruding rod by a socket. The pumphead is then bolted onto the pedestal with a rubber gasket in place [refer to Figure D.7.2, WRB/3L]. The handle can then be inserted into the pumphead and the axle bolt pushed (not hammered) through the flange plate bushes and handle bearings. The axle nut should be fitted as tightly as possible with the universal spanners.

h) The rod hanger is then lifted through the arms of the "tuning fork" handle, turned through 90°, dropped into the slots in the forks and locked in place by tightening the hanger nuts. The cover plate can then be bolted in place.

j) The extension pipe is then fitted, with a bend to deflect the discharge whilst apron construction is taking place, and the extension pipe pillar is temporarily installed as a support.

k) The pump is then operated to check correct installation and can then be used. It is essential that the apron team are ready to follow up with apron construction as soon as possible.

7.10.2. *The Mark V Malawi Pump (shallow) installed in a dug well*

As with the borehole, the dug well is capped by the construction crew after construction is completed. Pump installation should be carried out as soon as possible after apron construction materials have been collected by the community. After a site inspection to determine the location of the apron (to drain into a garden if possible) the pump is installed as follows:

a) Measure depth of well from surface of slab and subtract 0.25 m. Cut the 63 mm pump pipe at this length. File the edges of the cut smooth.

b) Clean the inside of the pump pipe with a wet cloth and plenty of water. The pump rod can be used to push the cloth through the pump pipe. Next dry the inside of the head and clean it with cleaning fluid.

c) Solvent cement the footvalve in the head of the pump pipe flush with the pipe end.

d) Solvent cement other end of rising main to 63 mm PVC collar in the pump adapter union.

e) Solvent cement plunger to pumprod.

f) Lay pumphead and pump pipe in line on the ground. Lay pumprod next to pump pipe so that the plunger is 10 cm above the footvalve. Screw the handle from the pumphead and position it next to the pumphead so that it is at the end of the down stroke. Cut the PVC pump rod at the place where the bolt is welded to the handle. Check if the PVC pump rod slides over the piece of PVC which is bolted to the handle. If not, heat the PVC rod and make a push fit.

g) Solvent cement 25 mm pump rod to handle making sure it is through the pump body.

h) Screw the pump base adaptor union into the 80 mm socket cast into the slab. Lower the rising main through the adaptor union.

j) Lower the pump rod and screw the body into the 50 mm socket of the adaptor union, not forgetting sealing ring of adaptor union. Tighten with pipe wrnech so that handle bars are perpendicular to pump outlet.

k) Check whether direction of the Tee is in line with the pillar. If not tighten the joints, but do not use excessive force on the adaptor union. Preferably use chainwrench on the pump base which screws into the 80 mm socket.

l) Check the operation of the pump carefully after waiting at least 15 minutes since the last solvent cement joint. The pump should not be used for another two hours.

Pump parts required:

Pumphead (includes handle) + sealing ring
3 m long outlet
Plunger and footvalve
25 mm PVC pipe class 16
63 mm PVC pipe class 10
3" socket cast in concrete slab
Pillar to support pump outlet

Tools and materials required:

Tape measure
Hacksaw
Half round file
Solvent cement
Mutton cloth
Chain wrench of 600 mm pipe wrench (450 mm pipe wrench may do)
350 mm pipe wrench

8. WATERPOINT APRONS

8.1. AIMS

8.1.1. After a waterpoint is constructed there is nothing to see except a pipe protruding from the ground. Despite all the effort that goes into the construction of a well-designed borehole it is the above ground features - the pump and its surround - that are in daily use and view of the village community. The pump, discussed in the Section 7, actually delivers the water to ground level, and without any surround but a pump plinth (as is the case in most of the old boreholes in Malawi) the vicinity soon becomes a muddy, unhealthy place which is unpleasant to visit and certainly no place to spend longer than necessary. The banks of the river are probably still a more pleasant place to go to wash children and clothes, despite the extra distance to walk.

8.1.2. Standing water around a pump will result in mosquito breeding, attract flies and animals and be a potential. health hazard, to some extent negating many of the benefits that the improved water supply should provide. Furthermore the risk of standing water getting back into the borehole or well, particularly if the pump plinth is cracked, and thus polluting the water at source, is greatly enhanced. So it is important to minimise standing water to eliminate the health hazard.

8.1.3. A borehole fitted with a handpump is generally capable of providing as much water as people can pump. It is therefore beneficial that as many water-using activities as possible are encouraged close to the waterpoint, particularly those that are associated with personal hygiene and general cleanliness. An important example is the wahsing of clothes, an activity that is traditionally carried out by a river or open well, using flat stones for pounding. Washing clothes is also commonly a social activity, when women gather and talk as they work. Provision for washing clothes at the water-point will provide a major social amenity where women will gather, and will probably result in more regular washing with all the associated health benefits of improved personal cleanliness.

8.1.4. However, funds are not unlimited and the cost of a waterpoint surround must be carefully controlled, so that maximum benefit is obtained for minimum cost. A poor example is the elaborate waterpoint surrounds constructed in the Lower Shire by Ngabu Agricultural Development Division during 1979 - 1981 at a cost of over K500 each. Our target should be nearer to a tenth of this figure.

8.1.5. In conclusion, our aims are:

a) To keep water away from the pump pedestal to avoid erosion and eventual cracking of the pedestal plinth and hence entry of polluted water into the borehole or well.

b) To provide clothes washing facilities.

c) To provide good drainage away from the waterpoint.

d) To provide a practical and utilitarian but nevertheless attractive amenity within the village where people (particularly women) will meet.

e) To provide a major opportunity for community involvement in construction, by both the supply of building materials (bricks, stones, sand and water) and voluntary labour.

8.2. <u>SOLUTIONS</u>

8.2.1. In order to avoid ingress of dirty water directly into the borehole in the vicinity of the pumphead, the pump is split into a top-head and a pedestal and the latter is concreted permanently into a plinth over the borehole (this is the same principle as that of the India Mark II handpump over 100,000 of which have already been installed).

8.2.2. A further way of keeping water away from the pump plinth is to use a 3 m extension pipe to take the water from the pump outlet to a completely separate apron. Even though this pipe is expensive, after much consideration it has been included in the standard apron design.

8.2.3. A washing slab is incorporated into the standard design. Again the inclusion of this has been the cause of much debate. Many have argued that it will not be used or that if used the waterpoint surrounds will deteriorate very quickly. Experience in the Livulezi Project has shown the opposite, the washing slab is used and in most villages is chosen in preference to washing clothes in the river. It has become clear that the cost of the slab is far outweighed by the benefits it offers.

8.2.4. Good drainage away from the waterpoint has posed problems. During the technical feasibility phase of the Livulezi Project 2 m x 2 m x 2 m soakaway pits were dug for all 34 waterpoints. It was estimated that up to 3,000 litres per day were discharged into each pit and within one or two months the pits were totally blocked, overflowing and unhealthy, due to the very impermeable nature of the clay saprolite. No alternative solution to the problem of drainage could be found except either to dig a very long channel or to spread water on land to maximise evaporation. This latter option obviously led to the conclusion that the most satisfactory solution would be to encourage villagers to channel all waste water straight into a small garden at the outlet of the drain, thereby solving the water disposal problem and providing some horticultural produce throughout the year. This is further discussed in Section 11.

8.2.5. The design of the apron and washing slab currently used is shown in Figure D.8.1. Early aprons were of the same basic design but did not have a stepped wall, resulting in considerable spillage off the apron itself. Furthermore concrete quality was poor resulting in rapid deterioration within less than a year. It is perhaps important to stress that the apron should be functional but nevertheless attractive to engender pride among its users, and hence ensure proper care and long life.

8.2.6. Apron designs should continue to be improved. Current ideas include the provision of a pillar to facilitate lifting buckets - most women require help to get a bucket of water (weighing up to 30 kg) onto their heads. A further possibility is the provision of a cast basin at one end of the washing slab, with a simple plug, to hold water for clothes washing and rinsing. The use of "sisal-cement" in the washing slab and basin is being considered, to cut down the use of cement. At present seven bags of cement are used

Fig. D. 8.1. TYPICAL HANDPUMP INSTALLATION IN MALAWI

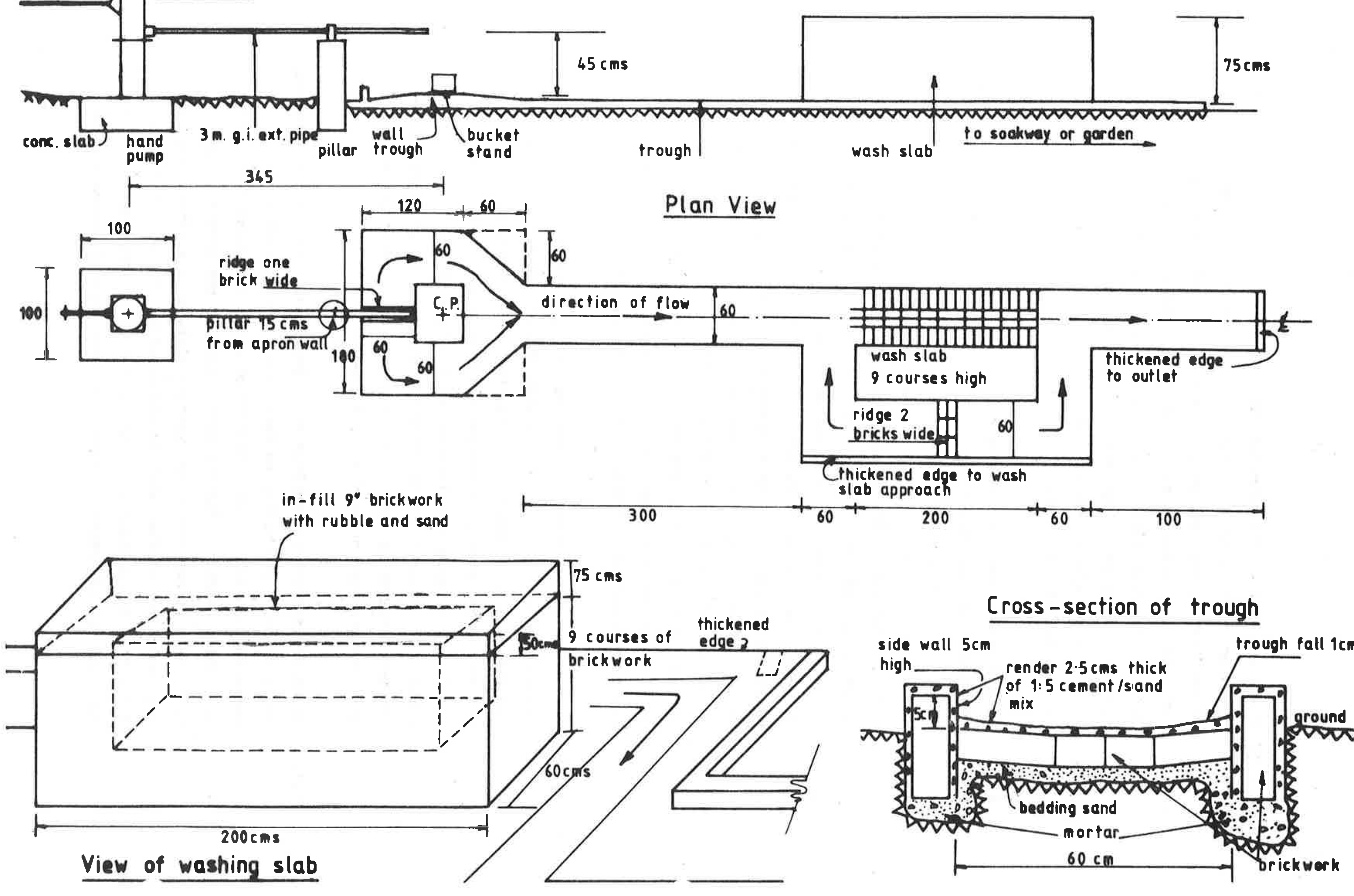
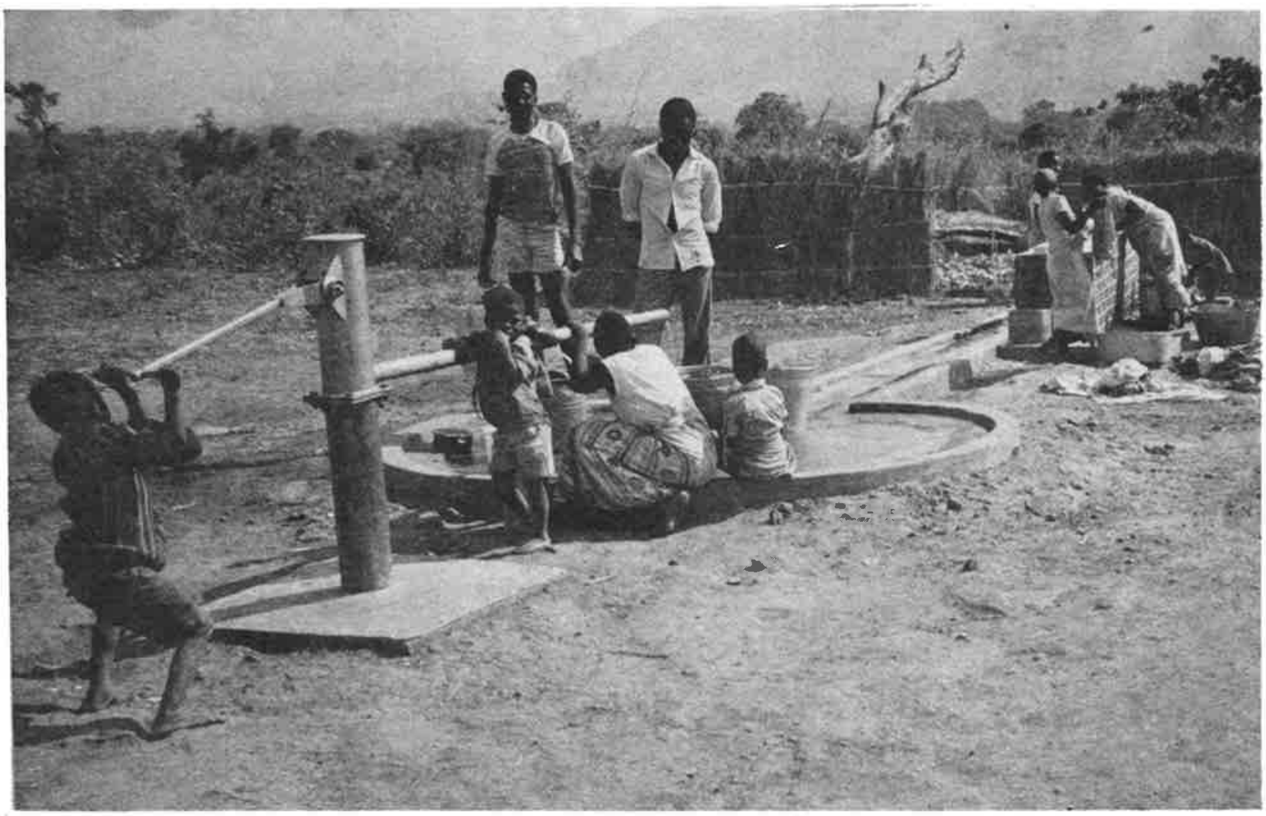
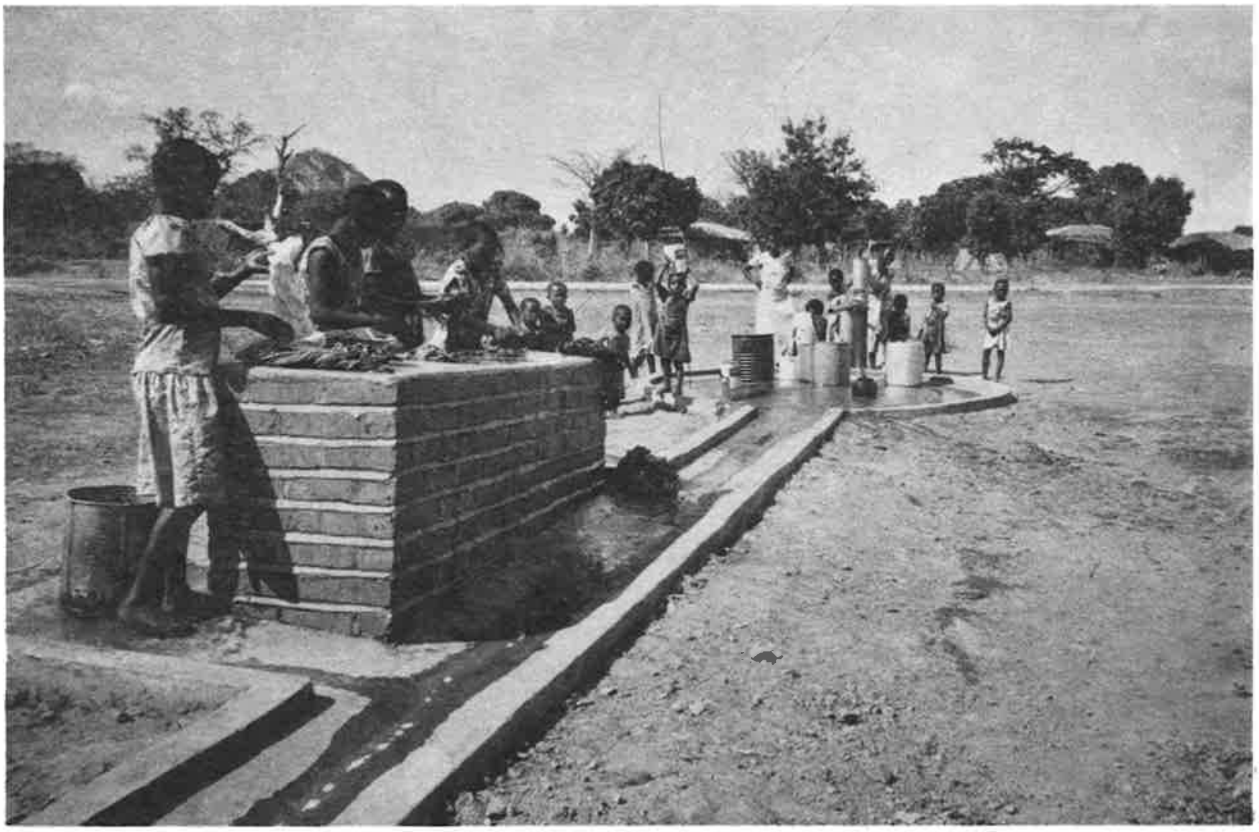


Figure D.8.3

Typical Handpump Installation and Apron, Upper Livulezi Inr[illegible]n Project





in one apron, giving a total cost to the Project of K50.00 including labour. Could a better facility be provided for the same amount of money?

8.3. APRON CONSTRUCTION

8.3.1. In the Upper Livulezi Project it was soon discovered that apron construction lagged far behind waterpoint completion and the quality of completed aprons was poor. Insufficient consideration had been given to the labour and transport requirements of this important aspect of the Project. A careful reappraisal was carried out. Aprons were redesigned, labour requirements established and material needs calculated.

8.3.2. *Design*

The design in current use is shown in Figure D.8.1. It is quite likely that individual builders will develop their own modifications but where possible the approved design should be adhered to, as it allows careful control of cement quantities. Cement is an expensive commodity which is much in demand and can be regarded as a temptation to be dishonest. However, worthwhile modifications should be discussed with Headquarters and incorporated if approved, after assessing any changes in material requirements.

8.3.3. *Labour*

As a rule of thumb, half as many apron teams are needed as waterpoint construction teams. Each building team comprises one Project staff builder and two locally employed builders (paid by the Project on a daily basis) and is supplemented by three to four men from the village. The latter are unpaid helpers and are nominated by the village water committee, as agreed at the Project Preparation meetings. It is very important indeed that these labourers are provided by the village and that they are kept occupied during apron construction(by mixing concrete, for example). The building team should complete an apron in two days. On the first day foundations are laid out and dug, bricks are laid and the washing slab erected. On the second day plastering, pointing and rendering are completed.

8.3.4. *Transport*

The pump installation and apron completion teams share one vehicle (in the Upper Livulezi Project this is a 2½ ton Toyota Dyna pickup). As with the waterpoint construction teams, the apron teams should work as close together as possible, preferably in the same or adjacent villages, to make supervision and material and staff transport easy and economical. As the apron teams are moving every two days, they live at the base camp and are transported to and from the apron site; these trips are also used to deposit cement and building tools. No other trips are made during the day. At night tools and cement are left in the care of the village headman, a village water committee member or other responsible person.

8.3.5. *Materials*

The village water committee will already have been informed of the materials that the village must collect for apron construction [see Section 9]. In summary the requirements are as follows:

a) 1000 fired bricks

b) unbroken stone to fill washing slab

c) 100 buckets of clean (river or washed) sand for concrete

d) 6 buckets of crushed stone for pump pedestal plinth [Section 9]

e) water as required for concrete mixing and curing

f) food for the builders - this is not required but is appreciated!

The project supplies seven bags of cement for the apron and one bag of cement for the pump pedestal plinth, totalling eight bags in all.

8.3.6. *Procedure*

The steps for pump and apron installation are given in Key Page D.8. The sequence is not a simple one as the pump must be installed before the apron and both pump pedestal plinth and apron need seven days to cure prior to use. The Progress Chart [Figure D.8.2] will assist organisation and supervision. The detailed procedure for apron construction is as follows [refer to Apron Design, Figure D.8.1]:

a) Remove 3 m extension pipe and 90° bend and replace extension pipe. Check that pumphead is correctly positioned (discharging downhill)

b) Measure 345 cm from centre of pedestal along centre of extension pipe to establish centre point (CP)

c) Using CP as centre, mark out square with 180 cm sides

d) From lower (trough outlet) corners of this square measure back along two sides towards pump 60 cm and towards trough 60 cm

e) Peg out and lay a trough centre line along line of extension pipe to a point 12 m from pump pedestal centre

f) Remove extension pipe, install 90° bend and replace extension pipe, to deflect discharge during apron construction and curing

g) Mark out troughs and slab about the trough centre line as indicated in Figure D.8.1

h) Lay sidewall bricks on end in 2.5 cm of 1:5 cement/ sand mortar, ensuring falls are correct from ridge to trough outlet (so top edge of brick wall is 5 cm proud of trough edge when latter is laid)

j) Construct apron central stand by laying bricks on sand and making a ridge one brick wide from CP to pump side of apron wall

k) Lay troughs and apron stand as shown in cross-section on Figure D.8.1 with bricks laid on sand

l) Check construction is correct, then rake out joints between bricks free of sand to 2.5 cm deep, work 1:5 cement/sand mortar into joints and render 2.5 cm thick over apron

m) Encase apron edges in mortar 2.5 cm thick

n) Construct washing slab with nine courses of bricks, back filling cavity with stone and sand. Top slab of 1:4 cement/sand concrete decreasing from 7.5 cm thick to 5 cm thick sloping towards the main trough. Point brickwork with weather pointing.

o) Washing slab approach should have no side wall but place bricks on end (ie long axis vertical to produce 2.15 mm wall, partially buried) flush with washing slab trough side to strengthen approach and

Figure D.8.2. <u>Progress Chart for Waterpoint Completion</u>

PROJECT :

Enter dates. Attempt to conclude STEPS 1 - 9 in one month

Borehole/ Dug well number	STEP 1 *Construction Team* drilling/digging		STEP 2 *Village Team* materials collected	STEP 3 *Pump Team* Bh pump pedestal in	STEP 5 *Pump Team* Pump installed	STEP 6 *Apron Team* Apron constructed		STEP 8 *Pump Team* Bend Removed	STEP 9 *HQ Staff* Handover
	Start	Finish				Start	Finish		

STEP 4
min. 7 day gap (for boreholes)

STEP 7
min. 7 day gap

protect trough from erosion. Provide ridge 2 bricks wide in centre of washing slab approach trough

p) Bricks on end should be similarly placed at trough outlet to prevent back scour.

q) Nominate and instruct responsible persons through village water committee or pump committee to water apron so that the whole of it is kept thoroughly wet for seven days, to prevent cracking. Rapid deterioration will occur if concrete is allowed to dry out. Covering the apron with grass will help to retard drying out. Thorn branches will keep children and animals away

r) After seven days remove extension pipe and bend and restore extension pipe to discharge over apron centre

s) A pump hand-over ceremony with a short hygiene speech should be held

Note: In general the apron should be kept at ground level, leaving side walls only sufficiently proud to construct troughs to proper levels. This provides a firm foundation, reduces the potential for damage by animals, minimises possible hazard to foot traffic and helps to prevent erosion and scour. Straight lines, correct levels and well finished work produces a neat piece of construction and provides an incentive to proper maintenance. Water draining from the trough outlet should be diverted to a garden [Section 11].

8.3.7. *Tools*

The following list of tools is required for each building team:

a) 3 x buckets

b) 3 x wood floats

c) 3 x trowels

d) 3 x 3 metre steel tapes

e) 3 x shovels

f) 3 x builders brushes

g) 1 x large builders square

h) 1 x small pointing trowel

j) 1 x pointing tool

k) 1 x 2 kg lump hammer

l) 1 x 1 metre spirit level

m) 1 x wheel barrow

n) 1 x pick-axe

o) 1 x concrete mixing tray for use on wet ground

p) 1 x chalk line (string)

q) 20 x steel pegs (or panga, to make bush pegs)

r) 1 x 50 mm pipe wrench (for pump extension pipe)

s) 4 x 1 m x 0.15 m x 12 mm timber shuttering.

Sequence for Waterpoint Completion
(Pump and Apron Installation)

A = steps for boreholes

B = steps for dug wells

Step 1 (AB)	Construction Team	drills/digs and completes borehole/dug well then installs temporary cap and moves
Step 2 (AB)	Village	collects materials for waterpoint apron
Step 3 (A)	Pump Team	installs borehole pump pedestal into plinth and fits cover plate
Step 4 (A)	Village	keeps pedestal plinth wet for 7 days
Step 5 (AB)	Pump Team	installs pumps with 90° bend to deflect 3 m extension pipe
Step 6 (AB)	Apron Team	removes bend and replaces extension pipe to mark out apron, restores bend and constructs apron
Step 7 (AB)	Village	Keeps apron wet for 7 days
Step 8 (AB)	Pump Team	removes bend so extension pipe discharges onto apron
Step 9 (AB)	Village	assumes responsibility for care of surrouds (preferably with handover ceremony and hygiene speech).

Every effort should be made to complete Steps 1 to 9 in one month. A progress chart [see Figure D.8.2] will assist in this.

9. COMMUNITY PARTICIPATION

9.1. AIMS

9.1.1. Each of the preceding Sections has in one way or another emphasised the great importance of community involvement in as many decisions and activities as possible, even when this may reduce the efficiency of the Project. It must always be remembered that the construction phase (perhaps one year) is only the very beginning of the Project. Operation and maintenance will hopefully continue for many years afterwards (perhaps 20 years before major rehabilitation is needed). To date, the borehole programme in Malawi (which serves about a million people) has not, on the whole been successful despite its high capital cost. The maintenance record is not good, and the centralised Government maintenance organisation is large and expensive to operate. Borehole surrounds are very poor (without proper aprons) and many boreholes are badly polluted from water which gets into them from around the pump. The five-fold increase in the size of the programme, which is needed if the people in the rural areas of Malawi are to have reasonable access to water, will only lead to very much greater problems unless considerable improvements can be made. The involvement of the community in the programme has been minimal, if not zero.

9.1.2. The rural piped-water programme in Malawi has a relatively successful record over 15 years and relies considerably on the community for construction, supervision and first-line maintenance. By implication a similar degree of involvement should have similar consequences in the new groundwater programme of Integrated Projects. However, a groundwater programme can never have the degree of community organisation and amount of voluntary physical labour that is involed in the digging of many kilometres of trenches and laying of pipes. It is, however, possibly true that an even greater community commitment to a groundwater supply is necessary because of the substantial burden of handpump maintenance.

9.1.3. The principle then, unproven as yet but implied by success in other rural development activities, is that by allowing people to make their own decisions where possible, by letting them pay in kind at least (for example with bricks) and by their own physical effort, their

commitment to the programme is as assured as it can be. There is thus a much greater feeling of ownership of their borehole or dug well, as a consequence of the volunatry contribution that has been made to its construction. The greater their contribution, the stronger their sense of ownership is likely to be and therefore the stronger their commitment to long-term operation and maintenance. If the technical and managerial aspects of Project implementation are effectively carried out, the community fully involved and the Government extension contribution to maintenance properly organised, the Project has every chance of success. If it still fails, where does the blame lie? Perhaps some people are not ready for their own improved water supplies, which require a high level of social commitment. That is hard to believe, as a better water supply is regarded by everybody as such an improvement in their lives. Perhaps the Project management was not as effective as it should have been. If the Integrated Groundwater Supply Projects do fail, then three quarters of the rural population of Malawi will be without adequate water. It is a big price to pay.

9.2. THE PROJECT AND THE COMMUNITY

9.2.1. The case for involving the community is amply made in the preceding paragraphs. The way in which the community provides its contribution to each of the activities of the Project is described in detail in the relevant Sections of this Chapter and brought together here in Key Page D.9. The following paragraphs summarise some very important points to remember in dealing with the local community. Many of these points arise from the experience gained in the Upper Livulezi and Dowa West Integrated Projects. With community participation, as with all other aspects of the Projects, lessons learnt must be continuously fed back into the planning, preparation, implementation and maintenance of future Integrated Projects.

9.2.2. The Project aims and the Project staff are first introduced to community leaders at the main meetings held in the preparation phase of the Project [Chapter C]. The importance of community involvement for the success of the Project should be emphasised at this stage and the community leaders should be made aware of all the tasks which the villagers will have to carry out [Key Page D.9]. The meeting is

a unique opportunity to stimulate the interest and support of those with considerable authority within the Project area and every effort should be made to ensure a good attendance.

9.2.3. The month of July is best avoided for the main meetings because of the involvement of the community in District and Area Independence Celebrations. Meetings may also be difficult to organise during the wet season because everyone is busy preparing their gardens, planting, weeding and then harvesting. It may be possible to hold meetings on Sundays and the advice of the DC should be taken. A certain amount of flexibility is important when planning Project meetings as other party and development meetings may have to be taken into consideration. It may be a good idea to have an alternative date to offer to the DC and District Party Chairman if it seems that many people may not be able to attend for some reason. The same flexibility will be required when organising meetings at a more local level. Occasions such as funerals are likely to cause sudden postponement of meetings as the whole village and many from the Group village will be involved at very short notice.

9.2.4. The village headmen are responsible for electing the Village Water Committee, under the supervision of Ward Councillors, Group village headmen and Area Party Chairmen. It should be made clear at the main meetings [Chapter C] that a committee comprised of both men and women is preferable so that balanced, unbiased decisions can be made. Where a Village Health Committee has aready been set up it may be desirable to combine the two to emphasise the importance and interrelationship of clean water and health. The majority of tasks performed by the community will be organised through the Village Water Committee; they should be encouraged to prepare rosters so that everyone is involved.

9.2.5. The Project hydrogeologist and his staff should visit each village and hold meetings so that the community are informed of the role of the Water Committee. The Committee itself should be informed of each task to be carried out in plenty of time so that the villagers are well prepared. For example the community will need to be told as soon as possible how many bricks they will need to supply, as it may require one to two months to mould and fire them. The Water Committee will need to be informed several days before a drilling rig comes to

the village so that they can organised the clearing of the site and for women to draw water for the drilling operations. All other tasks requiring community participation will also require a few days notice.

9.2.6. Whenever any meeting is to be held the Ward Councillors and the Area Party Chairman, together with the Group village headman or village headmen (depending on the level of the meeting) should be informed. These people will organise the meeting and should all be present. It is important that the proper village headman (afumu) and not his deputy, the village spokesman (nyakwawa) is approached, at least in the first instance, as this will help to limit any subsequent divisions and disputes in the village concerned.

9.2.7. The way in which the local leaders are approached is very important. They must fully understand why certain tasks should be carried out and exactly what should be done. The Project staff should approach the headman and Water Committee as members of the community themselves, offering to assist rather than ordering tasks to be performed, otherwise there will possibly be feelings of resentment and a lack of motivation. It may take considerable time for the leaders to understand that the Project depends on mutual co-operation. Staff should be patient and careful to ensure that they have the full community support which is a key to success of the Project. If the headman and the Water Committee are convinced of the reasons why they should be helping it will be easy for the community to follow.

9.2.8. For the success of the Project it is very important that the Community accept the Project staff as "fellow citizens". Members of staff should feel that they are full members of the village where the basecamp is situated, and should make an effort to be involved or help wherever a contribution can be made to the life of the village. Involvement with the local community should be encouraged right from the start of the Project and in this way acceptance and understanding by the people can be established. The headman of the village where the basecamp is situated will introduce the Project staff to all the Group village headmen in the Project area who in turn will introduce them to the village headmen in their own respective areas.

9.2.9. The Project hydrogeologist will be able to advise on suitable positions for waterpoints but the choice of site rests with the community. When checking the suitability of the chosen sites [Section 2] it is very important that the village headman (afumu) and the Water Committee are present. This is one of the occasions when the village spokesman (nyakwawa) should not represent the headman otherwise disputes amongst the villagers could arise.

9.2.10. The hydrogeologist must be satisfied that the community have carried out each task asked of them. If there is a lack of co-operation, the village is unable to have any waterpoints as their contribution is essential if the Project is to be able to help them. This is a very unlikely situation as most villagers are quickly aware of the benefits of an improved water supply.

9.2.11. If any village proves to be particularly difficult or unco-operative the best solution may be to take the headman, the Water Committee and some members of the village to another village where work has been successfully completed. They will then be able to discuss the Project and their involvement in it, hopefully be persuaded of the benefits and motivated to take part themselves. The visits to existing Integrated Projects [Chapter C] may help to avoid situations like this from arising.

9.2.12. If any Project equipment or material is stolen (for example diesel has been stolen from a rig fuel tank overnight) the Project staff will have to be very firm with the community so that further thefts are discouraged. The Group village headman, the Councillor and the Area Party Chairman should be informed of any theft and they will take the necessary actions. All activities by the Project staff should cease in the village concerned until the missing item or the thief is found. It is important that every effort is made to resolve the problem and it may be necessary for the Project hydrogeologist to temporarily disable any existing handpumps as a further incentive for the village to find the thief. In this case advance warning of his intended actions should be given. If the missing items are not found the villagers will have to organise amongst themselves to pay for replacements before the Project activities can continue in that village. It will do no harm for the villagers to suffer a little so

that everyone in the neighbourhood realises that anything stolen will not simply be replaced by the Project. If necessary the Police may be asked by the local leaders to investigate the theft. If the thief is found the Area Party Chairman, the Councillor, the Village headman together with the Water Committee should take the offender to the Police rather than to the Project staff although the Project may help by providing transport to the Police Station. It is important that the community feel that the correct legal procedure is being taken. If theft of any pump components or vandalism occurs after waterpoint completion (for example, a discharge extension pipe was stolen in the Upper Livulezi Project) similar steps should be taken to recover/replace the equipment and deal with the offenders. After construction is completed the Project Maintenance Assistant would be responsible for dealing with these situations.

Summary of Community Involvement

A. PREPARATION PHASE

Attend main meetings

Form Water Committees

Choose site

Mould bricks (1,000 + for each apron; 2,000 + in addition for each dug well if appropriate)

Form Pump Committees

Visit existing Integrated Projects

B. WATERPOINT CONSTRUCTION

a) For all waterpoints:

Clear site

Prepare access road

Provide labour to unload materials and equipment from trailer

Provide night watchman for safety of all equipment, tools and rig

Cook for drilling team and well digging team (optional but appreciated)

b) For a dug well:

Dig to water and as far below as possible

Supply bricks (2,000 +) and line well from surface to below water (if appropriate)

Provide labour for digging below water

Crush stones for rings (30 buckets)

Provide gravel or crushed stone for backfill behind rings and on top of bottom slab

c) For a borehole:

Provide water for drilling (keep 500 litre tank full)

Provide labour to collect gravel-pack material from Lakeshore

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KEY PAGE D.9 (Continued)

Summary of Community Involvement

C. APRON CONSTRUCTION

Supply sand (100 buckets) for concrete

Supply crushed stone (6 buckets) for pedestal

Supply bricks (1,000 +)

Supply unbroken stone to fill washing slab

Clear area

Provide labour to help builder

Supply water for builder as required

D. OPERATION AND MAINTENANCE

Channel drain water into garden

Pump Committees to care for pump and surrounds

Supply (Volunteer) Village Caretaker for preventive maintenance

Supply (Volunteer) Group Village Repair Team for pump repairs

Pay for replaceable parts for pump or apron repairs

Ensure no theft or vandalism at waterpoints

10. ACTIVITIES RELATED TO THE INTEGRATED PROJECTS

10.1. AIMS

In most areas of Malawi, waterpoints with handpumps can supply as much water as can be pumped without any danger of depleting replenishable groundwater resources. Other activities using water are encouraged as a further way of increasing the feeling of community ownership of the pump, which becomes a focal point within the villages. Income-generating activities (for example brick making or irrigated gardens) could provide incentive (or even the actual cash) for the villagers to pay for spare parts for the pumps. The simultaneous co-ordination with other rural development programmes (for example demonstrations of low cost sanitation and building techniques) rather than the provision of a safe water supply alone increases the impact on the community and optimises the benefits which can be obtained.

10.2. IRRIGATED GARDENS

10.2.1. The problems of drainage water disposal [Section 8] have led to the idea of establishing irrigated gardens downslope of the drainage channel outlets. The earliest waterpoints put into the Upper Livulezi Project in the feasibility study area all had soakaway pits infilled with stones which were intended to allow rapid disposal of excess water. However the very low permeability of the surface clays together with the infilling of pits with wind and water-borne detritus very quickly resulted in the blocking of soakaways and ponding of water around the waterpoint. This is both unsightly and a potential health hazard since it provides a breeding place for insects.

10.2.2. Spreading the water over the ground surface by a network of channels appears to be the best solution for disposal of excess water thus allowing it to seep into the soil and/or evaporate. It is estimated that each waterpoint may produce up to 3,000 litres waste water per day. The size of the plot required for adequate disposal of this water will vary depending on the soil texture and structure, slope of the ground, topo graphic position, rainy season and dry season

soil moisture conditions and local climate. A dug well is unlikely to be used as much as a borehole therefore it will produce less waste water but soil conditions are likely to be moister in the valley bottom sites. The agricultural extension staff should be consulted for advice on local conditions. A guide to the minimum plot size for adequate drainage is still being formulated. As the waterpoints can generally supply as much water as can be pumped, the plot size can be increased if desired. The garden can then be watered by drainage channels alone or also directly from watering cans/buckets. When a waterpoint is sited the potential garden position should be taken into account and a suitable area allocated. A sisal or thatch fence around the garden will help to prevent animals from trampling or eating the crops.

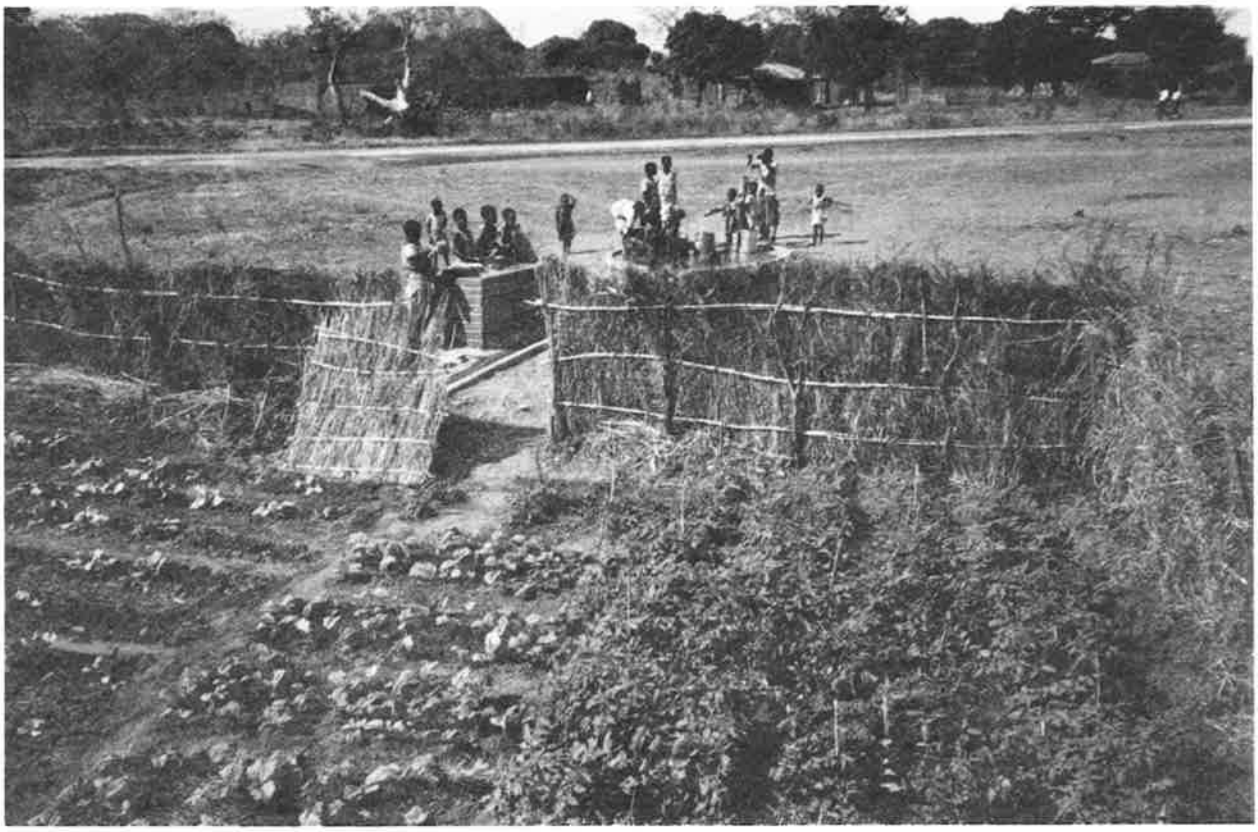
10.2.3. The establishment of small scale horticultural gardens should encourage greater community involvement and allow crops to be produced which otherwise could not be grown. Income from the produce could possibly be used to buy spare parts for the pumps, or at least will provide an incentive for speedy pump repair.

10.2.4. The questions of who cultivates the garden and who has the produce will need to be resolved by each village concerned. This will need to be discussed by the Village Headman and Water Committee. Members of the Pump Committee, or the Village Caretaker [see Chapter E], or members of the Water Committee, or a Farmers' Club might be suitable candidates to have responsibility for the plot. The crops are possibly best consumed locally rather than being taken to markets for sale but this may be a decision for the Headman.

10.2.5. There is much enthusiasm among villagers in the Upper Livulezi Project area who are excited about the prospect of irrigated plots and many gardens have already been started [Figure D.10.1]. However there is a need for agricultural guidance and advice in order that the use of drainage water is most effective and the gardens as productive as possible.

10.2.6. In the first instance the Programme Manager in the appropriate ADD should be approached at Headquarters level to discuss the programme. Support will be required from the agricultural Project Officers at district level and the Development Officers and their field

Figure D.10.1. Model Garden using Drainage Water,
Upper Livulezi Integrated Project Basecamp



assistants; the agricultural staff will need field visits so that they understand the background and aims of the Integrated Project and its associated activities. A garden should be established at the Project basecamp borehole so that it can be a demonstration for community members who visit the basecamp for maintenance training courses. The Project Hydrogeologist and Maintenance Assistant should continue to liaise with the agricultural Project Officer to ensure that the interest of the field extension staff is maintained. It is hoped that they will then be able to encourage the formation of Village Garden Committees and give talks at Farmers' Clubs, so that agricultural and horticultural advice on the most appropriate irrigation practises can be given.

10.2.7. The crops being grown at present in the small irrigated plots near waterpoints in the Upper Livulezi Project are mainly vegetables (cabbages, tomatoes, onions, pumpkins, beans). Horticultural experts advise that citrus trees could quite easily and successfully be grown and might produce more economic returns. The agricultural staff can give the farmers suggestions as to the type of crops which are most tolerant of excess water, but ultimately the choice will be made by the villagers themselves as they may prefer to eat specific fruit and vegetables, regardless of whether a wider variety of crops can be grown. Sugar cane and guavas are examples of easily grown and locally popular crops which prefer moist growing conditions.

10.3. LOW COST HOUSING

10.3.1. The UNDP Rural Low-Cost Housing Project operating within the Department of Community Services, has developed some very low-cost building techniques. These take advantage of locally available materials and use simple but aesthetically pleasing designs to construct buildings which should last for many years. This is a large advance from traditional buildings using sticks, reeds, mud and grass thatch which are easily damaged by tropical rainstorms and need to be renovated after every couple of years.

10.3.2. There are several building designs available at present ranging from a simple house with one room and a kitchen (K.500 for building materials at 1982 prices) to a three bedroomed house complete with

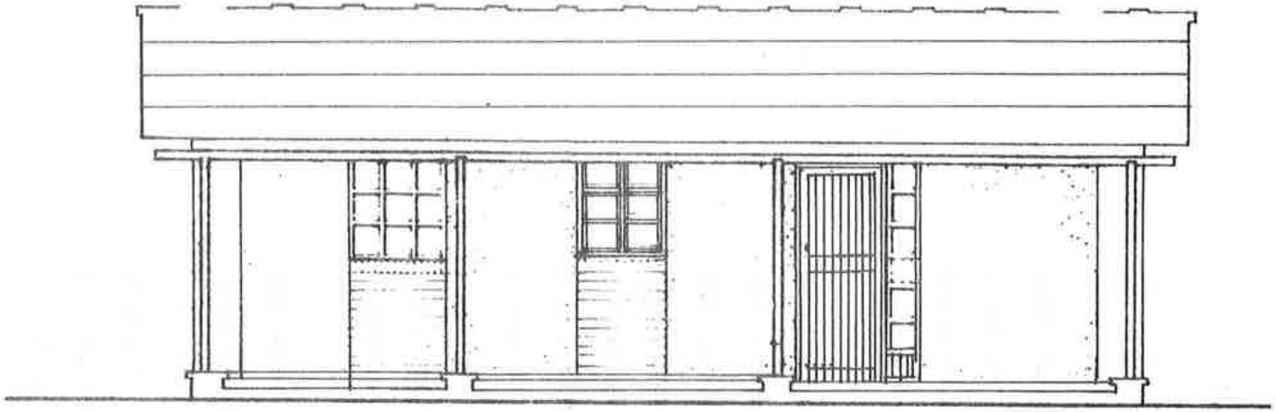
living room, kitchen, bathroom and small storerooms (K1,200 at 1982 prices). The buildings are called "growing houses" as they can be started as one of the smaller units and have further rooms added later.

10.3.3. An important design feature is the water resistant corrugated roofing tiles which are made from sand, cement and chopped sisal. These are laid overlapping each other with wide overhanging eaves supported by upright timbers to form a large verandah on either side of the building. This enables cheaper unfired mudbricks to be used for the two outside walls protected by verandahs, since they are unlikely to get wet during rainfall. During building, lengths of sisal are bedded into a clay mortar so that they protrude from between courses of mudbricks. These help to bind the cement which is applied to the mudbrick walls. Locally fired bricks are used only for the gable walls, foundations, and for the floors. The windows for the bedrooms are made from concrete moulds whilst the living room windows have wooden frames with glass which can be opened. Doors and door frames are wooden. The floors are laid with bricks which may be pointed and varnished or covered with a thin cement screed. The kitchen/bathroom block is separate from the rest of the building in the larger houses.

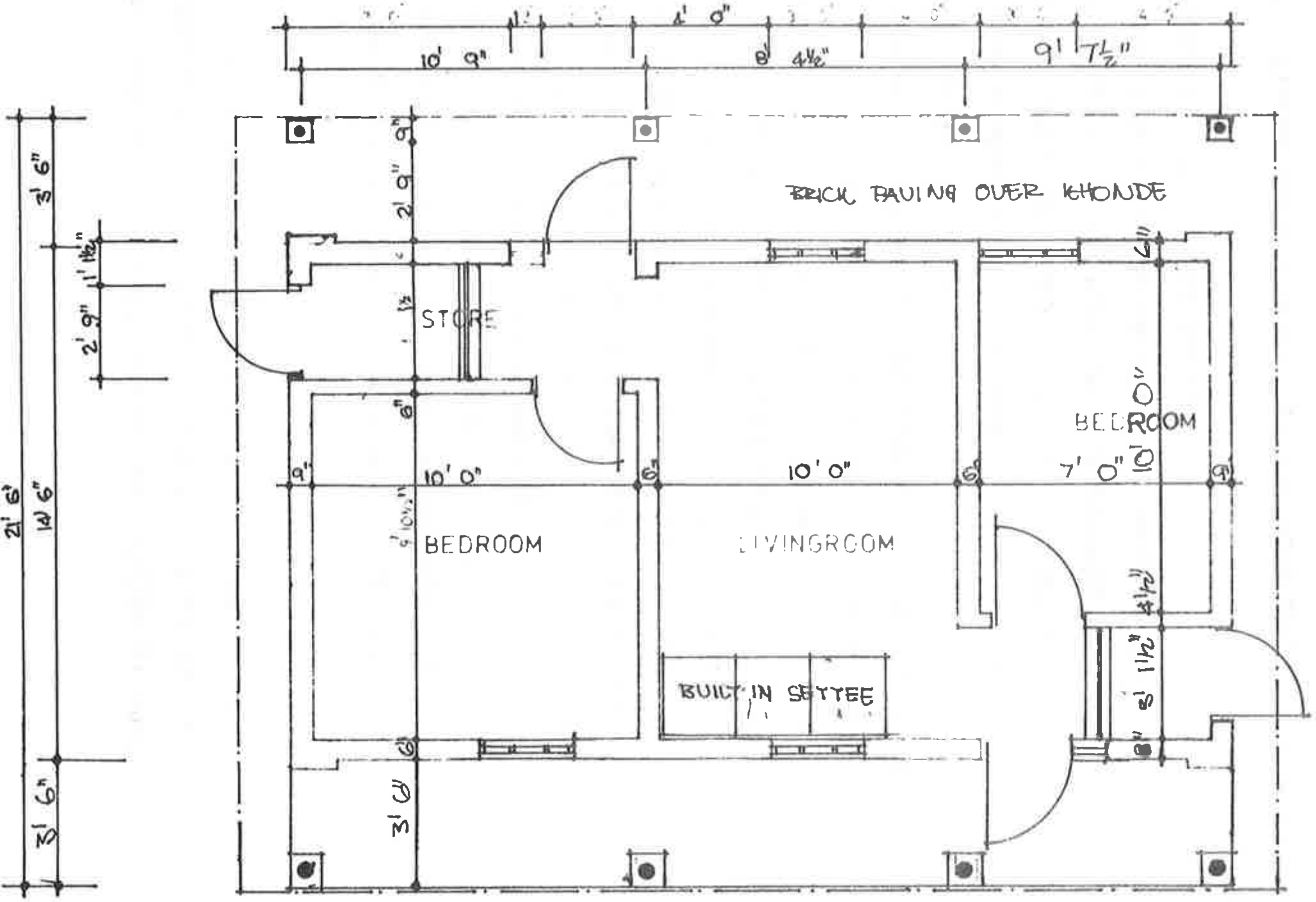
10.3.4. A two-bedroomed house [Figure D.10.2] and store building are being built for each of the Maintenance Assistants in the Upper Livulezi Project, at estimated material costs of K1,000 and K400 respectively. The UNDP Housing Project is providing a foreman with experience of the construction techniques together with a bricklayer, a carpenter and a roofing-sheet maker. Other builders, carpenters and tinsmiths required are being locally employed from villages in the Project area. In this way an appreciation of the low-cost and long-lasting building methods is transferred to the rural population.

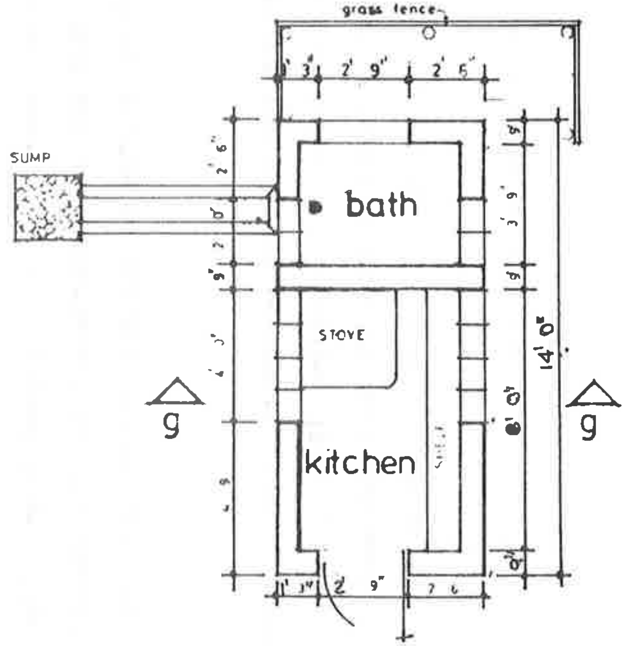
10.3.5. Very low-cost pit latrines are also to be constructed as demonstrations of improved sanitation [see Section 15] and building methods. The UNDP Rural Low-Cost Housing Project has been experimenting with designs; Figure D.10.3 shows the design which is likely to be tried in the Upper Livulezi Project. The bridging of the pit is achieved by constructing a vault of fired bricks with

Figure D.10.2. Plans for Low-cost House



REAR ELEVATION





kitchen - bath
plan

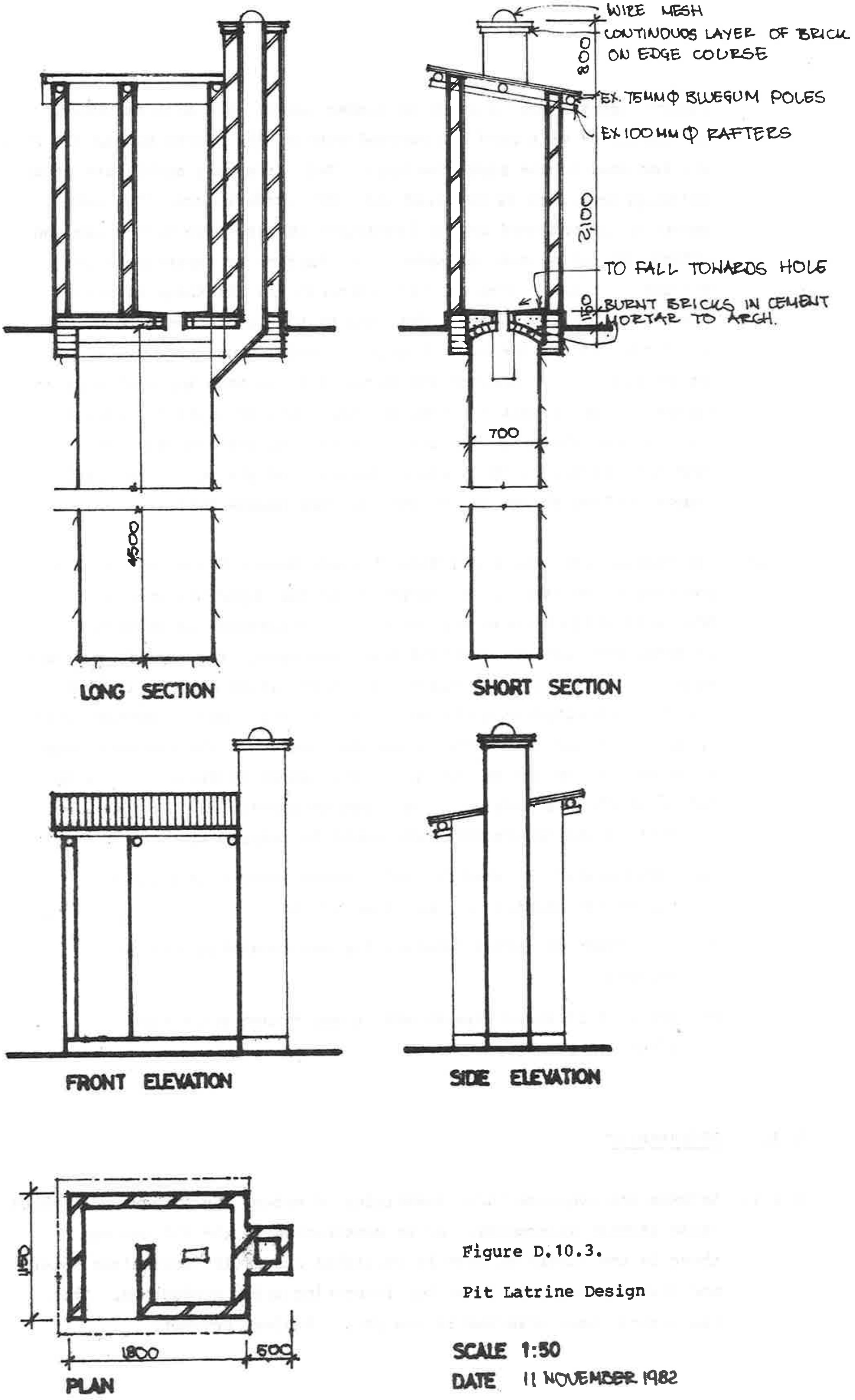


Figure D.10.3.

Pit Latrine Design

cement mortar, over a guide of timber beams. The arch structure is backfilled with sand and covered with a thin cement screed (20 mm), sloping towards the squatting hole. This is a very stable structure although some care is required with its construction. The total amount of cement used on the foundation is less than half a bag and efforts are being made to reduce this further by experiments with the use of sisal cement and reductions in the thickness of screed required. The vent pipe is designed so that above ground level it is to one side of the pit and below ground enters the pit at an angle. Designs may be modified to that the vent pipe is directly over the pit to allow greater entry of light to attract insects from the pit. The latrine walls are constructed from mudbricks covered with cement plaster, and the roof from sisal-cement roofing sheets as for the low-cost houses described above.

10.3.6. The Village Caretakers and Group Village Repair Teams responsible for pump maintenance [see Chapter E] in the Upper Livulezi and Dowa West Project areas will be offered assistance in construction of model pit latrines provided that they supply the locally available materials (fired bricks, mud blocks, sand, sisal etc.). In this way low-cost building techniques and sanitation can be demonstrated in every village within the Integrated Project. The estimated cost of materials for the pit latrine design shown in Figure D.10.3 is K25 of which about K18 would be borne by Government or a donor. The cost to the Government/donor could be reduced if:

a) fired bricks are used for walls which would only require cement for pointing not for plastering

b) the amount of cement required for the foundation can be reduced

c) the roof is thatched, although it would need renovation after every couple of years.

10.4. BRICKMAKING

10.4.1. Brickmaking requires large quantities of water. In Integrated Project areas several waterpoints may be constructed in the Village so there is now plenty of readily available and easily accessible water and thus considerable scope for increasing brick production. This has already been observed in the Upper Livulezi Project.

10.4.2. Brickmaking should be encouraged in as many villages as possible so that longer lasting buildings can be constructed. Traditional building materials - reeds, mud and wood - tend to deteriorate rapidly especially during the rainy season. Mudbricks are an improvement on reeds and mud plaster but fired bricks are better still.

10.4.3. In order to improve the standard of fired bricks which are already being widely produced as a consequence of additional water supplies, it would be desirable for staff from the Ministry of Trade and Industry to be involved. Great benefits could be gained by extension staff educating the villagers in better techniques.

11. VEHICLE OPERATION AND MAINTENANCE

11.1. INTRODUCTION - THE TRANSPORT PROBLEM

11.1.1. It may seem strange that vehicle operation and maintenance should warrant a Section of the Manual to itself. However, even a cursory examination of the costs of both the dispersed programme of borehole construction [Chapter A] and the existing maintenance system [Chapter E] shows the need for an appreciation of the very high cost of <u>any</u> operation that is dependent on a large number of vehicles. Accurate details of the transport components of construction and maintenance are difficult to obtain. It is clear, however that the direct cost of vehicles in terms of:

- fuel
- tyres and batteries
- repairs
- depreciation and capital replacements
- wages

are at least 40% of the total cost of the borehole construction programme and over 50% of the cost of the borehole maintenance programme (with the present structure). The indirect cost in terms of drilling rig time lost because of vehicle breakdown, and the cost to the community when handpumps are not repaired for many weeks (or even months), again because of vehicle breakdown, is impossible to estimate. What is it that makes the cost of the transport component so high?

11.1.2. In the dispersed drilling programme [Chapter A] each rig is operated as an individual unit, often far from headquarters and largely unsupervised. Each rig has its own 7 ton truck to be used (and perhaps misused) at will during construction. The longer construction takes (four to six weeks is not uncommon), the greater distance the truck covers. Four thousand kilometres on one borehole has been recorded; several hundred kilometres on a borehole is common. Because the drillers (TOs) are not allowed to hold funds or Local Purchase Orders (LPOs) they cannot purchase items in the field. Round trips of several hundred kilometres to collect charcoal worth less than K100 are therefore not uncommon. Efforts are being made to improve the operating efficiency of the dispersed drilling programme. However, even with good management and control, the need to move perhaps 200 km between sites (taking one round

trip for the rig and often a second for the casing, tools and crew) means that transport costs are inevitably high. This is reflected in the high invoice charge of K3.50 per kilometre for moving between sites. Thus, the very nature of the dispersed drilling programme means that many vehicles are needed and that their operating costs will be high.

11.1.3. Much the same can be said of the existing maintenance organisation [Chapter E], which also depends on vehicles which are controlled by relatively junior staff far from headquarters. The number of kilometres covered for each handpump repair is very high and there is ample opportunity for vehicle misuse, which is frequently reported.

11.1.4. It is clear, therefore, that any success in reducing the cost and improving the efficiency of vehicle use in the groundwater development programme would have far-reaching consequences. Vehicles are clearly essential to both the construction and the maintenance organisations, but it would be fair to say that they are a necessary evil. As this philosophy has become accepted, albeit very slowly, by the people responsible for vehicle control, so programme costs have been dramatically reduced.

11.2. SOLUTIONS

11.2.1. The Integrated Project philosophy of providing water supplies to all of the people within an area at once,with a number of drilling rigs and dug-well teams kept very close together,allows a very great reduction in the number of vehicles required; it enables them to be more efficiently used and permits very tight control over them. In the first few months of the Upper Livulezi Project, vehicle restraints were perhaps too severe and it was soon found that too few vehicles reduced operational efficiency, although not to the same extent as too many vehicles would increase operational costs.

11.2.2. In the dispersed programme a 7 ton truck is essential for moving the drilling rig the long distances between sites. While it is at each site, however, it is either idle and under-utilised or inefficiently used (and easily misused). Keeping the rigs very

close together (often within walking distance of each other) permits both a dramatic reduction in the rig/vehicle ratio and a change to a more appropriate vehicle. Thus, in the Upper Livulezi Project one tractor is being used to move all four rigs, with a trailer to supply them with casing and gravel pack material, and to move only essential drilling tools between sites. Keeping the rigs so close together also allows the less-frequently used drilling equipment to be kept at the basecamp unless required [Section 3]. At present the well-digging teams also share the use of the tractor and trailer to move them between sites and to transport concrete rings and slabs.

11.2.3. The supervisory staff for borehole and dug-well construction and for pump installation are provided with motorcycles. Management (two or three hydrogeologists) also use motorcycles for many of their routine supervisory and inspection visits. Again, this is greatly facilitated by having the construction teams concentrated close together; organising a programme so that this is the case is a prime objective of management. The capital and operating costs of transport for supervision are therefore very low, again a case of appropriate vehicles for the task [see also Section 14].

11.2.4. The concentrated approach of the Integrated Projects has permitted another significant innovation. As the construction teams work through the Project area they live in small sub-camps. They complete all the waterpoints within a radius of several kilometres from each sub-camp before moving on, rather than moving between each site as in the dispersed borehole and dug-well programme. This produces a considerable time saving and a somewhat more settled and comfortable life for the teams. In addition each team member is assisted by a Government loan to purchase a bicycle for use in the Project and is paid a monthly allowance to use the bicycle for his work. This is not in itself a revolutionary idea; Project Assistants in the piped-water and dug-well programmes have used bicycles for many years. It is, however, an innovation for the drilling teams, and provides a significant cost-saving in transport from sub-camps to sites and gives the team members independent mobility to take part more fully in the life of the community. The success of this venture is seen in the pleasure that owning a bicycle gives to the construction team members.

11.2.5. The pump installation and apron construction teams share a pickup or small truck. This is used for transporting pumps, rising main, rods and cement and for moving the teams from site to site. Project management also has a pickup for use when a motorcycle would not be appropriate, for example when the initial survey is being carried out or local meetings are being organised.

11.2.6. The vehicle requirements for an Integrated Project are summarised in Table D.11.1. The total capital cost of establishing the fleet is about K50,000. Having assembled a fleet of the right number of appropriate vehicles, it is then the task of Project management to ensure that they are efficiently deployed, that their use is tightly controlled [Section 14] and that they are properly maintained.

11.2.7. To ensure smooth operations, reduced vehicle running costs, maximum vehicle life and the minimum loss of construction time due to vehicle breakdown, the routine maintenance and servicing of vehicles (and all plant) should be carried out at the Project headquarters. The first line of regular servicing should be carried out by the drivers, and simple maintenance and repairs by a mechanic at the basecamp who is either resident in the Project or visits regularly.

11.3. PROCEDURE FOR VEHICLE REPORTING AND MAINTENANCE

11.3.1. *A Daily Preventive Maintenance Check* on the vehicle is the responsibility of the driver. The oil, water and fuel levels should be checked.

11.3.2. *A Weekly Inspection* should be carried out by the driver to check:

a) tyre pressures and condition (including spare)

b) all wheel nuts and tighten if necessary

c) there are no oil/fuel leaks

d) condition of windscreen wipers

e) functioning of all lights (including indicators).

Supervisors should ensure that these inspections are carried out properly, regularly and recorded in the log book.

11.3.3. The vehicles should also be checked regularly (ideally twice a month) by a mechanic who should:

a) note any defects

b) carry out repairs where possible

c) advise the Project hydrogeologist if any vehicle is not fit for duty and requires workshop attention

d) carry out servicing as necessary and record servicing dates and mileages.

If vehicles are "off the road" for servicing or repairs, standby vehicles should be identified (beforehand where possible) to ensure minimum disruption of Project activities.
The mechanic should be equipped with the following:

- full tool box
- grease gun
- puncture repair kit
- fuel/oil filters
- air filters
- supplies of oils and lubricants
- tow rope
- check lists for inspections.

If service spares are kept in the Project store these should be recorded, issued and restocked as described in Section 12.

11.3.4. *The vehicle logbook* must be completed by the driver for each journey, recording mileage, fuel/oil used, destination and reason for journey and each journey must be authorised by a supervisor. Supervisors should carry out a weekly inspection of all the vehicle log books so that tight control can be kept on journeys undertaken, mileages and fuel consumption.

11.3.5. A very major cost in the Integrated Project is that of transporting materials from Lilongwe to the basecamp. This expenditure must be clearly recorded by the storeman in the Visiting Vehicle Notebook [see Section 13]. This component of Project overheads costs is often very considerable and requires tight management control. Management at both Lilongwe Headquarters and in the Project should ensure that large capacity trucks (10 to 12 tons) are used whenever

possible for delivery journeys and that they are always fully loaded. This point is well illustrated in the example of Project costs given in Section 13.

Table D.11.1

Vehicle Requirements for an Integrated Project

ACTIVITY	VEHICLE TYPE	APPROXIMATE CAPITAL COSTS (K)		OPERATING COSTS (tambala/ km)
		UNIT	TOTAL	
Management	1 Pickup	7,000	7,000	40
Management	2/3 motorcycles	1,000	2/3,000	10
Supervision	4 motorcycles	1,000	4,000	10
Construction	2 Tractor and Trailers 1 unit for each 4 construction teams	15,000	30,000 (probably)	40
Pump Installation Apron Construction	1 pickup or small truck	8,000	8,000	40
Delivery of materials Gravel Collection	Headquarters-based 10 - 12 ton truck	30,000	30,000	90

12. STORES

12.1. AIMS

During the construction phase of an Integrated Project the drilling crews and the wells teams need a constant supply of materials. The ordering, storing and issuing of materials are vital functions in the day-to-day running of the Project. The stores organisation has three principal tasks:

a) To ensure that materials are always available as and when needed in order to prevent costly delays in construction work. This means keeping a close eye on the level of stocks of all construction materials, and ordering new supplies of materials in good time.

b) To prevent the misuse or theft of materials. Only authorised persons are allowed to request and receive materials from the stores, and these persons are accountable for the use of those materials.

c) To provide information about materials used. This information is required for use in project management and costing.

12.2. SOLUTIONS

A camp store is set up, comprising a number of sheds and bays, with a resident storeman. All materials are delivered to and issued from the stores. The storeman keeps a simple stores ledger, with a card for each item to record all receipts and issues for that item. At the end of each month he prepares a stocksheet which summarises the receipts and issues for all items during the month. The balance of materials remaining at the end of the month according to the stores ledger is checked by a physical count of the stocks in the store. Any discrepancies are noted, investigated, and if necessary acted upon. The record of materials issued is also used in project costing.

12.3. STOREKEEPING

12.3.1. This involves keeping records of all receipts and issues of materials and monitoring the level of materials stocks. The principal instrument of storekeeping is the stores ledger. This ledger has a sheet for each different item in the stores, one for cement, one for petrol, one for PVC pipes of a certain size and so on [see Figure D.12.1]. Each receipt or issue is recorded on the appropriate sheet. The storeman notes the date, the quantity of the material issued or received, and who delivered the material or to whom it was issued. In the case of issues, the member of project staff to whom the material is issued signs for the material. The storeman is told by the Project manager which staff members are authorised to request materials. With each entry in the stores ledger the storeman keeps a running balance of the level of stocks. A receipt of materials is added on to the previous balance, and an issue is subtracted. In this way the storeman can see at a glance how much of each item he has in stock. This enables him to alert the Project manager in good time to the need to reorder materials. When a sheet is full, the balance is carried forward to a new sheet. A simple check can be made to ensure that the balance is correct before carrying it forward: the balance at the end of the sheet should be equal to the balance at the beginning of the sheet plus the sum of the receipts on the sheet minus the sum of the issues on the sheet.

12.3.2. *Monthly returns*

The storeman prepares two reports at the end of each month. The first summarises the stock balance over the month and the second analyses the issues of materials.

a) *Stock balance* - a sheet is drawn up [see Figure D.12.2] listing all the different items, and showing for each item the total receipts and issues during the month, together with the balance at the beginning of the month (the "opening balance") and at the end of the month (the "closing balance"). For each item the following stock balance equation should be fulfilled:

Opening balance + Total Receipts - Total Issues = Closing balance

The closing balance is then checked against the amount of each item actually in stock, and any discrepancies are noted, reported to the Project manager and investigated. In this way a close

check can be kept on losses from the store.

b) *Analysis of materials issued* - Again a list of all the materials is drawn up, with a column showing the total issues for each item during the month. The total is then broken down to show issues to "Project basecamp" "transport", "drilling rigs"," dug-well teams" etc. [see Figure D.12.3.]. This analysis not only provides information directly for the cost monitoring exercise but it also provides a check on other sources of information, for instance the records of materials used in the construction of boreholes by each crew.

Figure D.12.1

LEDGER

ITEM: Charcoal

UNITS: Bag

REORDER LEVEL: 15 Sheet Number 11

DATE	Received from or issued to	Signature:	RECEIPTS	ISSUES	BALANCE
1/5/82	Balance brought forward				52
3/5	To Rig 2406	[illegible]		2	50
"	To Rig 2408	[illegible]		2	48
"	To Rig 2221	[illegible]		3	45
5/5	Delivered from Lilongwe		12		57
10/5	To Rig 365E	[illegible]		3	54
12/5	To Rig 2406	[illegible]		3	51
13/5	To Rig 2221	[illegible]		3	48
18/5	To Rig 2408	[illegible]		2	46
19/5	To Rig 2406	[illegible]		3	43
24/5	To Rig 2408	[illegible]		4	39
28/5	To Rig 2408	[illegible]		3	36
	May Totals		12	28	
	Balance carried forward				36

Figure D.12.2.

MONTHLY STOCK SHEET

MONTH: MAY '82

ITEM	UNIT	OPENING BALANCE	RECEIPTS	ISSUES	CLOSING BALANCE	REMARKS
Cement	bag	36	52	71	17	
Charcoal	bag	52	12	28	36	
Petrol	ltr	562	624	753	433	
PVC 110mm slotted	m	108	54	81	81	
PVC 110mm plain	m	153	72	102	123	

Figure D.12.3

MONTHLY ANALYSIS OF MATERIALS ISSUED

MONTH: MAY '82

ITEM	UNIT	TOTAL ISSUED	TO PROJECT CAMP	TO PROJECT TRANSPORT	TO RIGS				TO WELLS TEAMS			
					A	B	C	D	I	II	III	IV
Cement	bag	71	22		22	13	14					
Charcoal	bag	28			8	11	6	3				
Petrol	ltr	753		673					40	40		
PVC 110mm Slotted	m	81			9	24	15	33				
PVC 110mm Plain	m	102			9	54	12	27				

13. COST MONITORING, ANALYSIS AND CONTROL

13.1. AIMS

13.1.1. The importance of preparing budgets and of finding funds has already been discussed in the project planning phase [Chapter B]. The necessary counterpart to the activity in the project implementation phase is the monitoring of costs. It is important for project managers and others to monitor and control how much is being spent on what, in the course of implementing the project. Three reasons for this concern are:

a) to see whether or not budget targets are being met, which indicates whether or not the work can be done with the available funds

b) to identify areas of significant cost so as to concentrate cost-reducing efforts on those areas

c) to provide valuable information for future project planning and budgeting

13.1.2. The costs of the Project may be divided into two categories, "direct costs" and "indirect costs":

a) *Direct costs* are those which can be attributed to a particular waterpoint. These include, for example, the cost of labour and the cost of materials used in the construction of the particular waterpoint.

b) *Indirect costs* are those which cannot be directly attributed to particular waterpoints. They include, for example, the cost of Project transport and the cost of Project supervisory staff.

13.1.3. The total cost of the Project is the sum of all the direct and indirect costs. However, for reasons which will be listed below, we are concerned not only with total Project cost but also with the cost of each individual waterpoint. What we require, in fact, is an estimate of the "full cost" of each borehole and of each dug well. The full cost includes both the direct costs attributed to a particular waterpoint and a share of the total indirect costs. All the indirect costs are shared out among, or

"absorbed" by, all the waterpoints. In this way the total Project cost is broken down into the full costs of all the individual waterpoints.

13.1.4. Why is such a breakdown required? Why not just monitor the total Project costs? Three principal reasons are as follows:

a) Since the funds for the Project are acquired by submitting an invoice to the client/donor in respect of each waterpoint, it is important to know whether or not the value of the invoice will cover the full cost of the waterpoint. The difference between the invoice value charge to the client and the estimated full cost for each waterpoint can be calculated. If the difference is persistently unfavourable ie invoice charge less than the full cost then we know that either costs must be reduced or the charging rates must be revised upwards.

b) Furthermore, the invoices are based on a charging system, similar to that used by private contractors, whose structure and rates were devised on the basis of a fairly cursory review of the experience of waterpoint construction costs. It is hoped that our charging structure will more accurately reflect the costs of waterpoint construction than has previously been the case. By estimating the full cost of each waterpoint constructed and comparing this with the invoice charge, we obtain a good indication of how well the charging system does in fact reflect costs. Further revisions of the charging system may be suggested by the above comparison.

c) Thirdly, for the purposes of future planning, an estimate of the cost of each waterpoint provides more valuable information than does total Project cost.

13.1.5. Thus the overall aim of the cost-monitoring system is to record all Project costs and to divide them among all the individual waterpoints in a consistent and easily understandable way. To do this it is required that:

a) The system must be workable in the field with the available staff.

b) It must also be sufficiently flexible to adapt as necessary to conditions in the field and in response to experience of its use.

13.1.6. It was quickly recognised that the greater the degree of accuracy and detail required from the cost-monitoring system, the greater the amounts of time, skill and effort required from field staff to operate it. The system therefore evolved (and is still evolving) into a compromise between what is ideally required from the costing system and the limits imposed by what is practically feasible, given the staff and time available for the task.

13.2. SOLUTIONS

13.2.1. The cost-monitoring system comprises three elements:

a) a framework of cost categories

b) a set of simple procedures for the collection of cost data

c) a set of simple procedures for the analysis of cost data.

13.2.2. *The Framework of Cost Categories*

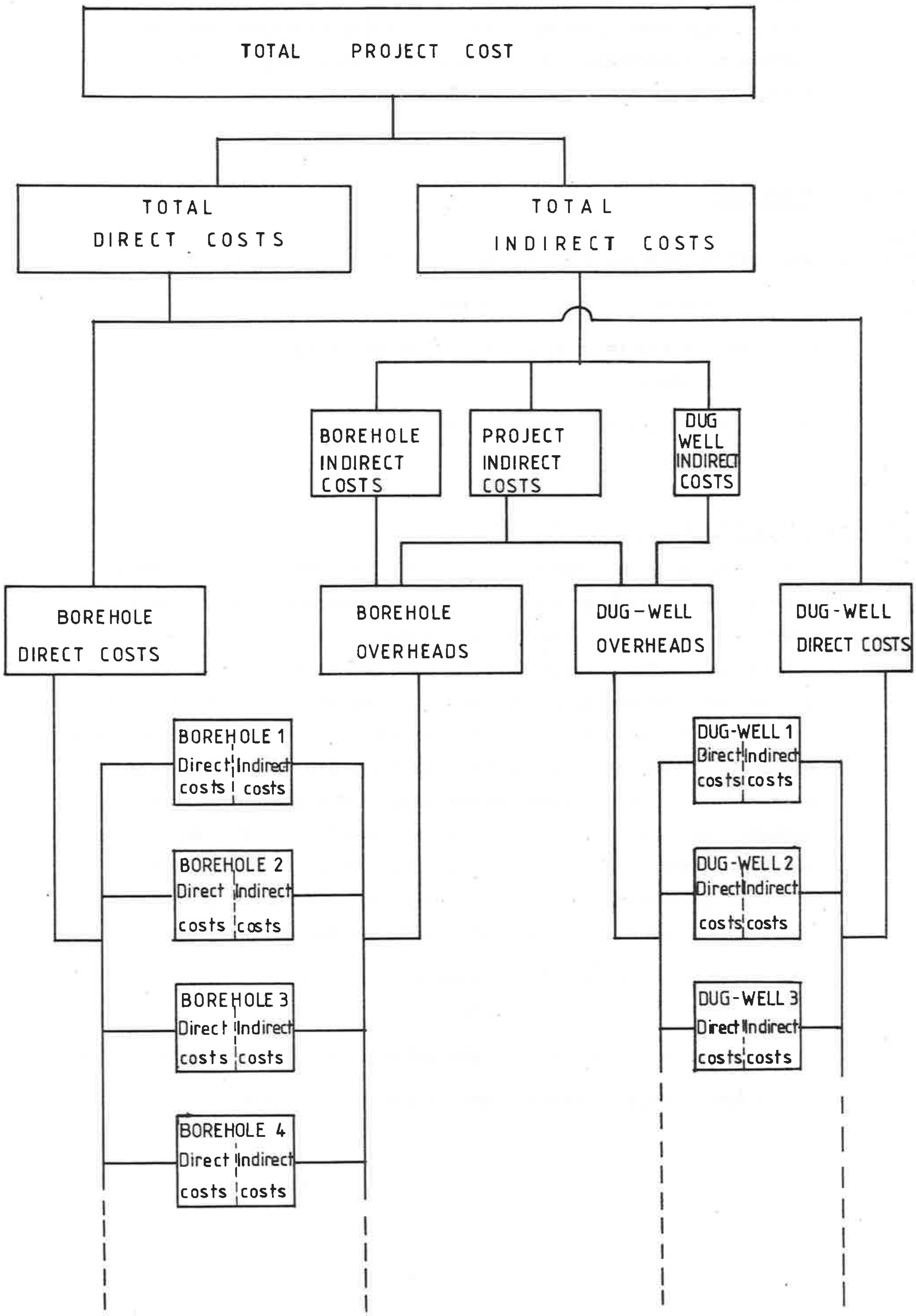
The two major cost categories, direct costs and indirect costs, have already been discussed. It will be remembered that indirect costs are those which cannot be attributed directly to particular waterpoints. Now, we are dealing with two distinct types of waterpoint, boreholes and dug-wells. Some of the indirect costs can be attributed exclusively to boreholes (eg the cost of drilling equipment), and some exclusively to dug wells (eg the cost of staff engaged solely on the supervision of well digging). There will, however, be some indirect costs which cannot be attributed exclusively to either boreholes or dug wells, such as the cost of the Project management. Thus the category of indirect costs may be subdivided into three smaller categories:

a) borehole indirect costs (those attributable exclusively to boreholes)

b) dug-well indirect costs (attributable exclusively to dug wells)

c) Project indirect costs (not exclusive to either).

Figure D.13.1. FRAMEWORK OF COST CATEGORIES



We may now sketch the whole framework of cost categories [see Figure D.13.1]. Total Project cost is first divided into direct costs and indirect costs. The direct costs are further divided into borehole direct costs and dug-well direct costs, which are then broken down into the direct costs of each individual borehole or dug well. The total indirect costs are divided between borehole indirect costs, dug-well indirect costs and Project indirect costs. These indirect costs must eventually be shared out amongst all the waterpoints. This is accomplished in two steps. First the Project indirect costs are split between boreholes and dug wells. The sum of the borehole indirect costs and the share of Project indirect costs allotted to boreholes is called "borehole overheads". Similarly "dug-well overheads" consists of dug well indirect costs plus the dug wells' share of Project indirect costs. The second step is to allocate these overheads to the boreholes and dug wells [the mechanics of these two steps will be described under Procedure, 13.3].

13.2.3. *The Collection of Cost Data*

Data on all Project costs are recorded by means of a series of forms filled in by Project staff [see Section 13.3]. There are registers to record the presence on the Project of staff and of items of equipment. There are forms to be completed for each waterpoint constructed, detailing the labour and materials used. Diary sheets record the activity of each drilling rig and well-digging team each day. The storeman maintains records of all materials issued [see Section 12, Stores], and he also records the visits of non-Project vehicles. These forms, diary sheets and records comprise the raw material for the cost-monitoring system, and so a great deal of attention has been given to their design and use. We have endeavoured to keep them simple and easily understood without sacrificing the necessary details and checks on accuracy.

13.2.4. *The Analysis of Cost Data*

The analysis of the raw cost data follows three basic steps.

a) The first step is to convert the information about numbers of days worked and about amounts of materials used into costs. That is, we need a list of prices and rates for all the materials,

13.2.4. (2)

equipment and staff used by the Project. The most straightforward of these are prices for materials - easily obtained from suppliers. The costs of staff employed are slightly more complicated : what we require is a cost per day for each person, so that their cost per month, or per activity, is easily calculated as the number of days worked in the month, or on a particular activity, multiplied by the cost per day or "day rate". The day-rate is calculated taking into account monthly, weekly, daily or hourly rates of pay, various allowances, pension rights and entitlements to leave [this is described in detail in Section 13.3, Procedure]. In the case of Project equipment, such as vehicles and drilling rigs, we require a monthly charge based on an allowance for the depreciation of equipment and on an estimate of maintenance expenses. These charges, while they are important costs, are clearly more notional than the labour and materials costs [again details are given under Procedure].

b) The second step, having placed a kwacha value on all costs, is to assign each cost to its appropriate cost category. Referring once more to Figure D.13.1, we can identify the boxes into which all costs will fall in the first instance. Each cost will be assigned either as a direct cost to a particular waterpoint box, or as an indirect cost to one of the three boxes:- "borehole indirect costs", "dug-well indirect costs" and "Project indirect costs". In effect we have to ask of each cost in turn, first, "can we attribute this cost to a particular waterpoint?". If not, then we ask, "can we attribute this cost exclusively to either boreholes or dug wells?". In this way we arrive at the direct costs of each waterpoint and the indirect costs are divided into the three boxes, boreholes, dug wells or Project.

c) The third step of the analysis is to share out the indirect costs among all the waterpoints, so that we end up with all the costs contained in the individual waterpoint "full cost" boxes. First the contents of the three indirect cost boxes must be transferred to the "borehole overheads" and "dug-well overheads" boxes. This is achieved by splitting the Project indirect costs between boreholes and dug wells in a manner which reflects the relative cost, effort and level of service. Secondly

the borehole and dug-well overheads must be allocated to the individual waterpoint boxes. This is done on the basis of the number of days worked directly on each borehole or well (an "indirect-cost team day" is one spent waiting, for example, for materials or for repairs to drilling rigs, which is not counted as a day actually worked on a particular waterpoint). This is regarded as the simplest and fairest way of allocating the overheads, since most of these costs relate to the passage of time and do not vary with the number of waterpoints constructed in a given period.

It will be appreciated from the discussion above that some parts of our cost estimates will be closer to the truth than others. The estimated direct costs will be very close to the true direct costs while, for example, the estimates of indirect cost per waterpoint contain much that is notional. Labour and materials cost estimates are easier and more accurate than estimates of the costs of using items of equipment. These limitations should be borne in mind when reviewing the results of the cost monitoring exercise. However, given our objective of seeking an estimate of the cost of each waterpoint by means of a costing system which is workable in the field, we believe that the cost monitoring system described here gives us the best chance of reaching that objective and producing sufficiently accurate and useful results.

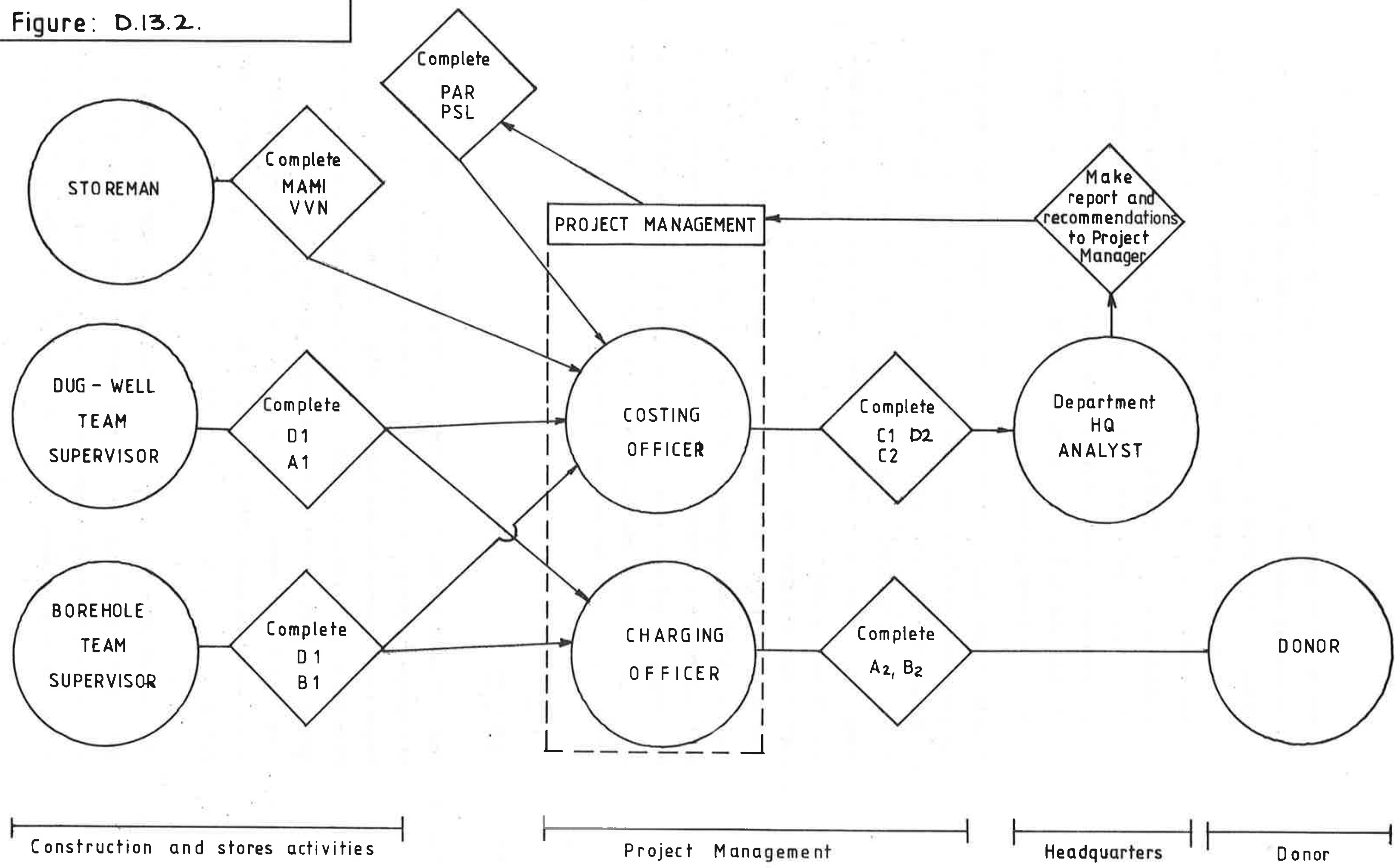
13.3. PROCEDURE

13.3.1. The rationale behind the procedures outlined below is to facilitate the smooth transfer of information from the Project construction teams and storeman to the Project manager for cost monitoring and from there to Headquarters for financial analysis. Information and advice can then be fed back from Headquarters to Project level so that strict cost control can be maintained and any improvements which would increase efficiency or reduce costs can be implemented. Figure D.13.2 shows these transfers of information.

13.3.2. The rest of this Section falls into two parts. The first part lists and briefly describes each of the forms used in the cost monitoring system. A completed example of each form is given. The second part is a step by step guide to the completion of the two principal cost

INFORMATION FLOWCHART

Figure: D.13.2.



forms, namely "Overheads Analysis" [Form C.1] and the "Waterpoint Cost Sheet" [Form C.2].

13.3.3. *List of Forms*

The forms are summarised in Table D.13.1, and Figure D.13.3 shows the relationship between the various forms. A brief description of each form, its content and its function, is given below.

13.3.4. *The Project Staff List (PSL)*

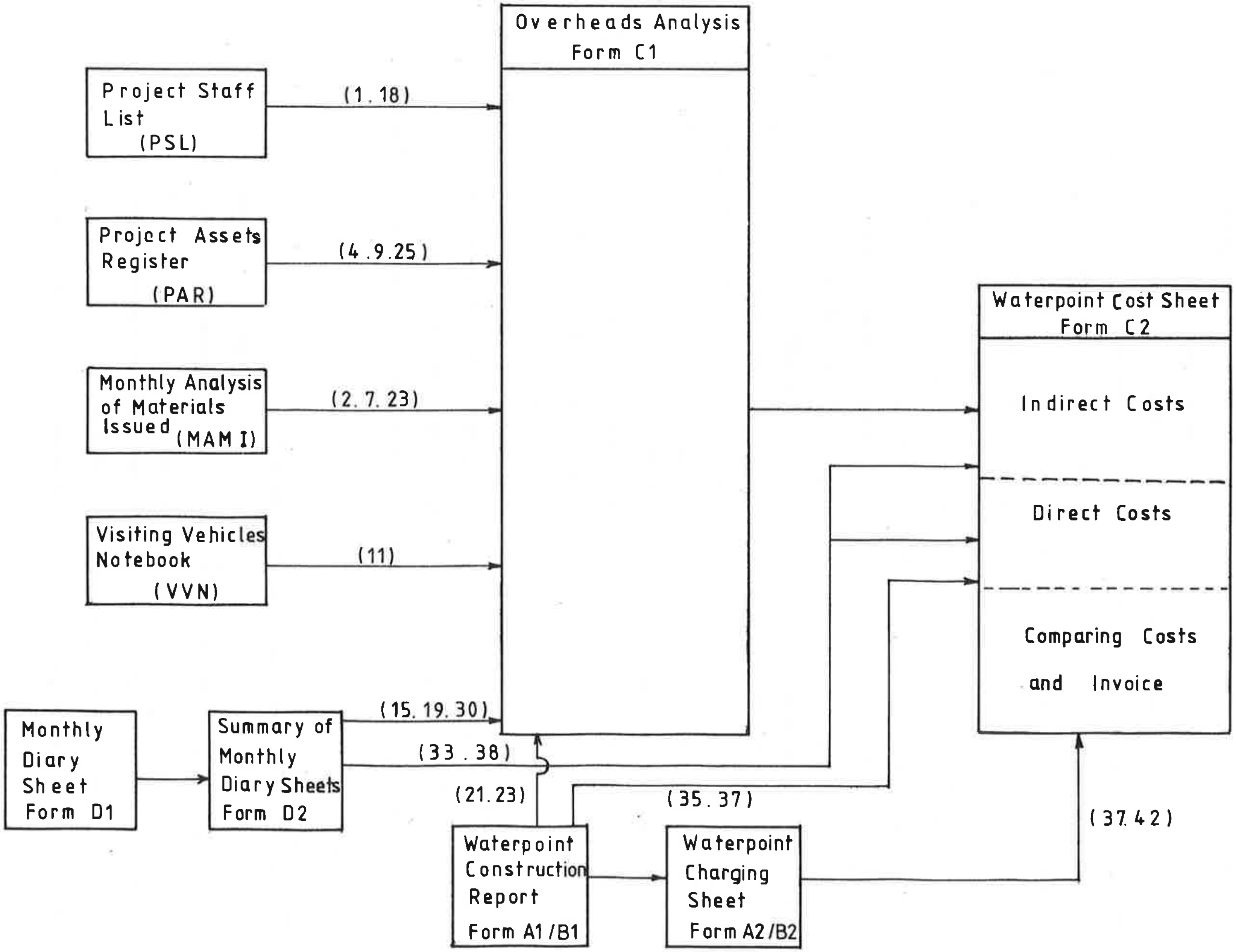
The PSL is a register of all the indirect-cost staff engaged on the Project. The direct-cost staff (the members of the construction teams) are not individually listed, as they are accounted together as a team to obtain the "team day rate" for determining the labour cost component of individual waterpoints [Form C.2 in Section 13.3.15]. A master list of these staff is kept for administrative and personnel requirements only. The PSL is opened at the beginning of the Project and is updated monthly. Its purpose is to provide the information about monthly staff costs which is required for completing the "Overheads Analysis" sheet. The designated Project Officer (probably one of the hydrogeologists) records in the PSL the name and function of each member of direct-cost staff, and he enters for each one their monthly salary or wage, their monthly allowances and their monthly pension contribution. Adding together the salary, allowances and pension contribution, the Project Officer obtains a cost per month or "month-rate" for each staff member. To convert this to a cost per working day the month-rate is divided by twenty (since there are on average just over twenty-two working days per month, and each staff member is entitled to two days leave for each month worked). This gives the "day rate" for each staff member. The cost in any particular month of a member of the staff is calculated by multiplying the staff member's day rate by the number of working days in the month. The staff are divided into three groups; Part 1 of the PSL lists the "Project Indirect-Cost staff", ie those whose work concerns both boreholes and dug wells, such as the Project Manager or the storeman. Part 2 lists the "Borehole Indirect-Cost staff", ie those whose work is concerned only with boreholes, such as the drilling supervisors. Part 3 lists the "Dug-Well Indirect-Cost staff", ie those concerned only with dug wells. A total cost for each of these groups is calculated each month.

Table D.13.1

Summary of Forms Used for Cost Monitoring

TITLE OF FORM	ABBR. OR NUMBER	COMPLETED BY	TIMING	DATA OBTAINED FROM	DATA CARRIED TO
Project Staff List	PSL	Project Management	Opened at start of project and updated monthly	-	Form C.1
Project Assets Register	PAR	Project Officer	Opened at start of project and updated monthly	-	Form C.1
Monthly Analysis of Materials Issued	MAMI	Storeman	Monthly	Stores Ledger	Form C.1
Visiting Vehicles Notebook	VVN	Storeman	Continuously	-	Form C.1
Dug-Well Construction Report	A.1	Dug-Well Supervisor	On completion of dug-well	-	Forms A.2 C.2 (C.1 if abandoned)
Dug-Well Charging sheet	A.2	Project Officer	On completion of A.1	A.1	Form C.2
Borehole Construction Report	B.1	Drilling Supervisor	On completion of borehole	-	Forms B.2 C.2. (C.1 if abandoned)
Borehole Charging sheet	B.2	Project Officer	On completion of B.1	B.1	Form C.2
Monthly Diary Sheet	D.1	Team Supervisor	Daily	-	Form D.2
Summary of Monthly Diary Sheets	D.2	Project Officer	Monthly	D.1	Forms C.1, C.2
Overheads Analysis	C.1	Project Officer	Monthly	PSL, PAR, MAMI VVN, A.1, B.1, D.2	Form C.2
Waterpoint Cost Sheet	C.2	Project Officer	Monthly	A.1 or B.1 A.2 or B.2, C.2	-

Figure D. 13. 3. COST MONITORING



Note : numbers in brackets indicate step numbers (Sections 13.3.17 and 13.3.18.)

13.3.5. *Project Assets Register (PAR)*

The PAR records all the various assets used on the Project, for example the drilling rigs, the project vehicles and the Project Manager's caravan. The function of the PAR is to provide an estimate of the cost of using these assets. This is a cost which must be borne by the Project, so it is added to the indirect costs on Form C.1, the "Overheads Analysis". A monthly cost is estimated by the Project Officer for each asset, comprising an element for depreciation and, where applicable, an element for maintenance. The depreciation charge for an asset is worked out first as an annual sum, following Government accounting conventions. In the present case this means that the annual depreciation charge is obtained by dividing the original cost of the asset by the number of years of its expected useful life. Then this annual sum is divided by twelve to give a monthly charge. Thus, for example, if a vehicle costs K9,600 and it is expected to last four years, then its annual depreciation charge is K2,400 and its monthly charge is K200. The maintenance charge for assets such as drilling rigs and vehicles is based on an estimate of their annual maintenance cost in a normal year. This estimate is divided by twelve to give the monthly charge. The monthly depreciation charge is added to the monthly maintenance charge to give the "total monthly charge" for each item. The assets are grouped into four sections in the PAR. Part 1 contains the "Project Indirect-cost Assets". These are the assets which are not used exclusively either by borehole teams or by dug-well teams, with the exception of Project vehicles, which appear under Part 2, "Transport Assets". Part 3 covers "Borehole Indirect-cost Assets" and Part 4 is "Dug-well Indirect Assets". These sections cover those assets which are used exclusively by borehole teams or by dug-well teams respectively. A total cost for each section is calculated each month.

13.3.6. *Monthly Analysis of Materials Issued (MAMI)*

This form is completed by the storeman as part of his storekeeping duties using data from the stores ledger. It gives a breakdown of materials issued to each user. Its function in relation to the cost monitoring system is to provide details of indirect-cost materials used, that is, materials used for "Project Camp" and "Transport" (and the petrol used by dug-well teams, which is not

costed directly to individual wells). The quantities of such materials used are carried to Tables on the "Overhead Analysis" sheet [Form C.1] to be converted into costs. An example is given in Section 12.

13.3.7. *Visiting Vehicles Notebook (VVN)*

The cost of delivering materials to the Project is one of the larger items of indirect costs. The VVN provides the information for calculating that cost, together with the cost of visits by the supervisory staff. Each visit to the Project by a non-project vehicle is recorded in the VVN by the storeman. He notes the date and purpose of the visit, the type and registration number of the vehicle, and the total number of kilometres travelled for the trip. The total kilometres travelled by each vehicle during the month is calculated and carried to a Table on Form C.1 where standard vehicle operating rates are applied to work out the cost per vehicle and the total cost for the month.

13.3.8. *Dug Well Construction Report : Form A.1*

This form is completed by the dug-well supervisor on the completion of a dug well. It records various construction details, the relevant part for costing being Part 2.B ("Construction Materials Used"). This provides the quantities of materials used on the dug well. In the case of a successful dug well the information required for calculating the direct-cost materials is entered and is carried to Form C.2. In the case of abandoned dug wells, the information is carried to Form C.1 as indirect-cost materials. Form A.1 also provides all the information required to fill in Form A.2, the "Dug Well Charging Sheet".

13.3.9. *Dug Well Charging Sheet : FORM A.2*

Form A.2 is used to calculate the charge to the client (generally a donor) for a dug well. A charge is made for each of a number of operations, such as siting, digging, moving between sites and installing pumps, according to an agreed schedule of charges. (note : the schedule of charges for dug wells is currently under review. The charges shown in the worked example are the rates currently proposed but not yet approved). The cost of materials used is computed in Part D of Form A.2, taking the quantities of materials used from Part 2.B of Form A.1 and multiplying them by their respective prices. This cost is added to the sum of the charges for various

operations (parts A, B and C of Form A.2 to give the total invoice value. This is the charge to the client/donor, against which we have to compare the estimated cost of the dug well. Form A.2 should be completed by the Project Officer.

13.3.10. *Borehole Construction Report : Form B.1*

This form is completed by the drilling supervisor on completion of each borehole. It gives various construction details (as in Form A.1) and information is carried to Forms C.2, C.1 and B.2 as appropriate.

13.3.11. *Borehole Charging Sheet : Form B.2*

As for Form A.2, charges for operations are made under parts A, B and C. Part D computes the cost of materials used, carrying the quantities from Part 2.B of Form B.1. The sum of the charges plus the materials cost is the invoice value which is charged to the client or donor.

13.3.12. *Monthly Diary Sheet : Form D.1*

The Monthly Diary sheet is filled in daily by the supervisors, recording the activities of each team. Depending on the activities, each half-day is marked down either to Direct-Cost Team Days (against a particular waterpoint number) or to Indirect-Cost Team Days. Direct-Cost Team Day activities are those which contribute directly to the construction of a waterpoint, such as drilling, digging, developing, lining and testing. At the end of the month the Direct-Cost Team Days are summarised in Table A, which shows the number of days worked at each waterpoint. The Indirect-Cost Team Day activities are those which cannot be directly attributed to a particular waterpoint, such as moving between sites, waiting for materials or for repairs, and working on abandoned waterpoints. These are summarised in Table B. The sum of the total Direct-Cost Team Days and the Indirect-Cost Team Days should be equal to the number of working days in the month.

13.3.13. *Summary of Monthly Diary Sheets : Form D.2*

This form summarises the information provided by the individual teams' Monthly Diary Sheets. Parts A and B are filled in from the Table A of each Form D. Parts C and D are derived from Table B of each Form D.1.. This form is completed by the Project Officer and it provides him with the total number of Indirect-Cost Team Days,

which he carries to Form C.1, Table 6, and the total numbers of Direct-Cost Team Days, which he carries to Part 10 on the front of Form C.1. Furthermore, Parts A and B are his source of information for the number of Direct-Cost Team Days worked on each particular waterpoint, which he needs to complete Form C.2.

13.3.14. *Overheads Analysis : Form C.1*

On this form the Project Officer summarises all the indirect costs for a month and computes a rig or well day-rate in order to share indirect costs out to individual waterpoints. Part A records the Project Indirect Costs (subdivided into Camp and Transport). In Part B these costs are split between boreholes and dug wells. Each borehole team is required to bear twice as much of the Project Indirect Costs as each dug-well team. This is based on the principle that on average a borehole will serve twice as many people as a dug well, and the observation that a borehole team has twice the manpower and requires roughly twice as much supervision by Project staff as a dug-well team. In Part C the shares of Project Indirect Costs are added to the separate Borehole Indirect Costs and Dug well Indirect Costs. The sums, the Total Overheads for boreholes and for dug wells, are divided by the number of Direct-cost days worked on boreholes and dug wells respectively. This gives the "rig day-rate" and the "well day-rate". The share of total overheads borne by each waterpoint is given by multiplying the number of direct-cost days worked on the waterpoint by the appropriate day-rate [see Part C of Form C.2 below]. In this way all the month's indirect costs are shared out amongst all the waterpoints worked on during the month, and can be carried to Form C.2. Detailed instructions for completing the form are given in Section 13.3.17.

13.3.15. *Waterpoint Cost Sheet : Form C.2*

The Project Officer completes Form C.2 for each successfully completed waterpoint. This form gives an estimate of the cost of the waterpoint, and also compares this cost with the invoiced charge. Part A computes the labour cost. The number of days worked on the waterpoint [which is found from Form D.2, see above] is multiplied by the "standard team day-rate". This rate is calculated in the same way as the day-rates in the PSL [Section 13.3.4] except that it is the rate for a whole team, not just one staff

member. In the case of boreholes the footage bonus earned by the drilling supervisor, at a certain rate per metre drilled, is added to the cost of the team to give the total labour cost. Part B contains the details of materials used from Forms A.1 and B.1 and calculates the cost of materials. The set of prices used is not the same as those used for the Materials Section of the Charging Sheet (Part D of Form A.2 or B.2) since these include a percentage for transport and handling. Part C indicates how much indirect cost is carried or "absorbed" by the waterpoint. The rig or well day-rate calculated on Form C.1 is multiplied by the number of Direct-cost days worked on the waterpoint. If the construction of the waterpoint spans two months then the number of days which fall into the first month are multiplied by the first month's day-rate and this is added to the product of the number of days in the second month and the second month's rig or well day-rate. In Part D the costs are added up to give the "Full Cost". Subtracting this from the invoice value [Part E] gives the net surplus or deficit (Part F). Detailed instructions for completing this form are given in Section 13.3.18.

13.3.16. *Step by Step Instructions for Completing Forms C.1 and C.2*

The following detailed procedure is given for the completion of the "Overhead Analysis" Form (C.1) and the "Waterpoint Cost Sheet" (C.2). This description is necessarily long and perhaps difficult to digest. It should be followed in conjunction with the worked examples. It is assumed that the Project staff have already completed PSL, PAR, MAMI, VVN, Forms A.1 and A.2, B.1 and B.2 and D.1 and D.2. The procedure can then be followed as given below.

13.3.17. *Completion of Form C.1 : Overheads analysis*

Step no:	Section of form:	To complete -		From	Directions:
		Box no:	Table no:		
1	A	1		PSL	Carry the month's total from Part 1 of the PSL
2	Tables		1	MAMI	Carry details of materials used in project camp, and compute total cost
3	A	2		Table 1	Carry total cost from table to box
4	Tables		2	PAR	Copy Part 1 of PAR for the month
5	A	3		Table 2	Carry total cost from table to box
6	A	4			Sum A.1, A.2 and A.3
7	Tables		3	MAMI	Carry details of materials used by project vehicles
8	A	5		Table 3	Carry total cost from table to box
9	Tables		4	PAR	Copy Part 2 of the PAR for the month
10	A	6		Table 4	Carry total cost from table to box
11	Tables		5	VVN	Carry the total km for each vehicle, and compute the total cost
12	A	7		Table 5	Carry the total cost from table to box
13	A	8			Sum A5, A6 and A7
14	A	9			Sum A.4 and A.8
15	Tables		9	Form D.2	Enter numbers of teams and compute proportionate shares
16	B	1		Table 9	Carry fraction (d), and compute A.9 x (d)
17	B	2		Table 9	Carry fraction (e), and compute A.9 x (e)
18	C	1		PSL	Carry totals from Parts 2 and 3 of the PSL
19	Tables		6	Form D.2	Carry totals of indirect cost team days from parts C and D of Form D.2, multiply by standard team day-rate
20	C	2		Table 6	Carry totals from the table to the boxes

13.3.17 Continued

Step no:	Section of form:	To complete - Box no:	Table no:	From	Directions:
21	C	3		Form B.1	Calculate footage bonus on abandoned boreholes (depth x rate/metre)
22	C	4			Sum C.1, C.2 and C.3
23	Tables		7	MAMI & Form B.1 and A.1	Carry details of materials used on abandoned boreholes dug wells (Forms B.1 & B.2 and of petrol used on all dug wells (from MAMI) Compute total costs
24	C	5		Table 7	Carry totals from table to boxes
25	Tables		8	PAR	Copy Parts 3 and 4 from PAR
26	C	6		Table 8	Carry totals from table to boxes
27	C	7			Sum C4, C.5 and C.6
28	C	8		Boxes B.1,B.2	Carry down shares of total Project indirect costs from Part B
29	C	9			Add C.7 and C.8
30	C	10		Form D.2	Carry totals from parts A and B of form D.2
31	C	11			Divide totals at C.9 by no. of direct cost team days for boreholes and for dug wells

13.3.18 *Completion of Form C.2 : Waterpoint cost sheet*

Step No.	Section of Form	From	Directions
32	A	–	Enter standard team day-rate in box
33	A	Form D.2	Carry number of direct cost team days to box
34	A		Calculate team labour cost (number of days multiplied by rate)
35	A	Form B.1	Enter footage bonus for boreholes
36	A		Add footage bonus, if any, to team labour cost
37	B	Forms A.1 or A.2 or B.1 or B.2	Carry details of materials used and compute total materials cost
38	C	Form D.2	Enter number of direct cost team days (split between months if necessary)
39	C	Form C.1	Carry Rig or Well Day-Rate (or Day-Rates if more than one month)
40	C		Calculate total overheads (days times day-rates)
41	D		Add total labour cost and total materials cost to give "total direct cost". Add "total indirect cost" (overhead cost) to give "full cost"
42	E	Form A.2. or B.2	Carry total invoice value to box.
43	F		Calculate differences between total invoice value and full cost

COST MONITORING AND ANALYSIS : WORKED EXAMPLE

In order to assist understanding of the cost monitoring procedure, a worked example is given comprising the main summary forms (PSL, PAR, VVN, Diary Summary Sheets [D.2], Overheads [C.1]) some of the Construction Reports [A.1 and B.1] Cost Sheets [C.2], Charging Sheets [A.2 and B.2] and Diary Sheets [D.1] and a summary report for the Upper Livulezi Project in May, 1982. An example of the stores form [MAMI] is given in Section 12.

PROJECT STAFF LIST

Sheet No: 1

Project: LIVULEZI

Period: APR - JUN

NAME AND FUNCTION	MONTHLY SALARY OR WAGE	MONTHLY ALLOWANCES	MONTHLY PENSION CONTRIBUTION	MONTH RATE	DAY RATE	MONTH (No. of days) APR (22)	MAY (20)	JUN (26)	
1 Project Indirect Cost Staff									
Msonthi (PM)	248 75	62 50	62 19	373 44	18 67	410 74	373 40	485 42	
Chavula (APM)	238 00	62 50	59 50	360 00	18 00		360 00	468 00	
Ruxton (APM)	200 00	62 50		262 50	13 13	288 86	262 60		
Richardson (APM)	200 00	62 50		262 50	13 13				
Govati (APM)	248 75	62 50	62 19	373 44	18 67				
Mkandawire (APM)	238 00	62 50	59 50	360 00	18 00				
Mansinje (Stores)	28 71	12 50	7 18	48 39	2 42	53 24	48 40	62 92	
Chikacha (Tractor driver)	37 40	12 50	9 35	59 25	2 96	65 12	59 20	76 96	
(Driver)					6 00	132 00	120 00	156 00	
(Driver)					6 00				
(Builders)					6 00	132 00	120 00	390 00	
Total carry to Form C1 (A1)						1081 96	1343 60	1639 30	
2. Borehole Indirect Cost Staff									
Chitaukali (Drill Supervisor)	154 25		38 56	192 81	9 64				
Tchubu (Drill Supervisor)	192 50		48 13	240 63	12 03		192 80	250 64	
Chapwetoka (Drill Supervisor)	192 50		48 13	240 63	12 03		240 60	312 78	
Nthala (Pump Installation Team)	154 25	37 50	38 56	230 31	11 52				
Msunyama (Pump Installation Team)	37 40	12 50		49 90	2 49		230 40	299 52	
Kapinja (Pump Installation Team)	37 40	12 50		49 90	2 49		49 80	64 74	
							49 80	64 74	
Total - to Form C1 (C1)						476 74	772 40	992 42	
3. Wells Indirect Cost Staff									
Msamba (Supervisor)	36 00		9 00	45 00	2 25	49 50	45 00	58 50	
Total - to Form C1 (C1)						49 50	45 00	58 50	

PROJECT ASSET REGISTER   Sheet No: 1

Project: LIVULEZI   Period: APR - JUN

ITEM	MONTHLY DEPRECIATION CHARGE	MONTHLY MAINTENANCE CHARGE	TOTAL MONTHLY CHARGE	MONTH: APR	MAY	JUN	
1. PROJECT F/C ASSETS							
Tents	500 00		500 00	500 00	500 00	500 00	
Caravans (each)	41 67		41 67	208 33	208 33	208 33	
Uniports	75 00		75 00	75 00	75 00	75 00	
Prelim expenses	210 00		210 00	210 00	210 00	210 00	
				993 33	993 33	993 33	
2. TRANSPORT F/C ASSETS							
Tractor + trailer	235 00	150 00	385 00	385 00	385 00	385 00	
Landrover P/U	176 00	250 00	426 00	426 00	426 00	426 00	
Datsun P/U	135 00	175 00	310 00		310 00		
Motorcycles	22 00	50 00	72 00	288 00	288 00	288 00	
Toyota Dyna							
				1099 00	1409 00	923 00	
3. BOREHOLE F/C ASSETS							
Rig MG 365E	250 00	42 00	292 00	292 00	292 00	292 00	
MG 2406		42 00	42 00	42 00	42 00	42 00	
MG 2408		42 00	42 00	42 00	42 00	42 00	
MG 2221		42 00	42 00	42 00	42 00	42 00	
				418 00	418 00	418 00	
4. WELLS F/C ASSETS							
Various equipment	25 00	10 00	35 00	35 00	35 00	35 00	
				35 00	35 00	35 00	

VISITING VEHICLES NOTEBOOK

Project.. Livulezi

Date:	Reg. No.	Type of Vehicle	km this trip	Purpose of visit
3/5/82	MG 837D	Bedford 5-ton	396	Delivery of materials from Lilongwe.
5/5/82	MG 331E	Motorcycle	185	Dug Wells Supervisory visit from Dedza.
6/5/82	MG 6531	Leyland 8-ton	410	Delivery of materials from Lilongwe
10/5/82	MG 279E	Toyota 2-ton	392	Delivery of material from Lilongwe.

FORM A1 front

WELL Nº W 16

OFFICE OF THE PRESIDENT AND CABINET
DEPARTMENT OF LANDS, VALUATION AND WATER
(GROUND WATER SECTION)

DUG — WELL CONSTRUCTION REPORT

District: Ntcheu
T. A: Ganya
Locality: Chachuka
Grid reference:
A. O. D:
Moved from:
Moving to:

Client: Livulezi Project
Address:
Well supervisor: Mzunla Crew Nº II
Digging started: 21/5/82
Digging finished: 27/5/82
Final completion: 11/7/82

1 DAILY RECORD

Date	Digging time	From (m)	To (m)	Other work (hrs)	Remarks
21/5/82		0	2.23		
22/5/82		2.23	3.25		
25/5/82		3.25	4.00		
26/5/82		4.00	4.50		
27/5/82		4.50	5.00		

2. DETAILS FOR COSTING AND CHARGING

A. CONSTRUCTION DETAILS

Diam .... mm, from 0 m, to 5 m
Total depth 5 m
Rest water level 1.8 m

B. CONSTRUCTION MATERIALS USED

Concrete rings .... no 3
Bottom slab .... no 1
Top slab .... no 1
110 mm guiding PVC pipe .... m 2.1
63 mm PVC rising main pipe .... m 2.1
25 mm PVC pump rod .... m
Foot valve .... no 1
Plunger .... no 1
Solvent cement .... tin
Cleaning fluid .... tin
Filter stones .... sum
Cement .... pkt 8
Pumphead .... no 1

FORM A1 front

WELL Nº W15

OFFICE OF THE PRESIDENT AND CABINET
DEPARTMENT OF LANDS, VALUATION AND WATER
(GROUND WATER SECTION)

DUG — WELL CONSTRUCTION REPORT

District: Ntcheu
T. A: Ganya
Locality: Chale I
Grid reference:
A. O. D:
Moved from:
Moving to:

Client: Livulezi Project
Address:
Well supervisor: Msambu Crew Nº II
Digging started: 12/5/82
Digging finished: 18/5/82
Final completion:

1 DAILY RECORD

Date	Digging time	From (m)	To (m)	Other work (hrs)	Remarks
12/5/82		0	1.98		
13/5/82		1.98	2.90		
17/5/82		2.90	3.60		
18/5/82		3.60	4.10		

2. DETAILS FOR COSTING AND CHARGING

A. CONSTRUCTION DETAILS

Diam .... mm, from 0 m, to 4.10 m
Total depth 4.10 m
Rest water level 1.1 m

B. CONSTRUCTION MATERIALS USED

Concrete rings .... no 3
Bottom slab .... no 1
Top slab .... no 1
110 mm guiding PVC pipe .... m 1.15
63 mm PVC rising main pipe .... m 1.15
25 mm PVC pump rod .... m
Foot value .... no 1
Plunger .... no 1
Solvent cement .... tin
Cleaning fluid .... tin
Filter stones .... sum
Cement .... pkt 8
Pumphead .... no 1

FORM B1(front)

OFFICE OF THE PRESIDENT AND CABINET
DEPARTMENT OF LANDS, VALUATION AND WATER
GROUNDWATER SECTION

Borehole Nº GP65

BOREHOLE CONSTRUCTION REPORT

District: Ntcheu
Client/Project: LIVULEZI
T.A: Ganya
Address:
Locality: Chimpudza
Driller: TCHUBA Rig Nº 2221
Grid reference:
Drilling started: 5/5/82
A.O.D.:
Drilling finished: 10/5/82
Moved from: GP63 Distance ... kms
Construction completed:
Moving to: ... Distance ... kms
Vehicle Nº ... Kms on hole ...

1. DAILY RECORD

Date	Hours Drilled	From (m)	To (m)	Other work (hrs)	W.L. at start (m)	Remarks
5/5/82	1 3/4	0·00	5·00	8½		Rigging up. Spudding.
6/5/82	4			½		drilling
7/5/82	2			2½		drilling
8/5/82	8			1½		drilling
10/5/82	3			6½		Completed drilling
11/5/82				9½		Inserted PVC and gravel pack.
12/5/82	4					Pump tested.

2. DETAILS FOR COSTING AND CHARGING

A. DRILLING DETAILS

200 mm, from 0·00 m, to 26·50 m
... mm, from ... m, to ... m
... mm, from ... m, to ... m
Nº of bailer tests: 2
Hours cleaning and developing: 4
Hours test pumping: 4
Hours recovery measurement: 2

B. CONSTRUCTION MATERIALS USED

(i) Plain casing 110 mm, 12·03 m
(ii) Slotted casing 110 mm, 14·71 m
(iii) Bottom cap 1
(iv) Centralisers 15
(v) Solvent cement ½ tin
(vi) Cleaning fluid 1 tin
(vii) Gravel pack 1·8 m^3
(viii) Cement ... pkts
(x) Pumphead ... m
(xi) Rising main ... m
(xii) Pump rods ... m
(xiii) Cylinder ...
(xiv) Charcoal 3 bag

FORM B1(reverse)

3. First water @ 17.00 m
Rises to 9.30 m

Main supply from ...... m to ...... m

200mm casing ...... m inserted at ...... m

4 hr specific capacity ...... l/min/m

[yield ÷ drawdown at 4 hours]

4. PUMPING TEST

From 7.30 hrs on 12/5/82

To 11.30 hrs on 12/5/82

Cylinder size small set at 24 m

Stroke length ...... mm/EC @ end ...... µs/cm

DRAWDOWN				RECOVERY	
Elapsed Time	Level m	Strokes p.m.	Yield l.p.m.	Elapsed Time	Level m
0.00	9.30			0.00	
0.02	11.06	28	15	0.02	
0.04	15.12	"	"	0.04	
0.06	18.40	"	"	0.06	
0.08	19.58	"	"	0.08	
0.10	24.00	"	"	0.10	
0.12	"	"	"	0.12	
0.14	"	"	"	0.14	
0.16	"	"	"	0.16	
0.18	"	"	"	0.18	
0.20	"	"	"	0.20	
0.25	"	"	"	0.25	
0.30	"	"	"	0.30	
0.45	"	"	"	0.45	
1.00	"	"	"	1.00	
1.15	"	"	"	1.15	
1.30	"	"	"	1.30	
1.45	"	"	"	1.45	
2.00	"	"	"	2.00	
2.30	"	"	"	2.30	
3.00	"	"	"	3.00	
3.30	"	"	"	3.30	
4.00	"	"	"	4.00	
5.00				5.00	
6.00				6.00	
8.00				8.00	

5 CONSTRUCTION DETAILS

300mm 250mm 200mm 150mm 150mm 200mm 250mm 300mm

Ground

depth (metres)

5/10/15

10/20/30

15/30/45

20/40/60

25/50/75

FORM B1(front)

OFFICE OF THE PRESIDENT AND CABINET
DEPARTMENT OF LANDS, VALUATION AND WATER
GROUNDWATER SECTION

BOREHOLE CONSTRUCTION REPORT

Borehole Nº GP 72

District: Ntcheu — Client/Project: LIVULEZI
T.A: Ganya — Address:
Locality: Kachamba Village — Driller: CHITAUKALI — Rig Nº MG 365E
Grid reference: — Drilling started: 22nd May 1982
A.O.D.: — Drilling finished: 26th May 1982
Moved from: GP 68 Distance: kms — Construction completed: 1st June 1982
Moving to: GP 75 Distance: kms — Vehicle Nº MG 330E Kms on hole:

1. DAILY RECORD

Date	Hours Drilled	From (m)	To (m)	Other work (hrs)	W. L. at start (m)	Remarks
22/5/82	½	0	3·00	4	–	Moving from GP68. Rigging up & drilling.
24/5/82	4	3·00	10·21	4½	–	Drilling, Bailer Testing, and Inserting Steel casing
25/5/82	3	10·21	13·00	5½	4·63	Drilling & Bailer Testing.
26/5/82	3	13·00	14·20	5½	2·96	Completing Drilling.
27/5/82	–	–	–	8½	2·96	Inserting PVC, gravel pack, and Developing.
1/6/82	–	–	–	8½	2·35	Pump Testing.

2. DETAILS FOR COSTING AND CHARGING

A. DRILLING DETAILS

200 mm, from 0 m, to 14·20 m
mm, from m, to m
mm, from m, to m

Nº of bailer tests: 4
Hours cleaning and developing: 2
Hours test pumping: 4
Hours recovery measurement: 1

B. CONSTRUCTION MATERIALS USED

(i) Plain casing 110 mm, 3·11 m
(ii) Slotted casing 110 mm, 1·89 m
(iii) Bottom cap 1
(iv) Centralisers 12
(v) Solvent cement ½ tin
(vi) Cleaning fluid 1 tin
(vii) Gravel pack 2·6 m³
(viii) Cement pkts
(x) Pumphead m
(xi) Rising main m
(xii) Pump rods m
(xiii) Cylinder
(xiv) Charcoal 3 bag

FORM B1(reverse)

3. First water @ 4·00 m
Rises to 2·67 m
Main supply from 4·00 m to 6·00 m
200mm casing ...... m inserted at ...... m
4 hr specific capacity ...... l/min/m
[yield ÷ drawdown at 4 hours]

4. PUMPING TEST

From 8·10 am hrs on 1/6/82
To 12·10 pm hrs on 1/6/82
Cylinder size 3" x 36" set at 12·00 m
Stroke length ...... mm/EC @ end ...... μs/cm

DRAWDOWN				RECOVERY	
Elapsed Time	Level m	Strokes p.m.	Yield l.p.m.	Elapsed Time	Level m
0.00	2·35			0.00	12·00
0.02	4·05			0.02	10·70
0.04	5·34			0.04	10·07
0.06	7·27			0.06	8·10
0.08	12·00			0.08	7·22
0.10	"	26	30	0.10	6·89
0.12	"			0.12	6·46
0.14	"			0.14	6·00
0.16	"			0.16	5·77
0.18	"			0.18	5·00
0.20	"			0.20	4·65
0.25	"			0.25	4·00
0.30	"			0.30	3·57
0.45	"			0.45	3·26
1.00	"	26	30	1.00	2·35
1.15	"			1.15	
1.30	"			1.30	
1.45	"			1.45	
2.00	"	26	30	2.00	
2.30	"			2.30	
3.00	"	26	30	3.00	
3.30	"			3.30	
4.00	"			4.00	
5.00				5.00	
6.00				6.00	
8.00				8.00	

5 CONSTRUCTION DETAILS

300mm 250mm 200mm 150mm 150mm 200mm 250mm 300mm

Ground

depth (metres)

5/10/15

10/20/30

15/30/45

20/40/60

25/50/75

FORM B1 (front)

OFFICE OF THE PRESIDENT AND CABINET
DEPARTMENT OF LANDS, VALUATION AND WATER
GROUNDWATER SECTION

Borehole Nº GP 67

BOREHOLE CONSTRUCTION REPORT

District: Mchen
T.A: Ganya
Locality: Mazenda Village
Grid reference:
A.O.D.:
Moved from: GP61 Distance: kms
Moving to: GP71 Distance: kms

~~Client~~/Project: LIVULEZI
Address:
Driller: CHITAUKALI Rig Nº 2408
Drilling started: 11/5/82
Drilling finished: 17/5/82
Construction completed: 18/5/82
Vehicle Nº: Kms on hole:

1. DAILY RECORD

Date	Hours Drilled	From (m)	To (m)	Other work (hrs)	W. L. at start (m)	Remarks
11/5/82	4	0	10·80	4½		Moving from GP61. Rigging-up and Drilling
12/5/82	5	10·80	19·97	3½		Drilling, Dressing Bits, and Bailer Testing
13/5/82	3	19·97	21·50	5½	14·50	Drilling, Dressing Bits and Bailer Testing.
14/5/82	–	–	–	–	–	Kamuzu Day – holiday.
15/5/82	–	–	–	4½	–	Building latrines at kanden camp
17/5/82	1	21·50	21·80	7½	14·67	Completing Drilling
18/5/82	–	–	–	8½	14·60	Developing and Pump Testing

2. DETAILS FOR COSTING AND CHARGING

A. DRILLING DETAILS

200 mm, from 0 m, to 21·50 m
150 mm, from 21·50 m, to 21·80 m
mm, from m, to m
Nº of bailer tests: 6
Hours cleaning and developing: 1
Hours test pumping: 5
Hours recovery measurement: 2½

B. CONSTRUCTION MATERIALS USED

(i) Plain casing 110 mm, 19·3 m
(ii) Slotted casing 110 mm, 3·0 m
(iii) Bottom cap 1
(iv) Centralisers 3
(v) Solvent cement ½ tin
(vi) Cleaning fluid 1 tin
(vii) Gravel pack 0·42 m^3
(viii) Cement pkts
(x) Pumphead m
(xi) Rising main m
(xii) Pump rods m
(xiii) Cylinder
(xiv) Charcoal 6 bag

FORM B1(reverse)

3. First water @ 19.00 m
Rises to 14.50 m
Main supply from 19.00 m to 20.00 m
200mm casing .... m inserted at .... m
4 hr specific capacity .... l/min/m
(yield ÷ drawdown at 4 hours)

4. PUMPING TEST

From 8.00 a.m. hrs on 18/5/83
To 1.00 p.m. hrs on 18/5/82
Cylinder size 3" x 36" set at 21 m
Stroke length .... mm/EC @ end .... µs/cm

DRAWDOWN				RECOVERY	
Elapsed Time	Level m	Strokes p.m.	Yield l.p.m.	Elapsed Time	Level m
0.00	8.35			0.00	21.00
0.02	10.78			0.02	20.35
0.04	12.97			0.04	19.57
0.06	16.33			0.06	18.03
0.08	21.00			0.08	17.10
0.10	〃	25	60	0.10	16.32
0.12	〃			0.12	15.64
0.14	〃			0.14	14.95
0.16	〃			0.16	14.50
0.18	〃			0.18	14.12
0.20	〃			0.20	13.81
0.25	〃			0.25	13.00
0.30	〃			0.30	12.78
0.45	〃			0.45	11.70
1.00	〃	25	45	1.00	11.10
1.15	〃			1.15	10.66
1.30	〃			1.30	10.30
1.45	〃			1.45	10.00
2.00	〃	25	45	2.00	9.12
2.30	〃			2.30	8.35
3.00	〃	25	45	3.00	
3.30	〃			3.30	
4.00	〃	25	45	4.00	
5.00				5.00	
6.00				6.00	
8.00				8.00	

5 CONSTRUCTION DETAILS

300mm 250mm 200mm 150mm 150mm 200mm 250mm 300mm

Ground

depth (metres)

5/10/15

10/20/30

15/30/45

20/40/60

25/50/75

FORM A2 front

JOB CHARGING SHEET

OFFICE OF THE PRESIDENT AND CABINET
DEPARTMENT OF LANDS, VALUATION AND WATER
(GROUND WATER SECTION)
DUG - WELL JOB CHARGING SHEET

WELLS SUPERVISOR Msamba
COSTED BY Chavula

Client / Project Livulezi
Location Chale I
Grid reference
Deposit recieved date

Well Nº W 15
Crew Nº II
Digging started 12/5/82
Digging completed 18/5/82
Final completion 16/7/82
Ledger folio Nº

A. SITING

Item	Price
Desk Study	
Siting	
Extra	
Vehicle km	
A SUB-TOTAL	—

B. DIGGING

Depth (m)	Diam (m)	Unit Cost (per m)	TOTAL
4·10	–	60-00	246-00
		B. SUB-TOTAL	246-00

C. OTHER OPERATIONS

Item	Unit	Unit cost	Nº	Item price
Moving between sites (min K35)	km	3·50	MIN	35-00
Decamping and moving equipment	sum			
Rings and filter stone transport	km			
Rings and slabs installation	sum	25-00	1	25-00
Cleaning and disinfecting	sum	10-00	1	10-00
Mud plinth	sum	25-00	1	25-00
Pump installation	sum	10-00	1	10.00
C. SUB-TOTAL				105-00

INVOICE TOTAL

Sub Total	Amount
A. Siting	—
B. Digging	426-00
C. Others	105-00
D. Material	324-00
FINAL TOTAL	675-00

SUMMARY OF CONSTRUCTION DETAILS

Well depth (m)	4-10
Rest water level (m)	1·1

FORM A2 reverse

D. MATERIALS

ITEM	Unit	Unit cost	Nº	Item price	NOTES
Concrete Rings	no	20-00	3	60-00	
Bottom slab	no	20-00	1	20-00	
Top slab	no	20-00	1	20-00	
110mm Guiding PVC pipe	m		—		
63 mm PVC rising main pipe	m		—		
25 mm PVC pump rod	m		—		
Foot value	no		—		
Plunger	no		—		
Solvent cement	tin		—		
Cleaning fluid	tin		—		
Filter stones	sum		—		
Cement	pkts	8-00	8	64-00	
Pump~~head~~ Complete	no	160	1	160-00	

D(1) Total material cost	324-00
D(2) Material cost carried over (where different)	

FORM A2 front

JOB CHARGING SHEET

OFFICE OF THE PRESIDENT AND CABINET
DEPARTMENT OF LANDS, VALUATION AND WATER
(GROUND WATER SECTION)
DUG - WELL JOB CHARGING SHEET

WELLS SUPERVISOR M.SAMBA
COSTED BY Chawula

~~Client~~/Project Liuuezi
Location Chachuka
Grid reference
Deposit recieved date

Well Nº W 16
Crew Nº II
Digging started 21/5/82
Digging completed 27/5/82
Final completion 11/7/82
Ledger folio Nº

A. SITING

Item	Price
Desk Study	
Siting	
Extra	
Vehicle km	
A SUB-TOTAL	

B. DIGGING

Depth (m)	Diam (m)	Unit Cost (per m)	TOTAL
5-00		60-00	300-00
		B. SUB-TOTAL	300-00

C. OTHER OPERATIONS

Item	Unit	Unit cost	Nº	Item price
Moving between sites (min K35)	km	7-50	MIN	35-00
Decamping and moving equipment	sum	—	—	
Rings and filter stone transport	km	—	–	
Rings and slabs installation	sum	25-00	1	25-00
Cleaning and disinfecting	sum	10-00	1	10-00
Mud plinth	sum	25-00	1	25-00
Pump installation	sum	10-00	1	10-00
C. SUB-TOTAL				105-00

INVOICE TOTAL

Sub Total	Amount
A. Siting	
B. Digging	300-00
C. Others	105-00
D. Material	324-00
FINAL TOTAL	729-00

SUMMARY OF CONSTRUCTION DETAILS

Well depth (m)	5
Rest water level (m)	1·8

FORM A2 reverse

D MATERIALS

ITEM	Unit	Unit cost	Nº	Item price	NOTES
Concrete Rings	no	20-00	3	60-00	
Bottom slab	no	20-00	1	20-00	
Top slab	no	20-00	1	20-00	
110mm Guiding PVC pipe	m		—		
63mm PVC rising main pipe	m		—		
25 mm PVC pump rod	m		—		
Foot value	no		—		
Plunger	no		—		
Solvent cement	tin		—		
Cleaning fluid	tin		—		
Filter stones	sum				
Cement	pkts	8-00	8	64-00	
Pump~~head~~ complete set	no	160-00	1	160-00	

D(1) Total material cost	324-00
D(2) Material cost carried over (where different)	

FORM B2

JOB CHARGING SHEET (Front)

OFFICE OF THE PRESIDENT AND CABINET
DEPARTMENT OF LANDS, VALUATION AND WATER
(GROUND WATER SECTION)
BOREHOLE FUND JOB CHARGING SHEET

Client /Project: LIVULEZI PROJECT
Location: CHIMPUDZA
Grid Reference:
Deposit Received K........date........

Driller: TCHUBA
Rig №: 2221
Costed by: CHAVULA

Borehole №: GP 65
Drilling Started: 5-5-82
Drilling Completed: 10-5-82
Final Completion: 12-5-82
Ledger Folio №:

A. SURVEY

Item	Price
Desk study	
Survey	
Detailed Survey	
Extra days	
Extra Vehicle km	
A. SUB TOTAL	

B. DRILLING

Depth (m)	Diam. (mm)	Unit Cost (per m)	Total
0.0-15.0	200	30	450.0
15.0-26.5	200	40	460.0
B. SUB-TOTAL			910-00

C. OTHER OPERATIONS

Item	Unit	Unit Cost	№	Item Price
Moving between sites (min K35)	km	MINIMUM		35-00
Rigging up and down	sum	50	1	50-00
Bailer test	sum	5-00	2	10-00
Cleaning and development	hr	20-00	4	80-00
Test pumping, first 8 hours	hr	20	4	80-00
Test pumping, subsquent hours	hr			
Recovery measurements	hr	5	2	10-00
Analysis of test results	sum			
Slotting casing	m			
Cement grout and plinth	sum			
Operating vehicles	km			
C. SUB TOTAL				265-00

INVOICE TO CLIENT

Sub-Total	Amount
A Survey	
B Drilling	910-00
C Other	265-00
D Materials (From over)	451-26
E	
F	
G	
Remarks	
FINAL TOTAL	1626.26

SUMMARY OF CONSTRUCTION DETAILS

Borehole depth (m)	26.5
Rest water level (m)	9.3
4 Hour pump test yield (l/min)	15
4 Hour pump test pumping level (m)	24

FORM B2 reverse

JOB CHARGING SHEET
D. MATERIALS

Item	Unit	Unit Cost	Nº	Item Price	Notes
Plain casing	m	8-02	12.03	96-48	
Slotted casing	m	14-73	14.71	216-68	
Bottom cap	no	4-00	1	4-00	
Centralisers	no	0-38	15	5-70	
Solvent cement	tin	6-80	0.5	3-40	
Cleaning fluid	tin	2-00	1	2-00	
Gravel pack	m^3	60-00	1.8	108-00	
Cement	pocket				
Pumphead	no				
Rising main	m				
Pump rods	m				
Cylinder	no				
Charcoal	bag	5	3	15-00	

$D_{(1)}$ Total material cost	451-26
$D_{(2)}$ Material cost carried over (where different)	

Client /Project LIVULEZI PROJECT
Location MAZONDA
Grid Reference
Deposit Received K .... date ....

JOB CHARGING SHEET (Front)

OFFICE OF THE PRESIDENT AND CABINET
DEPARTMENT OF LANDS, VALUATION AND WATER
(GROUND WATER SECTION)
BOREHOLE FUND JOB CHARGING SHEET
Driller CHITANKALI
Rig Nº 2408 2402
Costed by CHAVULA

FORM B2

Borehole Nº GP 67
Drilling Started 11-5-82
Drilling Completed 17-5-82
Final Completion 18-5-82
Ledger Folio Nº

A. SURVEY

Item	Price
Desk study	
Survey	
Detailed Survey	
Extra days	
Extra Vehicle km	
A. SUB TOTAL	

B. DRILLING

Depth (m)	Diam. (mm)	Unit Cost (per m)	Total
0.0–15.0	200	30	450.00
15.0–21.5	200	40	260.00
21.5–21.8	150	30	9.00
B. SUB TOTAL			719

C. OTHER OPERATIONS

Item	Unit	Unit Cost	Nº	Item Price
Moving between sites (min K35)	km	MINIMUM		35.00
Rigging up and down	sum	50	1	50.00
Bailer test	sum	5	6	30.00
Cleaning and development	hr	20	1	20.00
Test pumping, first 8 hours	hr	20	5	100.00
Test pumping, subsequent hours	hr			
Recovery measurements	hr	5	2.5	12.50
Analysis of test results	sum			
Slotting casing	m			
Cement grout and plinth	sum			
Operating vehicles	km			
C. SUB TOTAL				247.50

INVOICE TO CLIENT

Sub-Total	Amount
A Survey	
B Drilling	719
C Other	247.50
D Materials	264.72
(From over)	
E	
F	
G	
Remarks	
FINAL TOTAL	1231.22

SUMMARY OF CONSTRUCTION DETAILS

Borehole depth (m)		21.8
Rest water level (m)		14.5
4	Hour pump test yield (l/min)	45
4	Hour pump test pumping level (m)	21

FORM B2 reverse

JOB CHARGING SHEET
D. MATERIALS

Item	Unit	Unit Cost	Nº	Item Price	Notes
Plain casing	m	8-02	19.3	154-79	
Slotted casing	m	14-73	3.0	44-19	
Bottom cap	no	4-00	1	4-00	
Centralisers	no	0-38	3	1-14	
Solvent cement	tin	6-80	0.5	3-40	
Cleaning fluid	tin	2-00	1	2-00	
Gravel pack	m^3	60	0.42	25-20	
Cement	pocket				
Pumphead	no				
Rising main	m				
Pump rods	m				
Cylinder	no				
Charcoal	bag	5	6	30-00	

$D_{(1)}$ Total material cost	264-72
$D_{(2)}$ Material cost carried over (where different)	

FORM B2

JOB CHARGING SHEET (Front)

OFFICE OF THE PRESIDENT AND CABINET
DEPARTMENT OF LANDS, VALUATION AND WATER
(GROUND WATER SECTION)
BOREHOLE FUND JOB CHARGING SHEET

Client /Project: LIVULEZI PROJECT
Location: KACHAMBA
Grid Reference: ....
Deposit Received K: ...... date: ......

Driller: CHITAUKALI
Rig Nº: 365E
Costed by: CHAVULA

Borehole Nº: GP 72
Drilling Started: 22-5-82
Drilling Completed: 26-5-82
Final Completion: 1-6-82
Ledger Folio Nº: ....

A. SURVEY

Item	Price
Desk study	
Survey	
Detailed Survey	
Extra days	
Extra Vehicle km	
A. SUB TOTAL	

B. DRILLING

Depth (m)	Diam. (mm)	Unit Cost (per m)	Total
0.0-14.2	·200	30	426-00
B. SUB TOTAL			426-00

SUMMARY OF CONSTRUCTION DETAILS

Borehole depth (m)	14·2	
Rest water level (m)	2·67	
4	Hour pump test yield (l/min)	30
4	Hour pump test pumping level (m)	12

C. OTHER OPERATIONS

Item	Unit	Unit Cost	Nº	Item Price
Moving between sites (min K35)	km	MINIMUM		35-00
Rigging up and down	sum	50	1	50-00
Bailer test	sum	5	4	20-00
Cleaning and development	hr	20	2	40-00
Test pumping, first 8 hours	hr	20	4	80-00
Test pumping, subsquent hours	hr			
Recovery measurements	hr	5	1	5-00
Analysis of test results	sum			
Slotting casing	m			
Cement grout and plinth	sum			
Operating vehicles	km			
C. SUB TOTAL				233-50

INVOICE TO CLIENT

Sub-Total	Amount
A Survey	
B Drilling	426-00
C Other	230-00
D Materials	385-05
(From over)	
E	
F	
G	
Remarks	
FINAL TOTAL	1041·05

FORM B2 reverse

JOB CHARGING SHEET

D. MATERIALS

Item	Unit	Unit Cost	Nº	Item Price	Notes
Plain casing	m	8-02	3.11	24-95	
Slotted casing	m	14-73	11.89	175-14	
Bottom cap	no	4-00	1	4-00	
Centralisers	no	0-38	12	4-56	
Solvent cement	tin	6-80	0.5	3-40	
Cleaning fluid	tin	2-00	1	2-00	
Gravel pack	m^3	60-00	2.6	156-00	
Cement	pocket				
Pumphead	no				
Rising main	m				
Pump rods	m				
Cylinder	no				
Charcoal	bag	5	3	15-00	

$D_{(1)}$ Total material cost	385-05
$D_{(2)}$ Material cost carried over (where different)	

FORM D1

MONTHLY DIARY SHEET

PROJECT: LIVULEZI MONTH: MAY

Please indicate team title and supervisor :-

DRILLING TEAM: RIG Nº 2408
DUG WELL TEAM Nº

APRON TEAM: Nº
PUMP TEAM: Nº

SUPERVISOR: CHITAUKALI

DATE	DAY	MORNING ACTIVITY:*	WATERPOINT NUMBER**	AFTERNOON ACTIVITY:*	WATERPOINT NUMBER**
1	S				
2	S	LONG WEEKEND			
3	M				
4	T	Repairing rig	GP 61	Repairing rig	GP 61
5	W	Drilling	GP 61	Drilling	GP 61
6	T	Drilling	GP 61	Drilling	GP 61
7	F	Inserting PVC	GP 61	Inserting PVC	GP 61
8	S	Inserting PVC	GP 61	Inserting PVC	GP 61
9	S				
10	M	Pump Test	GP 61	Pump Test	GP 61
11	T	Rigging up + down	GP 67	Drilling	GP 67
12	W	Drilling	GP 67	Drilling	GP 67
13	T	Drilling	GP 67	Drilling	GP 67
14	F	HOLIDAY			
15	S				
16	S				
17	M	Drilling	GP 67	Drilling	GP 67
18	T	Pump Test	GP 67	Pump Test	GP 67
19	W	Rigging up + down	GP 71	Drilling	GP 71
20	T	Drilling	GP 71	Drilling	GP 71
21	F	Drilling	GP 71	Drilling	GP 71
22	S	Inserting PVC	GP 71	Inserting PVC	GP 71
23	S				
24	M	Pump Test	GP 71	Pump Test	GP 71
25	T	Rigging up + down	GP 73	Drilling	GP 73
26	W	Drilling	GP 73	Drilling	GP 73
27	T	Drilling	GP 73	Drilling	GP 73
28	F				
29	S	LONG WEEKEND			
30	S				
31	M				

SUMMARY OF MONTH'S ACTIVITIES

A. DIRECT COST TEAM DAYS

	Waterpoint number	Number of days
1	GP 61	5
2	GP 67	5
3	GP 71	5
4	GP 73	3
5		
6		
	TOTAL:	18

B. INDIRECT COST TEAM DAYS

	ACTIVITY	NUMBER OF DAYS
1	Waiting for materials	
2	Waiting for repairs	1
3	Moving between sites	
4	Working on abandoned waterpoint	
5	Funerals	
6	Other	1
	TOTAL:	2

* enter operation e.g. drilling, digging, moving between sites, waiting for materials, etc.

** insert waterpoint number for normal operations (direct cost) such as drilling, digging, casing, gravel packing, developing, testing, Insert 0 for all indirect cost operations as listed in B) above.

FORM D1

MONTHLY DIARY SHEET

PROJECT: LIVULEZI MONTH: MAY

Please indicate team title and supervisor :-

DRILLING TEAM: RIG Nº 222

DUG WELL TEAM Nº

APRON TEAM: Nº

PUMP TEAM: Nº

SUPERVISOR:

DATE	DAY	MORNING ACTIVITY:*	WATERPOINT NUMBER**	AFTERNOON ACTIVITY:*	WATERPOINT NUMBER**
1	S				
2	S	LONG WEEKEND			
3	M				
4	T	Moving to GP 65	0	Moving to GP 65	0
5	W	Rigging up	GP 65	Drilling	GP 65
6	T	Drilling	GP 65	Drilling	GP 65
7	F	Drilling	GP 65	Drilling	GP 65
8	S	Drilling	GP 65	Drilling	GP 65
9	S				
10	M	Drilling	GP 65	Drilling	GP 65
11	T	Developing	GP 65	Developing	GP 65
12	W	Pump Test	GP 65	Pump Test	GP 65
13	T	Repairs	0	Repairs	0
14	F	Holiday		Holiday	
15	S	Repairs	0	Repairs	0
16	S				
17	M	Repairs	0	Repairs	0
18	T	"	0	"	0
19	W	"	0	"	0
20	T	"	0	"	0
21	F	"	0	"	0
22	S	"	0	"	0
23	S				
24	M	Repairs	0	Repairs	0
25	T	"	0	"	0
26	W	"	0	"	0
27	T	"	0	"	0
28	F				
29	S	LONG WEEKEND			
30	S				
31	M				

SUMMARY OF MONTH'S ACTIVITIES

A. DIRECT COST TEAM DAYS

	Waterpoint number	Number of days
1	GP 65	7
2		
3		
4		
5		
6		
	TOTAL:	7

B. INDIRECT COST TEAM DAYS

	ACTIVITY	NUMBER OF DAYS
1	Waiting for materials	
2	Waiting for repairs	12
3	Moving between sites	1
4	Working on abandoned waterpoint	
5	Funerals	
6	Other	
	TOTAL:	13

* enter operation e.g. drilling, digging, moving between sites, waiting for materials, etc.

** insert waterpoint number for normal operations (direct cost) such as drilling, digging, casing, gravel packing, developing, testing, Insert 0 for all indirect cost operations as listed in B) above.

FORM D2

SUMMARY OF MONTHLY DIARY SHEETS

PROJECT *Livulezi* MONTH *MAY*

A. DIRECT COST TEAM DAYS — BOREHOLES

RIG NUMBER	2406						Sub Total 1	2221						Sub Total 2
	1	2	3	4	5	6		1	2	3	4	5	6	
BOREHOLE NUMBER:	GP66	GP70	GP74					GP65						
NUMBER OF DAYS:	3	4	3				10	7						7
RIG NUMBER:	2408						Sub Total 3	365E						Sub Total 4
	1	2	3	4	5	6		1	2	3	4	5	6	
BOREHOLE NUMBER:	GP61	GP67	GP71	GP73				GP63	GP68	GP72				
NUMBER OF DAYS:	5	5	5	3			18	4	7	5				16

TOTAL DIRECT COST TEAM DAYS = SUBTOTALS 1 [10] +2 [7] +3 [18] +4 [16] = [51]

B. DIRECT COST TEAM DAYS — DUG WELLS

WELL TEAM NO:	I						Sub Total 1	II						Sub Total 2
	1	2	3	4	5	6		1	2	3	4	5	6	
DUG-WELL NUMBER:	W17							W13	W15	W16				
NUMBER OF DAYS:	4						4	3	5	5				13
WELL TEAM Nº :							Sub Total 3							Sub Total 4
	1	2	3	4	5	6		1	2	3	4	5	6	
DUG-WELL NUMBER:														
NUMBER OF DAYS:														

TOTAL DIRECT COST TEAM DAYS = SUBTOTALS 1 [4] +2 [13] +3 [ ] +4 [ ] = [17]

C. INDIRECT COST TEAM DAYS - BOREHOLES

	RIG NO:	2406	2408	2221	365E	
	ACTIVITY	No of days	No of days	No of days	No of days	TOTALS
1	AWAITING MATERIALS					
2	AWAITING REPAIRS		1	12	2	15
3	MOVING BETWEEN SITES	3		1	2	6
4	WORKING ON ABANDONED BORE HOLES	6				6
5	FUNERALS		1			1
6	OTHERS	3				3
	TOTALS	12	2	13	4	31

To Form C1 Table 6

D. INDIRECT COST TEAM DAYS - DUG WELLS

	WELL TEAM Nº	I	II			
	ACTIVITY					TOTALS
1	AWAITING MATERIALS					
2	AWAITING REPAIRS					
3	MOVING BETWEEN SITES	1	2			3
4	WORKING ON ABANDONED DUG-WELLS	10				10
5	FUNERALS					
6	OTHER	5	4			9
	TOTALS	16	6			22

To Form C1 Table 6

OVERHEADS ANALYSIS	PROJECT: LIVULEZI	MONTH: MAY YEAR: 1982	FORM C1 (Front)

A PROJECT INDIRECT COSTS

CAMP:	1. LABOUR COSTS (from PSL)	=	1343-60	
	2. MATERIALS COSTS (from table 1)	=	152-80	
	3. EXPENSES (from table 2)	=	993-33	
	4. SUBTOTAL (1+2+3)			2489-73
TRANSPORT	5. FUEL etc (table 3)	=	857-23	
	6. EXPENSES (from table 4)	=	1409-00	
	7. NON-PROJECT VEHICLES COSTS (table 5)	=	1886-50	
	8. SUBTOTAL (5+6+7)			4152-73
	9. TOTAL PROJECT INDIRECT COSTS (4+8)	=		6642-46

B ALLOCATION OF TOTAL PROJECT INDIRECT COSTS

1. SHARE TO BOREHOLES	A.9 × 0.8	table 9(d)	=	5313-97	carry to C·8
2. SHARE TO DUG-WELLS	A.9 × 0.2	table 9(e)	=	1328-49	carry to C·8

C BOREHOLE / DUG WELLS INDIRECT COSTS

			BOREHOLES	DUG WELLS
LABOUR COSTS	1. SUPERVISORS (from PSL)		772-40	45-00
	2. TEAMS (from table 6)		352-16	94-60
	3. FOOTAGE BONUS (abandoned holes)		18-47	—
	4. TOTAL LABOUR COSTS (1+2+3)		1143-03	139-60
MATERIALS COSTS	5. (from table 7)		32-38	67-20
EXPENSES	6. (from table 8)		418-00	70-00
	7. TOTAL INDIRECT COSTS (4+5+6)	=	1593-41	276-80
ADD	8. SHARE OF PROJECT INDIRECT COSTS (From B)	=	5313-97	1328-49
	9. TOTAL OVERHEADS (7+8)	=	6907-38	1605-29
10. DIVIDE BY Nº OF DIRECT COST TEAM DAYS (from monthly summary of diary sheets)			51	17
11. RIG / WELL DAY-RATE		=	135-44	94-43

Table 1: PROJECT MATERIALS FORM C1 (reverse)

ITEM	CEMENT	HACKSAW BLADES					
UNIT COST	6-40	2-00					
QUANTITY	22	6					
TOTAL COST	140-80	12-00					152-80 (carry to A2)

Table 2: PROJECT EXPENSES (from PAR) (i.e. depreciation and maintenance of camp equipment)

ITEM	TENTS	CARAVANS	UNIPORTS	PRELIM EXPENSES			
MONTHLY CHARGE	500-00	208-33	75-00	210-00			993-33 (carry to A3)

Table 3: TRANSPORT FUEL AND OTHER MATERIALS

ITEM	PETROL	DIESEL	OIL	TTA OIL	BRAKE FLUID		
UNIT COST	0.84/ltr	0.78/ltr	3.50/ltr	4.25/ltr	1.62/ltr		
QUANTITY	673	300	10	5.2	0.5		
TOTAL COST	565-32	234-00	35-00	22-10	0-81		857-23 (carry to A5)

Table 4: TRANSPORT EXPENSES (from PAR) (depreciation and maintenance of vehicles)

ITEM	TRACTOR + TRAILER	LANDROVER P/u	DATSAN P/u	M'CYCLES (X4)			
MONTHLY CHARGE	385-00	426-00	310-00	288-00			1409-00 (carry to A6)

Table 5: TRANSPORT COSTS (non-project vehicles) (i.e. delivery vehicles)

VEHICLE	MG-837D 5-ton	MG-834D 5-ton	MG-6531 8-ton	MG 6685 10-ton	MG-279E 2-ton	MG-331E H'cycle	
RATE/km	0.50	0.50	0.80	0.80	0.40	0.10	
kms	396	474	1093	398	554	371	
TOTAL COST	198-00	237-00	874-40	318-40	221-60	37-10	1886-50 (carry to A7)

Table 6: INDIRECT COST TEAM DAYS boreholes/dug-wells

TOTALS (from Form D2)	boreholes	31	std team day rate	11-36	= 352-16	carry to C2 (boreholes)
	dug-wells	22	std team day rate	4-30	= 94-60	carry to C2 (wells)

Table 7: CONSTRUCTION OVERHEAD MATERIALS - boreholes / wells

ITEM	CHARCOAL	DIESEL	PETROL				
UNIT COST	4-00	0.78	0.84				
QTY - BOREHOLES	4	21					
COST - BOREHOLES	16-00	16-38					32-38 (carry to C3)
QTY - WELLS			80				
COST - WELLS			67-20				67-20 (carry to C3)

Table 8: CONSTRUCTION OVERHEADS EXPENSES - boreholes

ITEM	Rig 365E	2406	2408	2221			
MONTHLY CHARGE	292-00	42-00	42-00	42-00			418-00 (carry to C6)

wells

ITEM	Equip I	Equip II					
MONTHLY CHARGE	35-00	35-00					70-00 (carry to C6)

Table 9: ALLOCATION OF PROJECT INDIRECT COSTS

Number of borehole teams [4] × 2 = [8] (a)

Number of dug-well teams ---------------- [2] (b)

Total (a) + (b) = [10] (c)

Share of indirect costs allocated to boreholes = (a) ÷ (c) = [0.8] (d) carry to B1

Share of indirect costs allocated to dug-wells = (b) ÷ (c) = [0.2] (e) carry to B2

FORM C2

WATER POINT COST SHEET MONTH / YEAR: MAY/82

PROJECT: LIVULEZI — RIG/TEAM Nº: 2221 — BOREHOLE WATER POINT Nº: GP65 — REF:

SUPERVISOR: TCHUBA — CONSTRUCTION DATES: 5/5 TO 12/5 — NUMBER OF DIRECT COST TEAM DAYS: 7 (From form D2)

A. LABOUR COST

Standard team-day-rate 11.36 X no. of days 7 = 79-52 add footage bonus 26-50 = Total labour cost 106-02

B. MATERIALS COST

ITEM	PVC Plain	PVC Slotted	Centra-lizers	Bottom Cap	Solvent Cement	Cleaning Fluid	Chanel	Diesel	Grease	Oil						
PRICE	7.06/m	12.96/m	0.34 each	10.59 each	5.98 tin	2.27 tin	4.00 bag	0.78 ltr	2.00 Kg	3.50 ltr						
QUANTITY	12	14.7	15	1	1/2	1	3	35	–	–						
COST	84-72	190-51	5-10	10-59	2-99	2-27	12-00	27-30								

Total materials cost: 335-48

C. OVERHEADS

7 days @ rig/well day-rate 135-44 = 948-08

days @ rig/well day-rate =

Total Overheads = 948-08

D. COST SUMMARY

Total Direct Costs = A + B = 441-50

Total Indirect Costs = C = 948-08

Full Cost = A+B+C = 1389-58

E. INVOICE VALUE — Carried from invoice no. — = 1626-26

F. NET SURPLUS / DEFICIT = Invoice value – Full cost = 236-68

REMARKS

Compiled by: date: checked:

FORM C2

WATER POINT COST SHEET	MONTH / YEAR MAY/82	PROJECT LIVULEZI RIG/TEAM Nº MG 2408	BOREHOLE WATER POINT Nº GP67 REF

SUPERVISOR: G.B CHITAUKALI   CONSTRUCTION DATES 11 TO 18   NUMBER OF DIRECT COST TEAM DAYS 5 (From form D2)

A. LABOUR COST

Standard team-day-rate 11-36 X no of days 5 = 56-80 add footage bonus 21-50 = Total labour cost 178-30

B. MATERIALS COST

ITEM	PVC Plain	PVC Slotted	Centra-lizers	Bottom Cap	Solvent Cement	Cleaning Fluid	Charcoal	Diesel	Grease	Oil						
PRICE	7.06/m	12.96/m	0.34 each	10.59 each	5.98 Tin	2.27 Tin	4.00 bag	0.78 Litre	2.00 kg	3.50 litre						
QUANTITY	19.3	3.0	3	1	0.5	1	6	60	1	—						Total materials cost:
COST	136-26	38-88	1-02	10-59	2-99	2-27	24-00	46-80	2-00							264-81

C. OVERHEADS

5 days @ rig/well day-rate 135-44 = 677-20
days @ rig/well day-rate =
Total Overheads = 677-20

D. COST SUMMARY

Total Direct Costs = A + B = 343-11

Total Indirect Costs = C = 677-20

Full Cost = A+B+C = 1020-31

E. INVOICE VALUE Carried from invoice no. — = 1231-22

F. NET SURPLUS / DEFICIT = Invoice value − Full cost = 210-91

REMARKS

Compiled by: date: checked:

WATER POINT COST SHEET

MONTH / YEAR: MAY/82

PROJECT: LIVULE 21

RIG / TEAM Nº: 365

BOREHOLE

FORM C2

WATER POINT Nº: GP-72

REF:

SUPERVISOR: G.B CHITAUKALI

CONSTRUCTION DATES: 22 TO /

NUMBER OF DIRECT COST TEAM DAYS: 11 (From form D2)

A. LABOUR COST

Standard team-day-rate 11-36 X no. of days 6 = 68-16 add footage bonus 14-20 = Total labour cost 82-36

B. MATERIALS COST

ITEM	PVC Plain	PVC Slotted	Centra lizers	Bottom Cap	Solvent Cement	Cleaning Fluid	Charcoal	Diesel	Grease	Oil						
PRICE	7.06/m	12.96/m	0.34 each	10.59 each	5.98 tin	2.27 tin	4.00 bag	0.78 litre	2.00 kg	3.50 litre						
QUANTITY	3.11	11.89	12	1	0.5	1	3	20	1	—						
COST	21-96	154-09	4.08	10-59	2-99	2-27	12-00	15-60	2-00							

Total materials cost: 225-58

C. OVERHEADS

5 days @ rig/well day-rate 135-44 = 677-20

1 days @ rig/well day-rate 147-69 = 147-69

Total Overheads = 824-89

D. COST SUMMARY

Total Direct Costs = A + B = 307-94

Total Indirect Costs = C = 824-89

Full Cost = A+B+C = 1132-83

E. INVOICE VALUE Carried from invoice no. — = 1041-05

F. NET SURPLUS / DEFICIT = Invoice value – Full cost = (91-78)

REMARKS

Compiled by: date: checked:

WATER POINT COST SHEET MONTH / YEAR: MAY/82 | PROJECT: LIVULEZI | RIG/TEAM Nº: II | DUG WELL | FORM C2

WATER POINT Nº: W/5 | REF:

SUPERVISOR: MSAMBA | CONSTRUCTION DATES: 12/5 TO 18/5 | NUMBER OF DIRECT COST TEAM DAYS: 3 (From form D2)

A. LABOUR COST

Standard team-day-rate 4-30 X no. of days 3 = 12-90 add footage bonus [ ] = Total labour cost 12-90

B. MATERIALS COST

ITEM	PVC Plain 110mm	PVC Plain 63mm	Rings Large	Rings Small	Bottom Slab	Top Slab	Pillar	Pump	Rising Main	Cement						
PRICE	4.60/m	1.55/m	25-00	20-00	20-00	20-00	5-00	120-00	6.00/m	6.40 pag						
QUANTITY	1.2	1.2	–	3	1	1	1	1	3	8						
COST	5-52	1.86	–	60-00	20-00	20-00	5-00	120-00	18-00	51-20						

Total materials cost: 301-58

C. OVERHEADS

3 days @ rig/well day-rate 94-43 = 283-29

[ ] days @ rig/well day-rate [ ] = [ ]

Total Overheads = 283-29

D. COST SUMMARY

Total Direct Costs = A + B = 314-48

Total Indirect Costs = C = 283-29

Full Cost = A+B+C = 597-77

E. INVOICE VALUE Carried from invoice no. — = 675-00

F. NET SURPLUS / DEFICIT = Invoice value – Full cost = 77.23

REMARKS

Compiled by: date: checked:

WATER POINT COST SHEET

MONTH / YEAR: MAY/82

PROJECT: LIVULEZI

RIG/TEAM Nº: II

DUG WELL

FORM C2

WATER POINT Nº: W16

REF:

SUPERVISOR: MSAMBA

CONSTRUCTION DATES: 21/5 TO 27/5

NUMBER OF DIRECT COST TEAM DAYS: 6 (From form D2)

A. LABOUR COST

Standard team-day-rate 4-30 X no. of days 6 = [ ] add footage bonus [ ] = Total labour cost 25-80

B. MATERIALS COST

ITEM	PVC Plain 110mm	PVC Plain 63mm	Rings Large	Rings Small	Bottom slab	Top Slab	Pillar	Pump	Rising Main	Cement						
PRICE	4.60/m	1.55/m	25-00	20-00	20-00	20-00	5-00	120-00	6.00/m	6.40 bag						
QUANTITY	2.10	2.10	–	3	1	1	1	1	3	8						
COST	9-66	3-26	–	60-00	20-00	20-00	5-00	120-00	18-00	51-20						

Total materials cost: 307-12

C. OVERHEADS

6 days @ rig/well day-rate 94-43 = 566-58

[ ] days @ rig/well day-rate [ ] = [ ]

Total Overheads = 566-58

D. COST SUMMARY

Total Direct Costs = A + B = 332-92

Total Indirect Costs = C = 566-58

Full Cost = A+B+C = 899-50

E. INVOICE VALUE — Carried from invoice no. [—] = 729-00

F. NET SURPLUS / DEFICIT = Invoice value – Full cost = (170-50)

REMARKS

Compiled by: date: checked:

FROM : Planning Economist DLVW

TO : Project Hydrogeologist, Upper Livulezi Integrated Project

PROJECT COST MONITORING - ANALYSIS AND REPORT

PROJECT : Livulezi MONTH : May, 1982

(Please refer to the Overheads Analysis sheet [Form C.1] for May, 1982, the Monthly Summary of Costs and Charges, and the Summary of Monthly Diary Sheets [Form D.2]).

1. INTRODUCTION

During May there were four borehole teams and two dug-well teams working in the Livulezi Project. The costs and charges for the nine boreholes and the three dug wells which were started during May are summarised in the Monthly Summary of Costs and Charges (note that the costs are for boreholes without handpumps and aprons, while for dug wells the costs include pumps and aprons). The costs of the boreholes averaged K1,164, while the invoices averaged K1,308. Thus the charges gave a slight margin over costs, and both costs and charges were close to the target of K1,250. The dug-well costs averaged K790, slightly above the target of K750, while the invoice charges fell a little below this at K711. In both cases indirect costs made up the greater part of full costs (nearly two-thirds). It is these indirect costs which require the closest analysis and most stringent control. The direct costs offer little room for cost reduction, so long as the teams exercise reasonable care in their use of materials. The indirect costs, on the other hand, offer much greater scope for cost saving. They are considered in more depth in the following section.

2. INDIRECT COSTS

The indirect costs borne by a waterpoint is determined by the number of days worked on the waterpoint and on the Rig or Well Day-Rate. The Day-Rate in turn depends on two key factors:

a) the total overheads
b) the number of direct-cost days

The Day-Rate can be reduced only by reducing a) or increasing b) or both.

a) Total overheads

In May the total overheads borne by boreholes was K6,907, of which K5,313 (or 77%) was the share of Project Indirect Costs to boreholes [see Section B of Form C.1]. The total overheads for dug wells was K1,605, of which K1,328 (or 83%) was the share of Project Indirect Costs. Clearly the major part of total overheads for both types of waterpoint was the share of Project Indirect Costs. We can see from Form C.1 Part A that of the total of K6,643, some K4,153 (or 63%) was due to transport. The largest single item was non-project vehicle costs, at K1,887 (or 28% of total Project Indirect Costs). This item deserves closer scrutiny and tighter control, making sure, for example, that materials delivery trips are organised as efficiently as possible. No other item under Project Indirect Costs offers much scope for cost saving.

b) Number of Direct-Cost Days

In May the borehole teams worked a total of 82 team-days, of which only 51 (or 62%) were Direct Cost Team Days. The major cause of lost days was "awaiting repairs". One rig suffered a major breakdown and was out of action for 12 days. The dug-well teams worked a total of 39 team-days, of which only 17 (or 44%) were Direct-Cost Team Days. Ten days were lost working on an abandoned dug well, and nine days were lost for unspecified "other" reasons. Clearly there is room for improvement here. Reducing the number of days lost, by improving rig maintenance and repair facilities for example, could significantly reduce the Rig and Well Day Rates. The Project Management should give considerable attention to this point. Another way of increasing the number of Direct-Cost Team Days would be to bring in more construction teams. This would, of course, raise some of the overheads costs, but this increase in total overheads might easily be offset by the greater number of Direct-Cost Team Days over which to spread the costs. It is an option worth careful consideration.

3. CONCLUSION AND RECOMMENDATIONS

The performance of the Project in May was satisfactory, with the average waterpoint costs and charges being more or less on target. There is, however, room for improvement. Specifically, attention should be

given to the following points:

1) Controlling the non-project vehicle costs

2) Reducing the proportion of team-days lost as Indirect Cost Team Days

3) Appraising the possibility of using more construction teams

PLANNING ECONOMIST
(Planning Section, Water Division, DLVW)

MONTHLY SUMMARY OF COSTS AND CHARGES

PROJECT : Livulezi

MONTH : May, 1982

Waterpoint No.	Direct Costs	Indirect Costs	Full Fosts	Invoice Value	Net surplus (deficit)
Boreholes					
GP 65	441.50	948.08	1,389.58	1,626.26	236.68
GP 66	317.78	406.32	724.10	1,276.94	552.84
GP 67	343.11	677.20	1,020.31	1,231.22	210.91
GP 68	421.51	1,083.52	1,505.03	1,348.66	156.37
GP 70 B	294.64	837.14	1,131.78	953.55	(178.23)
GP 71	352.13	677.20	1,029.33	1,210.34	181.01
GP 72	307.94	824.89	1,132.83	1,041.05	(91.78)
GP 73	461.14	849.39	1,310.53	1,729.37	418.84
GP 74	380.65	849.39	1,230.04	1,355.69	125.65
Total	3,320.40	7,153.13	10,473.53	11,773.08	1,299.55
Average	368.93	794.79	1,163.73	1,308.12	144.39
Wells					
W 15	314.48	283.29	597.77	675.00	77.23
W 16	332.92	566.58	899.50	729.00	(170.50)
W 17	334.15	539.25	873.40	729.00	(144.40)
Total	981.55	1,389.12	2,370.67	2,133.00	(237.67)
Average	327.18	463.04	790.22	711.00	(79.22)

14. MANAGEMENT

14.1. INTRODUCTION

14.1.1. The Section on staffing [Chapter C] opened with the simple and obvious statement that one pre-requiste for the success of an Integrated Project is suitably-trained and well-motivated staff. A further essential pre-requisite for success is good Project Management.

14.1.2. The difficulties of the previous dispersed national borehole programme have been mentioned at several points in the Manual [particularly in Chapter A]. One of the main difficulties of a programme in which the individual drilling rigs and dug-well teams are widely scattered over the country is effective management and supervision. Neither sound technical practice, timely decision-making nor efficient operations can be achieved. In contrast, the close concentration of plant and vehicles possible (and necessary) in an Integrated Project provide exactly the right basis for good technical and logistical management. This has been a major consideration in the evolution of the Integrated Projects. This Section discusses the management concepts and tools that have developed from experience to date in the Upper Livulezi and Dowa West Integrated Projects and are appropriate for the young professional field staff who will be running Projects without any formal management training.

14.2. MANAGEMENT OBJECTIVES

14.2.1. Stated in the simplest terms, the management objectives are to achieve the Integrated Project objectives and to meet the production targets. The Project objectives will have been stated in the Project Submission Document [Chapter B] - perhaps in slightly different words - but can be summarised as:

> *the provision of well designed and constructed waterpoints to give clean water throughout the year to the design population at design consumption levels [Chapter B] in such a way that the life of the supply will be maximised, all for the minimum necessary cost.*

14.2.2. Looking at the Project objectives as they are summarised above, three distinct (but linked) aspects of management's role can be defined:

a) to supervise and direct technical activities to ensure good design and construction

b) to stimulate at every opportunity the sense of ownership that comes from community involvement, in order to maximise the life of the supplies through a village-based maintenance structure

c) to control all cost-related activities of the Project.

The cost accounting described in Section 13 shows quite clearly how the Project costs money even when no construction is going on. The desire for minimum necessary cost, therefore, implies speed and continuity of operations but it must be a management objective to ensure that this is achieved without jeopardising community and staff relations or the quality of the waterpoints.

14.3. MEETING THE OBJECTIVES

14.3.1. *Technical Management*

Meeting the objective of providing clean water throughout the year to the design population at design consumption levels requires technical expertise to:

a) evolve good design and construction principles

b) implement good design and construction practice.

Many of the design and construction principles and practices will have been evolved in previous Integrated Projects. It is, nevertheless, the role of management continuously to appraise these principles and practices critically and communicate any proposals for improvement to Headquarters for discussion and possible inclusion in current and future Projects. Good examples of this are:- the improvement to apron designs during the course of the Upper Livulezi Project; the development of improved siting procedure in the Dowa West Project; the much more careful planning and preparation procedure that has been developed for the Dedza Hills Project. On a day-to-day basis the objective of technical management is to ensure that the design

and construction practice of the Integrated Project is correctly implemented by using the technical skills of all the staff appropriately to each task, as set out in Table D.14.1. This shows the highest level of staff whose essential involvement is required for each activity. It is, for example, essential for the professional staff to be fully involved in borehole design, which is to instruct that drilling should stop, to design the screen setting [Section 3] and to supervise the placing of the gravel pack in each borehole. Drilling itself, however, is undertaken by the rig headm n and crews with occasional visits from the drilling supervisors. The Table also shows very clearly the differences between the levels of skills required for dug-well and borehole construction and consequently the much lower level of community involvement in the latter. The need for relevant professional skills right through the construction process from siting to maintenance training emphasises that Project management must be carried out by trained and experienced hydrogeologists.

14.3.2. *Management and the Community*

The objective of ensuring a long operating life for the Project is hopefully met by building up the sense of community ownership of waterpoints so that there is the incentive to maintain them. The role of management in achieving this is to make sure that the community is fully involved in the Project by performing the tasks summarised in Section 9 and described in detail in the appropriate Sections of the Manual. All levels of Project staff have a full-time commitment to the task of informing, motivating, involving and educating the community. In addition, management should ensure that staff of other Government departments are carrying out their agreed tasks as contributions to the other activities associated with the Integrated Projects such as waterpoint gardens, sanitation, low-cost housing and health education. It is the particular responsibility of management to ensure that commitments made by staff of other Departments to the community at the main Project meetings are acted upon. If the community feels let down by lack of commitment from Government Departments, their own contribution may be less forthcoming and the objectives of the Project will suffer.

14.3.3. *Management and Cost Control*

To achieve the objective of implementing the Project for the minimum necessary cost, management must control all cost-related activities of the Project. In order to do this, there must be the most cost-effective combination of:

- the right quantity, eg number of staff
- the right suitability, eg type of vehicle
- the right use on Project activities

for each of these components of the Project:

- staff
- vehicles
- plant and equipment
- materials.

This concept is best explained by examples. An extreme and obviously nonsensical example of too many, unsuitable staff poorly used would be to have a hydrogeologist with a pickup stationed continuously at each rig observing every operation. In contrast the chosen cost-effective way of achieving good borehole construction is to have one drilling supervisor responsible for two rigs, visiting each regularly on a motorcycle to supervise operations [Table D.14.1] and backed up by a hydrogeologist responsible for four rigs, also visiting on a motorcycle but only to supervise the most critical activities [Table D.14.1].

14.4. MANAGEMENT TOOLS

14.4.1. *Chain of Command*

An essential management requirement is a chain of command which everyone in the Project understands. Organising a Project with the right number of suitable staff [see above] implies the delegation of authority through the chain of command, with the parallel implication of delegation of responsibility. It is particularly important for middle-level supervisory staff to be fully aware of their responsibilities and giving them written job descriptions [see Staffing in Chapter C] at the beginning of the Project may be a great help in this respect.

In the Integrated Projects the chain of command stretches right from Headquarters in Lilongwe through the management team of

Table D. 14. 1. MANAGEMENT GUIDE TO STAFF DEPLOYMENT ON TECHNICAL ACTIVITIES

Technical Activity	Professional Management	Technical Supervisor	Skilled Teams	Unskilled Village
1. Siting	✓			✓
2. Boreholes				
(a) drilling		✓×	✓	
(b) bailer testing	✓×	✓	✓	
(c) design	✓			
(d) casing installation		✓	✓	
(e) gravel packing	✓	✓	✓	
(f) developing	✓×	✓	✓	
(g) test pumping		✓×	✓	
3. Dug - wells				
(a) digging				
(b) deepening		✓×	✓	✓
(c) design	✓			
(d) lining		✓×	✓	✓
(e) completion		✓×	✓	✓
4. Pumps				
(a) design setting	✓×	✓		
(b) installation		✓×	✓	✓
5. Apron Construction		✓×	✓	✓
6. Maintenance Training	✓	✓	✓	✓

✓ full - time involvement

✓× partial involvement – occasional supervision

hydrogeologists to the supervisors, foremen and rig headmen, the skilled team members and down to the unskilled labour provided by the community. It is important that the chain of command is observed; communication should always be from one level to the next, in both directions. For example, referring to the Project staffing structure [Figure C.6.1], if a well-digging team has a well ready for pump installation, they should not themselves ask the installation team to come there. Instead, they should report through the dug-well foreman to the dug-well supervisor who will arrange with management for the pump supervisor to fit it into the installation programme as soon as possible. Similarly the dug-well team should not request the tractor driver directly to move them to another site. It is especially important for transport requirements to be channelled through the supervisory staff.

A clear chain of command becomes particularly important when a contractor is carrying out the drilling. In any contractual relationship it is essential for both parties to know who is giving instructions and who is receiving them. It is customary [Chapter C] to inform each other in writing of the names of Contractor's and Project's Representative and any changes of Representative. Further, all management and supervisory staff directly involved in inspecting the contractor's work and giving instructions must be fully conversant with the conditions and technical specifications of the contract. It is also customary to give instructions, in writing, to the Contractor's Representative retaining a copy for the Project in case any misunderstandings arise (a duplicate book must be kept specifically for this purpose). Supervising a drilling contract is a difficult task; a hydro-geologist who will be faced with this problem in an Integrated Project should seek advice from others who have had experience of contract supervision.

14.4.2. *Communication*

Communication is the means by which the management chain of command is made to function. There are three principal means of communication:

a) A formal system of reporting is essential to provide information to management on whether production targets are being achieved in terms of design and costs and, if they are not, what are the problems?

The system by which each of the staff levels in the Integrated Projects reports to the next higher level is summarised in Table D.14.2. Examples of most of the forms are included in Section 12 on Stores or in Section 13 on Cost Monitoring.

b) The second means of communication is the feedback that the reporting is designed to generate. In the case of the verbal daily reporting, feedback may be immediate, in the form of verbal advice or an instruction. In the case of monthly costing reports the feedback may be much slower. The process can be summarised:

Information →

skilled teams ⇄ supervisors ⇄ management ⇄ headquarters

← Advice and instructions

Adequate, reliable and regular reporting permits continuous feedback into the management of the Project to :

- improve design and construction principles and practices
- identify where cost savings can be made
- relate actual expenditure to budget control requirements
- identify and rectify problems if production targets are not being met
- improve management itself.

c) The third means of communication is the holding of Project meetings. The routine meetings held by the hydrogeologists during waterpoint siting have already been described [Sections 2 and 9]. These are not strictly management meetings but they are the main means of keeping the community informed at a local level. Thus, these meetings are the community's chance to report to the Project and receive feedback from it, and vice versa. In addition to these routine meetings, further meetings may be called whenever required to resolve problems between the Project and the community, for example if something has been stolen [Section 9]. Personal or staff problems within the Project may also warrant the calling of ad hoc meetings.

Experience in the Upper Livulezi Project has shown that regular monthly meetings of all Project staff can be a very useful aid to

Table D.14.2

Summary of Reporting System for Integrated Projects

PERIOD	REPORT FROM	REPORT TO	FORM OF REPORT
1. Daily	a) drilling teams	drilling supervisors	Daily Drilling Report
	b) all skilled teams	supervisors	Daily verbal Reports
	c) drivers	supervisors	Check vehicle log books
	d) supervisors	management	Evening verbal report
	e) management	headquarters	Morning radio schedule
2. After Waterpoint Completion (ie about weekly)	a) supervisors	management	Dug-well construction reports [A.1] Borehole construction reports [B.1]
3. Weekly	a) supervisors	management	Regular checks of team Monthly Diary Sheets [D.1]
	b) storeman	management	Stores requisition from reorder levels
	c) management	headquarters	Stores requisition
4. Monthly	a) supervisors	management	Completed diary sheets [D.1], Overtime claims, Night allowance claims, Footage bonus claims
	b) stores	management	Visiting Vehicles Notebook [VVN], Monthly Analysis of Materials Issued [MAMI]
	c) management	all staff	Monthly Seminar [see text]
	d) management	headquarters	Overheads Analysis [C.1] Dug-well and borehole Charging Sheets [A.2, B.2] Dug-well and borehole Cost sheets [C.2] Summary Report of Monthly Progress, Completed Cardex cards for bore-holes, Claim forms
	e) headquarters	management	Cost analysis and report for previous month with cost control advice
5. End of Project Construction	a) Management and headquarters		Final Project Report and Analysis of Costs
6. Project Operation	a) ——— headquarters ———		Maintenance Monitoring and Supervision [chap. E]
	b) ——— headquarters ———		Project Evaluation Reports

management. The meetings are held in the form of a half-day seminar chaired by the Project hydrogeologist and provide an opportunity for the skilled and unskilled junior staff to communicate directly with management. The seminar includes the following topics:

- monthly progress report from each supervisor
- plans for the following month
- a study topic, eg community development, borehole construction, dug wells, handpumps, health
- problems, eg personal, administrative, staff relationships, technical.

14.4.3. An additional requirement for good Project management is to develop the management skills of the Project hydrogeologists. In addition to professional skills in their own subject (themselves a necessary basis for good management) the hydrogeologists need to be highly motivated to make the Project a success. They are in fact the key personnel who determine the success or failure of the Project by their sense of responsibility, sympathy for and action on behalf of their staff and the community and by the level of respect with which they are treated by the community. It is also clear that senior Groundwater Section staff at Headquarters in Lilongwe, and above them senior Branch, Division, Department and Ministry staff respectively all have a role to play in ensuring adequate support for the Project.

15. WATER AND HEALTH

15.1. INTRODUCTION : THE RELATIONSHIP BETWEEN WATER AND HEALTH

15.1.1. In an Integrated Project a considerable amount of effort and funding goes into providing a supply of good clean water. Nevertheless, the resultant impact on health may be minimal if health education and improved sanitation are ignored. It is indisputable that an adequate supply of clean drinking water is a prerequisite for good health, but it should be emphasised that the mere provision of improved water supplies does not significantly reduce the occurrence of water-related diseases. The reason for this is that it is possible (and more frequent) for most of these diseases to be spread by the more direct "faecal-oral route" whereby traces of human faecal matter are passed, by various routes, from excreta to the mouth.

15.1.2. Examples of the "faecal-oral route" could arise by

a) lack of handwashing after defaecation

b) insect and animal vectors having access to faecal material and subsequently contaminating food or alighting on people's hands, lips, etc.

c) indiscriminate defaecation by children around the house and people of all ages in the surrounding bush.

Often traces of excreta in the form of bacteria and viruses (some of which may be harmful) are found in unprotected water sources, water storage pots in the home (often contaminated after water collection) and more rarely in protected groundwater sources (for example where there has been contamination from a poorly constructed or sited pit latrine).

15.1.3. The relationship between water quality and health is well understood. It must also be stressed that there is a definite relationship between water quantity and health. If greater quantities of water are used for personal and environmental cleanliness there will be less chance for diseases to be spread through the faecal-oral route.

15.1.4. The most frequently transmitted water-borne (and also faecal-oral) diseases are diarrhoea, cholera, hepatitis, typhoid and roundworm. Diseases of the skin and eyes such as scabies and conjunctivitis are caused by insufficient use of water for bathing and washing. Diseases such as malaria and bilharzia are also water-related but the route of transmission is more complicated and via an insect or animal carrier.

15.1.5. If the provision of a protected water supply is combined with a health education programme and the promotion of improved sanitation, the impact on community health and disease control could be significantly greater than that which can be achieved by the provision of clean water alone.

15.2. THE ORGANISATION OF HEALTH ACTIVITIES IN RURAL AREAS OF MALAWI

15.2.1. *The Ministry of Health (MoH)*

Given the close relationship between water and health, it is important that Integrated Project staff are aware of both the organisation and the nature of health activities being carried out in rural areas of Malawi. The Ministry of Health is the principal organisation responsible for co-ordinating both preventive and curative measures to improve health; health education and improved sanitation are important preventive health measures and are closely linked to the provision of clean water by an Integrated Project.

15.2.2. *The Health Inspectorate*

The staffing of MoH field extension work is described for the benefit of Integrated Project personnel as they will be closely liaising with them throughout the Project:

a) Health Inspectors : most Health Inspectors serve as District Health Inspectors (DHI) and as such are responsible for all public health activities in their district; they report directly to the District Medical Officer as well as to the Regional Health Inspector. Some Health Inspectors serve as Area Health Inspectors covering a portion of a district and report to the respective DHI.

b) <u>Health Assistants</u> (HA) : These work under the supervision of Health Inspectors, are assigned a portion of a District and have public health duties. They are usually based at a Health Centre or Sub-Centre.

c) <u>Health Surveillance Assistants</u> (HSA) : These are the "front line" workers and are responsible mainly for community contact, organisation and health education.

d) <u>Primary Health Care (PHC) Workers</u> are volunteers from rural villages, elected through the Village Health Committee, and work under the supervision of HSAs.

15.2.3. *Village Water Committees and Village Health Committees*

Village Health Committees have already been formed in many rural areas of Malawi in order to promote improved community sanitation and personal hygiene. In past years such committees have been extremely useful, for example in times of cholera outbreaks. Due to the close ties between water supplies and health it would seem sensible to combine Village Water Committees with Village Health Committees wherever they are already established. This should be encouraged by the Integrated Project staff at the main public meetings. The actual function of the Committee will vary given the priority and phasing of the task in hand (water supply installation, pit-latrine construction, etc.).

15.2.4. *Co-ordination between DLVW and MoH*

It is essential that there is effective co-ordination between DLVW and MoH at all staff levels in order to ensure that health benefits will result from the provision of clean water. In an Integrated Project all staff should understand the principles of health and sanitation and wherever possible they should co-operate with the field staff of MoH. Co-ordination between MoH and DLVW is facilitated by the following:

a) There is a National Action Committee for the IDWSSD, chaired by the Controller of Lands, Valuation and Water, whose members include representatives of Ministries involved in water and health related activities, including MoH. This Committee is the main policy-making body for the Decade.

b) At Headquarters level in MoH, there is a Principal Health Co-ordinator who is responsible for liaising with DLVW;

15.2.4. (2) regular meetings of senior officials are held to share information and encourage joint activities.

c) The Health Education Section of MoH is able to advise DLVW Integrated Project staff on the choice and correct application of education techniques and the design and production of educational materials. Such materials are being produced on water and sanitation and will be available on request for health education activities.

d) Improved sanitation is being promoted jointly by MoH and DLVW along with the provision of clean water [see Sections 10 and 16]. In co-operation with the Department of Community Services, development is being carried out of appropriate designs and materials for very low-cost pit latrines to be promoted in Malawi's rural villages. Various models are being constructed as demonstrations and will be tested. The Integrated Projects will help to construct a model pit latrine in each village within the Project area, as a demonstration of improved sanitation and low-cost building techniques.

e) At Project level, professional staff are encouraged to liaise with the DHI and his staff. Initial meetings [Chapter C] should be held to share information so that the DHI is informed of water development in his district and the Project staff are aware of health activities. The DHI should be invited to attend the main community meetings in order to develop close ties with the Project; the Project hydrogeologist may in turn be asked to attend or contribute to health meetings in the district. The DHI will generally instruct his staff to give importance to villages in the Project area. The Integrated Project staff should assist the health workers by conveying health information to the villagers (for example the importance of protected water supplies and how to ensure the water is kept clean after collection) throughout the Project preparation, implementation and operation stages.
A talk on the principles of hygiene and sanitation should be given at the opening ceremony of each new water point by MoH extension staff (if available) or by Integrated Project staff. This can be followed up by the health

personnel who can concentrate on encouraging the Village Water and Health Committee members to adopt better sanitation and personal hygiene practises, so that they in turn can persuade their fellow villagers to do likewise. Health education can also be achieved through the hand-pump maintenance and repair training sessions [see Chapter E], in which the DHI or members of his staff will participate.

It is believed that the new waterpoints should provide added incentive for the community to respond to the need for improved sanitation and hygiene practices.

15.2.5. *Health Education*

Health education is one of the main activities promoted by MoH as a preventive measure to improve health. Whilst some people may change their behaviour by blindly copying others or by conforming to fashion, most require some education to induce them to change their habits. There are a variety of techniques, each with their own merits, but the most successful appear to be those based on the Primary Health Care approach, whereby the community is helped to identify and solve its own problems using its own resources. Several of these educational techniques are explained below (and could also be used by the Integrated Project Staff when approaching the community):

a) *Individual dialogue* : this involves sitting down with one person or a family, preferably in their home, to speak about specific problems and behaviour and discuss ways in which they can be respectively resolved and improved. Although this is a very effective technique, it is not feasible for such a dialogue to occur with each village family given the limited field staff available.

b) *Village Health and Water Committee education* : realising that individual communication is not possible on a large scale it has been found that the next best approach is to educate the Village Committees on this basis and let them in turn educate the rest of the villagers. Given a large population and limited field staff this is the most effective method of spreading messages.

c) *Group Dialogue* : this is a method of facilitating discussion amongst the group so that they are helped to identify and solve their own problems. The educator initiates the discussion, then steps back once it is started and only contributes further to keep the discussion focussed on the topic. This is most effective with small groups such as Village Health and Water Committees or groups of Village Caretakers at preventive maintenance training sessions.

d) *Role Playing* : this involves an enactment of some community problem acted spontaneously by some of the villagers. A discussion of the drama takes place afterwards so that all in the group gain an understanding of what they acted or observed.

e) *Mass Media* : this includes radio shows, posters, films and leaflets made available to large groups of people. Such techniques are very efficient in getting information to great numbers of people but are only effective in raising awareness of problems. Follow-up on an individual or small group basis is necessary to reinforce the messages and promote behaviour change.

15.3. PRINCIPLES OF RURAL SANITATION AND PERSONAL HYGIENE

15.3.1. The need for Integrated Project staff to understand the importance of the relationship between health and water has been emphasised. For this reason some principles of rural sanitation and personal hygiene are given here. The Project staff can then help the health workers wherever possible by setting a good example in both base-camp and sub-camps and by raising general awareness of the problems during their day-to-day contact with the community.

15.3.2. *Water Collection and Storage*

Much of the good work done by providing a clean water supply is negated by improper water handling and storage after collection; considerable faecal contamination of drinking water storage pots has often been observed. The following techniques should be encouraged in order that the water is kept clean after collection:

a) hands should be washed at the handpump before the water collection bucket is washed

b) water storage pots should be washed regularly

c) To minimise multiplication of organisms and further contamination, drinking water must be refreshed daily by pouring out the old water from the storage pot and replacing it with fresh water

d) storage pots must be covered to prevent the entry of insects and animals

e) the dipper used for scooping water from the main storage pot should not be used for drinking or any other purpose; water should be poured from it into another cup or container. It should be held by the handle only and should be hung up after use

f) young children should ask an adult or older child to pour out water for them

15.3.3. *Pit Latrines*

A pit latrine should not merely be a hole in the ground to hide excreta, but a tool used to provide a barrier against the spread of disease. The traditional latrines built in rural villages comprise a pit (3 m to 6 m deep) covered with logs or stones with a squatting hole in the middle, enclosed by a simple super-structure. Although adequate to contain human excreta such latrines may create as much of a public health hazard as they prevent. Without vector control, insects are free to enter and leave the pit and, having been in contact with human excreta, can spread disease by landing on food, hands, eyes, etc. Research has shown that, by the addition of a simple screened vent, both insects and odours can be significantly reduced in pit latrines. This is because the insects are attracted to the light at the top of the vent pipe as the latrine itself is dark, and furthermore strong upward draughts are induced in the vent pipe. The insects are trapped by the screen mesh at the top of the vent and remain there until they become dehydrated, die and fall back into the pit. Odours are virtually eliminated by the up-draught produced in the vent pipe, as long as there is adequate ventilation of the latrine to allow a complimentary down-draught through the squatting hole. Pit latrines can also be the source of groundwater contamination if they are improperly built or sited. It is important that the bottom of the pit should be at least 2 m above the maximum expected groundwater level (or more if the unsaturated zone is highly permeable) so that there is a sufficient thickness of soil and unconsolidated strata to act as

an effective filter to remove faecal micro-organisms [see Section 16.5]. Latrines should not be used to dispose of bath water. Digging of pits as deep as possible, until the water table is reached will allow direct faecal pollution of the aquifer. The lateral separation required between a pit latrine and a waterpoint to ensure adequate protection from pollution will vary depending on the nature of the strata [see Section 16.5]. Generally, where the soils and unsaturated zone are unconsolidated and of low permeability there should be a lateral separation of at least 15 m, and where the strata are of higher permeability this should be increased to at least 30 m. The latrines should be sited downslope from the waterpoint wherever possible to reduce the risk of pollution. It is estimated that only half the premises in rural villages of Malawi have pit latrines. Few of these are well constructed and even fewer of an "improved" type (ie vented). Families without latrines should be encouraged to construct them using improved designs. Wherever latrines are being constructed in Integrated Projects eg at the basecamp, at Maintenance Assistants' houses and as models in each village, they should be of the ventilated type to serve as a demonstration to the community [see Section 10].

15.3.4. *Bathing Houses*

A private and convenient place for bathing should be encouraged as a feature of every household. They may vary from a simple open reed enclosure to a more elaborate brick structure. A few large stones should line the floor of the bathing area. The waste water should be channelled into a soakaway pit.

15.3.5. *Soakaway Pits*

A soakaway pit filled with stones should be used to dispose of all household liquid wastes. The size required will vary depending on the permeability of the soil and the volumes of water to be disposed. For an average family a 1 m^3 pit should be adequate to avoid accumulation of standing water and mud. If the pit fills up with fine material with time a new one should be dug.

15.3.6. *Rubbish Pits*

To avoid the indiscriminate disposal of solid wastes and reduce the attraction of flies it is recommended that a shallow pit about 1 m^3 is dug for rubbish disposal. Such pits should be about 10 m from the houses and a layer of soil or ashes should be added every few days.

15.3.6. *Personal hygiene*

It is important that people, children and adults, wash their bodies regularly to remove pathogens that spread disease. This is best done at least once daily and should be accomplished with water from the safe waterpoint to break contact with bilharzia-infested water sources. Soap should be used if available, but if not a smooth stone or traditional sponge can be used. With the provision of the new waterpoints close to the home more frequent washing using more water should be encouraged. Hands should be washed after defaecation, after tending the gardens, before cleaning the water-collection buckets and before preparing food. Clothes must also be washed regularly, an activity which should be greatly facilitated by the provision of washing slabs at all Integrated Project waterpoints. Again, from a public health point of view, the reason is to remove pathogenic bacteria and parasites to avoid infection. This extends to bedding which should also be washed regularly (or at least exposed to sunlight).

15.3.7. *Cleanliness in the home*

Dirty cooking utensils and crockery should not be left on the floor, accessible to children or animals. They should be washed after use and left to air dry outside on a dish rack made of sticks or bamboo located above ground. In addition to daily sweeping of floors and the area surrounding the home, it is important that the home be kept in good repair ie, roof well thatched, floors and walls properly smeared. Cracks in floors and walls provide good shelter for vermin and parasites and should be repaired. It is of special importance to keep latrines clean; as well as daily sweeping inside, wood ashes should be thrown into the pit regularly (once every few days) and also sprinkled around the squatting hole to keep it dry. Again, cracks in floor and walls should be repaired.

15.3.8. *Cleanliness around the waterpoint*

It is important to keep the waterpoint surroundings clean, dry and free from rubbish; this is the responsibility of the Pump Committee [see Chapter E]. Any excess drainage water should be channelled away into a garden. Animals should be kept away from the waterpoint to avoid surface contamination from their excreta; if necessary the area around the handpump may need to be fenced and/or the animals kept in kraals.

16. WATER QUALITY AND POLLUTION

16.1. CHEMICAL PURITY AND QUALITY STANDARDS

16.1.1. Chemically pure water does not exist in nature because of its ability to dissolve other substances. Even rainwater has the ability to dissolve gases (such as carbon dioxide from the atmosphere) as it falls to earth. The dissolved constituents in natural water depend on many interrelated factors (including climate, topography, soils, biological processes and time) but rock weathering is usually the main source of chemical constituents.

16.1.2. Surface waters, especially in upland areas are generally less mineralised than groundwater because they have had less time in contact with the soils over which they flow and thus less chance to dissolve the rock minerals. Groundwater, especially deep groundwater, has usually been in contact with rocks for very long periods, sometimes for tens of thousands of years. Such ancient groundwater tends to be highly mineralised.

16.1.3. The waterpoints in Integrated Projects normally draw water from depths of less than 30 m. This shallow groundwater is usually quite young and often contains water recharged during the previous rainy season. Generally this water is of good chemical quality and is quite safe to drink without any treatment.

16.1.4. The World Health Organisation (WHO) has recommended a level of 1,500 mg/l total dissolved solids (TDS) (the combined concentrations of all the constituents) as a maximum concentration in water for human consumption. However, it is not uncommon to find people in many parts of the world, especially in arid areas, drinking water with higher concentrations of dissolved solids.

16.1.5. The Electrical Conductivity (EC) of the water is a measure of its ability to conduct an electric current. Pure water is a poor electrical conductor (low EC) whereas highly mineralised water is a very good conductor (high EC), thus the EC is a good indicator of TDS. The EC (measured in µS/cm) is normally 1.4 - 1.8 times TDS (measured in mg/l). It is a very useful tool for primary reconnaissance because it is quickly and very easily measured in the field [Section 16.6].

16.1.6. The EC of the groundwater should be measured during the construction of boreholes (using water from a bailer test) and digging of wells. If the EC is found to be greater than 3,000 µs/cm, the site should be abandoned immediately rather than going to the expense of completing a waterpoint which would provide water that is chemically unfit to drink. The project hydrogeologist should immediately make a special effort to find an alternative site so that the villagers are not left dependent on their traditional (possibly grossly polluted) source and so that the set back does not discourage the continuing participation of the community in the Project. Abandoning dug wells or boreholes in this way should be a relatively uncommon event resulting from very local occurrences of poor quality groundwater. More extensive areas should have been identified at the Project planning [Chapter B] or preparation [Chapter C] stages and will have been ruled out before construction commences.

16.1.7. The pH of a water is a measure of the hydrogen ion activity in that water. The pH scale extends from 0 (very acidic), to 14 (very alkaline), with 7 corresponding to exact neutrality. The pH of most natural waters falls within the range of 6 - 9. Groundwaters in the weathered basement aquifer are usually slightly acidic with pH values around 6.5. The commonly used terms acidity and alkalinity refer to a measure of how resistant the water is to pH change. Waters of high acidity tend to be corrosive in nature and will attack metal pipes and fittings, whereas waters with high alkalinity tend to be passive. If the high alkalinity is associated with calcium or magnesium there may be a tendency to deposit certain minerals out of solution. If the pH is <6 or >9.2 the Senior Water Chemist should be consulted.

16.1.8. The major and secondary constituents of natural unpolluted groundwater [see Table D.16.1] are not usually present in harmful concentrations in Malawi. It is generally considered that the WHO limits for drinking water are too strict and inappropriate for untreated rural groundwater supplies where any alternative source is likely to be highly polluted [see Section 16.2]. The standards given in Table D.16.2 for drinking water in arid regions are considered to be a more realistic guide to the desirable and achievable water quality standards in Malawi.

Table D.16.1. Dissolved Constituents in Unpolluted Groundwater

MAJOR CONSTITUENTS (range of concentration 1.0 - 1,000 mg/l)

Sodium (Na)	Bicarbonate (HCO_3)
Calcium (Ca)	Sulphate (SO_4)
Magnesium (Mg)	Chloride (Cl)
Silica (Si)	

SECONDARY CONSTITUENTS (range of concentration 0.1 to 10.0 mg/l)

Potassium (K)	Carbonate (CO_3)
Iron (Fe)	Nitrate (NO_3- N)
Strontium (Sr)	Fluoride (F)
Ammonia (NH_3)	Phosphate (P)
Manganese (Mn)	
Boron (B)	

16.1.9. There are also some trace elements in groundwater which may be present in concentrations varying from 0.00001 to 0.1 mg/l. Some of the dissolved constituents have a beneficial effect on health. For example where water sources are deficient in iodine (an important element for healthy growth) enlargement of the thyroid gland (goitre) may be common in young adults.

16.1.10. Problems can arise when certain chemical constituents are present at even relatively low concentrations. A good example of this is fluoride which has a beneficial effect in promoting the formation of strong, decay-resistant teeth in children at concentrations in the range of 1.0 to 2.0 mg/l. People, especially young children, consuming water with concentrations higher than this upper limit are subject to two diseases:-

a) 2 - 15 mg/l, dental fluorosis; brown discoloration or mottling of teeth,

b) greater than 15 mg/l, skeletal fluorosis; a crippling disease affecting the bones.

Fortunately groundwaters with high fluoride concentrations are not very common in Malawi, being associated mainly with rocks of volcanic origin.

Table D.16.2.

Standards for Drinking Water in Arid Regions
(Modified from Schoeller, 1937, 1955, in Groundwater Studies [UNESCO, 1977] Geochemistry of Groundwater)

	Suitability for permanent supply			
	Good	Fair	Moderate	Poor
Colour	Colourless	Colourless		
Turbidity	Clear	Clear		
Odour	Odourless	Hardly Perceptible	Slight	Slight
Taste at 20°	None	Perceptible	Pronounced	Unpleasant
Total dissolved solids (mg/l)	0 - 500	500 - 1,000	1,000 - 2,000	2,000 - 4,000
EC (μS/cm)	0 - 800	800 - 1,600	1,600 - 3,200	3,200 - 6,400
Na (mg/l)	0 - 115	115 - 230	230 - 460	460 - 920
Mg (mg/l)	0 - 30	30 - 60	60 - 120	60 - 120
$\left\lvert \frac{Mg}{12} + \frac{Ca}{20} \right\rvert$ hardness as $CaCO_3$	0 - 5	5 - 10	10 - 20	20 - 40
Cl (mg/l)	0 - 180	180 - 360	360 - 710	710 - 1,420
SO_4 (mg/l)	0 - 150	150 - 290	290 - 580	580 - 1,150

parameters (pH and bicarbonate) are particularly likely to be erroneous since they were not measured in the field.

16.1.16. A DLVW Water Quality Laboratory is being set up (November, 1982) in Lilongwe with facilities to make more accurate and reliable chemical analyses. In the near future it will be equipped to analyse the major and secondary constituents and some trace elements present in groundwater. Chemical data records will be kept at the central laboratory where they will be available for consultation, and chemical data from boreholes and dug wells will go into the cardex system as part of the continual updating process. If an examination of the chemical records in conjunction with Tables D.16.1 and D.16.2 suggests that any chemical constituent appears particularly high the Senior Water Chemist should be consulted for advice.

16.1.11. Iron and manganese, whilst not harmful in themselves, when present in water at concentrations above 1 mg/l may render water unfit for consumption because of the objectionable taste and may also cause problems of staining of clothes washed with the water. This may cause consumers to seek alternative unprotected water sources possibly containing disease-producing bacteria and viruses.

16.1.12. High sulphate concentrations in groundwater in some parts of Malawi may also make the water unpalatable. If the concentration in water is higher than about 400 mg/l it can cause diahorrea.

16.1.13. The activities of man can also have an effect on groundwater quality. Chemical fertilizers applied to land used for agriculture can be leached by rainfall and thus reach the water table. Also it is not uncommon for shallow groundwaters underlying densely populated areas where the common method of excreta disposal is pit latrines, to have elevated concentrations of nitrate. The source of this nitrate is the nitrogenous material in the faecal matter; man typically excretes 5 kg of nitrogen per year. Part of this nitrogen load may be oxidised to nitrate by biochemical reactions in the soil and the nitrate so formed may eventually be leached to the water table by recharge from rainfall. Excessive concentrations of nitrate in water are reported to cause methaemoglobinaemia (infant cyanosis). In 1977 a WHO European Working Group on health hazards from drinking water proposed the adoption of 11.3 mg NO_3- N/l (50 mg No_3/l) as the maximum concentration for infants and 22.6 mg NO_3- N/l (100 mg No_3/l) for the population as a whole to safeguard against this disease.

16.1.14. Whilst techniques are available to remove harmful or objectionable constituents, these techniques are usually sophisticated and/or expensive. The philosophy of the low-cost Integrated Project approach is therefore to locate and protect water sources that do not require treatment.

16.1.15. Groundwater chemical data obtained prior to 1982 (mainly major element analyses) is recorded on the cardex system of borehole data [Figure B.4.11 This archive is considered to be a useful indication of water quality but it cannot be taken as completely reliable. Caution must be taken in interpreting the analyses as some of the sampling/analytical techniques are likely to have been poor. Unstable

16.2. MICROBIOLOGICAL PURITY

16.2.1. Of far more serious consequence than the health hazards attached to chemical substances in drinking water are diseases related to contaminated water which are spread by a biological agent of disease (a pathogen). These are the so-called water related infections and are the greatest cause of disease and infant mortality in developing countries.

16.2.2. Excreta may contain viruses, pathogenic bacteria, parasitic protozoa and helminths (worms), in varying concentrations depending on the state of health and age of the individual. If a water source is contaminated by excreta, these organisms may be drunk with the water and hence cause infection. It should however be noted that both viruses and bacteria are transmitted by many other faecal-oral routes, which are more likely to spread disease, for example food contaminated by dirty hands, flies and other insects. Many public health workers are of the opinion that it is the quantity of water used and not the water quality which has most effect in the reduction of water-related diseases. Briefly there are four mechanisms of water-related disease transmission:

a) water-borne,

b) water-washed or water-short,

c) water based, e.g. bilharzia,

d) water-related insect vectors, e.g. malaria.

It is beyond the scope of this Manual to go into any depth on this subject.

16.2.3. Whether or not an individual who drinks a contaminated water will become infected depends upon a number of factors, but primarily on the type of organism and the infectious dose required to initiate the disease. In general, viral infections require very low infectious doses (less than 100 organisms) whereas the median infectious dose for the bacterial enteric pathogens is typically 10,000 or more. Bacteria, however, unlike viruses are able to multiply outside their host and under certain conditions even moderate contamination may build up to quite severe contamination. The diseases and their agents which might be spread by contaminated groundwater are shown in Table D.16.3.

Table D.16.3. Diseases and their Agents

Viral Diseases

Disease	Pathogen
Infectious hepatitis	Hepatitis A virus
Poliomyelitis	Poliovirus
Diarrhoeal diseases	Rotavirus, Norwalk agent, other viruses
Varied symptoms and diseases	Echoviruses and Coxsakievirus

Bacterial Diseases

Disease	Pathogen
Cholera	*vibrio cholera*
Typhoid fever	*salmonella typhi*
Paratyphoid fever	*salmonella paratyphi*
Bacilliary dysentry	*shigella* spp.
Diarrhoeal diseases	Enterotoxigenic *E. Coli*
	Enteroinvasive *E. Coli*
	Enteropathogenic *E. Coli*
	Salmonella spp.
	Campylabacter petus spp.
	Jejuni

16.3. BACTERIOLOGICAL QUALITY STANDARDS

16.3.1. When determining the bacteriological quality of the water ideally it would be desirable to test directly for pathogenic micro-organisms. However, because of the highly variable densities of pathogenic bacteria in faeces, it is not feasible to test for all disease producing organisms. A more practical approach is to test for a particular group of bacteria common to the faeces of all warm blooded animals and which can be used as an indicator of faecal

pollution. The organisms which are commonly used as indicators of faecal pollution include total coliforms, faecal coliforms and faecal streptococci. It must be emphasised that the indicator organisms only serve to indicate faecal pollution and cannot be taken as a measure of the quantitative degree of faecal pollution or of the presence of pathogenic micro-organisms. The general philosophy is that if it is shown that faecal contamination of water has occurred, then pathogens may also be present.

16.3.2. Values for faecal coliform populations in tropical waters should however be interpreted with caution. The standard enumeration procedures were developed in Europe and North America where the climates are temperate. Recent studies in the tropics have detected a considerable proportion of coliforms of probable non-faecal origin which have the ability to ferment lactose at 44.5°C. When the results of any laboratory examination indicate that pollution of a water source has occurred one should not condemn that particular source without a follow up investigation. This is very important because it must be established beyond doubt that the contamination observed was in fact pollution of the source and not simply due to contamination of the sample by poor collection or laboratory examination techniques. There have been instances where boreholes have been abandoned simply on the basis of one test result. If one considers that a typical Project borehole costs in the region of K1,500 to construct and equip, it is important that precious funds are not wasted needlessly. Equally it is also important to realise that a water source cannot be assumed to be wholesome if a single examination proves negative. A history of samples is required covering all the seasons; micro-biological pollution of both surface water and groundwater sources is likely to be very much more evident immediately after the onset of the first heavy rains.

16.3.3. The WHO have set the following bacteriological standards for drinking water:

a) No sample should contain *E. Coli* in 100 ml
b) No sample should contain more than 10 coliform organisms/100 ml

These standards have been set primarily for the protection of people supplied by disinfected piped water. However, the great majority of people in rural areas of Malawi drink untreated water. It is therefore pointless to set such stringent standards for these water supplies. For example, there have been cases in other countries where overzealous health officials have closed down contaminated boreholes or wells in a village because they were found to contain 50 faecal coliforms/100 ml and thus forced the villagers to use polluted irrigation canals containing 10,000/100 ml. Even if great attention is paid to selecting the purest available water source and distributing the water through a well-designed and maintained system, it will not usually be possible to meet a zero faecal coliform standard at all times without chlorination. It is difficult, outside the philosophy and beyond the financial constraints of Integrated Projects, to maintain a reliable chlorination system in remote rural areas. A more realistic approach to the zero faecal coliform standard is to set a standard that can be achieved and which can be improved upon with progress. An improved supply (borehole, protected well or piped-water supply from a protected catchment) providing water with up to 50 faecal coliforms/100 ml, is a great advance when many people in the country may be drinking water containing over 1,000/100 ml.

16.4. PREVENTION OF FAECAL CONTAMINATION

16.4.1. Bacteriological examination of improved shallow groundwater supplies during the dry season in Malawi has revealed that on the whole bacteriological water quality is good; many boreholes and dug wells even satisfying WHO requirements. Examination of the water after collection and storage in the home, shows that in very many instances indicator bacteria concentrations have increased alarmingly. This clearly demonstrates that the water is contaminated after collection and that much of the effort to protect and supply a wholesome water has been nullified. A major cause of this contamination is the common practice that has been observed of drawing water from the storage vessel (clay pot or bucket) with a cup or gourd and drinking directly from that cup, which is then used again by other users without prior washing. The above serves to emphasise that the provision of safe water is not the end of the story and that health education on how to preserve the quality of this improved supply is vitally important [see Section 15].

16.4.2. Sanitary protection of the source supply must be considered the first line of prevention of contamination. This cannot be emphasised too strongly. In this respect it is essential to maintain a high standard of well or borehole completion including the provision of a good apron and drain [see Section 8]. Improper grouting techniques can lead to direct contamination of the water source since water spillage around the well or borehole will convey pollutants directly down to the water table, short circuiting the normally adequate protection afforded by the overlying soils.

16.5. SITING OF WATERPOINTS IN RELATION TO POTENTIAL SOURCES OF POLLUTION

16.5.1. There is a growing awareness of the risk of faecal contamination of groundwater from the use of low cost sanitation units. In the past public health workers and water-supply engineers have adopted the general rule of thumb of a 15 m lateral distance of separation between groundwater supply installations and pit latrines; without giving any forethought as to the applicability of this guideline to the hydrogeological environment in which they are working. In certain hydrogeological environments, increasing the separation to even 50 m would not be reliable method of protection against microbial contamination. There are a number of reasons for this, the main one being that very few aquifers are uniform and permeability variation will normally be present. Very localised high permeability zones may allow rapid movement of contaminants to the waterpoint.

16.5.2. A recent review of the published literature on the risk of groundwater pollution by the use of pit latrines emphasises that soil (and unconsolidated strata) is a very effective waste water purification system, having the ability to remove faecal microorganisms, and that the unsaturated zone of the ground profile should be considered as the most important line of defence against faecal pollution of aquifers. Unfortunately, the common practice of digging the latrine as deep as possible in order to extend its useful life, removes this effective barrier against faecal contamination. Generally, the risk of faecal pollution of groundwater is minimal when the thickness of relatively fine-grained (< 1 mm)

unsaturated soil and weathered material beneath the base of the latrine is greater than 2 m, and provided the latrine is not used to dispose of bath and other washing water.

16.5.3. It was recognised that the close association of groundwater supplies and pit latrines involves more risk in certain hydrogeological environments than in others. In order to formulate guidelines different types of soil and rocks have been grouped into a risk array, a framework of relative pollution vulnerability [see Figure D.16.1.]. It should be realised that no such grouping can be fully comprehensive and free from ambiguity. The vertical sub-division in the array made on the basis of degree of consolidation, is fundamental. The vast majority of all consolidated deposits are traversed by discontinuities at various spacings which increase pollution vulnerability. Such fissuring is more likely to be associated with higher hydraulic conductivity in carbonate and some basic volcanic rocks, than in siliceous and acid rock types.

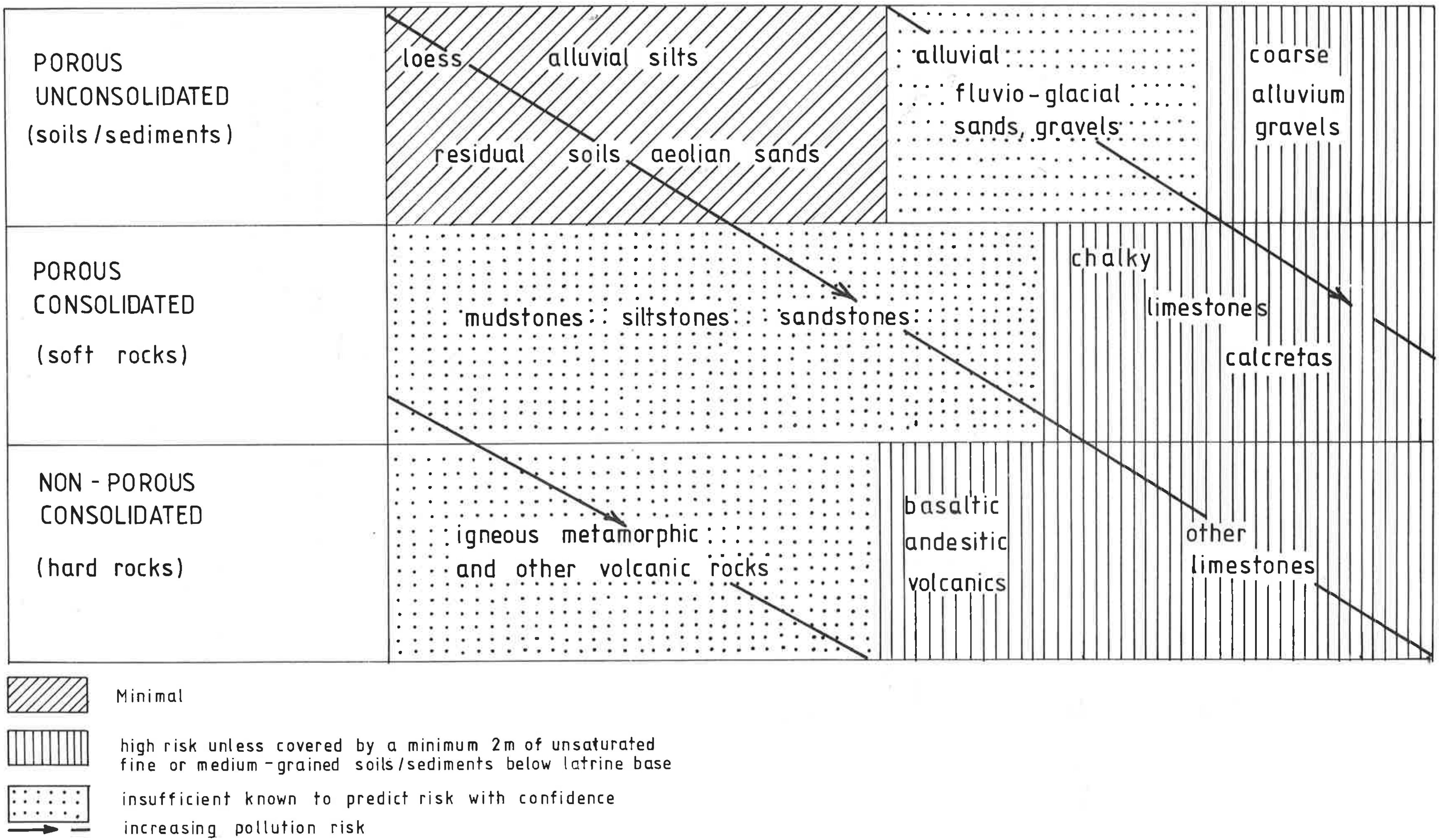
16.5.4. In the plateau region of Malawi most of the soils should fit into the top left hand grouping of the array, i.e. minimal pollution risk. Provided that the water table at any time is not less than 2 m below the bottom of the pit latrine and that the dug well or borehole has been properly completed with regard to the requirements for sanitary protection then a lateral separation of at least 15 m between waterpoint and pit latrine should be adequate.
However, if in doubt and no expert advice is available, the separation should be increased to at least 30 m. In high pollution risk environments specialist opinion should be sought.

16.6. OPERATIONAL PROCEDURE FOR FIELD STAFF

16.6.1. *Sample Collection*

Chemical analysis of water samples is a time consuming and expensive operation and it is therefore of the utmost importance to ensure that any samples submitted for analysis are representative. Sample bottles for both acidified and unacidified samples should be collected from the Water Quality Laboratory in Lilongwe. The initial discharge from pumped boreholes and wells should not be collected but they should be pumped for at least five minutes first. One

Figure D.16.1 CLASSIFICATION OF SOILS AND ROCKS IN AN ARRAY OF RELATIVE POLLUTION RISK
(after Lewis et al, 1982)



acidified and one unacidified sample should be collected. The unacidified bottle should be rinsed well with the sample, completely filled and tightly stoppered. The bottle containing the acid should not be rinsed. Samples should be returned to the Water Quality Laboratory as soon as possible, each sample being accompanied by a completed request form for analytical services [Form WQPC-2, see Figure D.16.2].

16.6.2. *Field Measurements*

It is often useful or necessary to perform certain tests in the field. Certain parameters, especially pH, change significantly between the time of collection and subsequent analysis at a laboratory. When field pH measurements are made these should be communicated to the central laboratory when submitting the samples [see example on Figure D.16.2].

16.6.3. *Field Measurements of pH (using PHOX System Model 42 pH meter)*

Calibration

a) Turn the selector switch to pH, plug in the electrode.

b) Immerse the electrode in approximately 25 ml of pH 7 buffer solution.

c) Set the temperature control to the temperature of the solution.

d) Allow the electrode to stabilise for three minutes and adjust the pH to 7.0 with the calibration screw.

e) Carefully wipe the electrode with tissue paper and immerse it in 25 ml of pH 4 buffer solution.

f) Allow electrode to stabilise and note the reading which should be 4.0. If a low or high reading is obtained repeat calibration procedure. If still not satisfied return pH meter to senior chemist.

g) When the instrument is calibrated switch to "CHECK" and note the value. Whilst the instrument is in calibration this value will always remain the same and will serve as a ready method of recalibration.

h) Switch off.

pH Measurements

a) Turn the selector switch to "pH" and set the temperature control to the temperature of the sample being measured.

b) Fill a suitable container with water, immerse the electrode and allow to stabilize for three minutes.

c) Note the pH reading to the nearest 0.1.

d) Switch to "check" and note the value, adjust if necessary and repeat step b).

e) Switch off.

16.6.4. *Field Measurements of Electrical Conductivity (EC) (using Phox Conductivity Meter, Model 52)*

Checking Meter Operation

a) Turn function switch to "test" and range switch to any scale range, e.g. x1, x10.

b) The needle should give a full scale deflection to the right with a reading of 10, otherwise adjust the test knob screw to give a reading of 10. If you cannot set pointer to 10 by adjusting the screw, replace batteries.

c) Turn range switch to "off".

Measuring EC

a) Turn function switch to "Test Comp in".

b) Turn range switch to the range which gives a reading closest to mid scale.

c) Note the reading on the top scale and multiply this by the relevant range factor to give EC [see Example below]

Example D.16.4.

Reading	Range Factor	EC
4.25	10	42.5
4.95	10^2	495
3.10	10^3	3,100

d) Turn range switch to "off".

The meter should be returned to the central laboratory every six months for recalibration.

Figure D.16.2. FORM WQPC - 2

DEPARTMENT OF LANDS, VALUATION AND WATER
WATER QUALITY AND POLLUTION CONTROL SECTION

REQUEST FOR ANALYTICAL SERVICES

1. NAME AND ADDRESS OF PERSON REQUESTING SERVICES ....MR C. RUXTON (DOWA WEST PROJECT)....
....D.L.V.W.....
....P/BAG 311 LILONGWE....

2. SAMPLE SOURCE*:- ~~RIVER~~; ~~STREAM~~; ~~SPRING~~; ~~DEEP BOREHOLE~~; SHALLOW BOREHOLE; ~~WELL~~; ~~EFFLUENT~~.

3. NAME OF RIVER ETC. ....N/A....

4. NO. OF BOREHOLE ....D.W.9....

5. METHOD OF COLLECTION*:- PUMPED; ~~BAILED~~; ~~SCOOPED~~; ~~OTHER (SPECIFY)~~
....

6. TYPE OF SAMPLE*:- ACIDIFIED AND/~~OR~~ UNACIDIFIED

7. DATE COLLECTED ....4.10.82....

8. LOCATION ....NAWENJE VILLAGE....
....

9. DISTRICT ....DOWA....

10. MAP SHEET (1:50,000) AND GRID REFERENCE ....1333B3 WA 731106....

11. WATER RESOURCE UNIT ....5D....

12. WATER USE*:- DRINKING WATER SUPPLY; ~~IRRIGATION WATER~~; ~~OTHER (SPECIFY)~~
....

13. WATER QUALITY PARAMETERS PARTICULARLY REQUIRED ....FULL CHEMICAL ANALYSIS....
....
....

14. ANY OTHER RELEVANT INFORMATION (e.g. field pH, EC, temperature etc) ....COLLECTED AT PUMP TEST....
....FIELD pH 6·8 FIELD EC 570....
....TEMPERATURE 24°C....

** Please delete* LABORATORY NO's............

CHAPTER E

PROJECT OPERATION AND MAINTENANCE

CHAPTER E

PROJECT OPERATION AND MAINTENANCE

CONTENTS

PREFACE

Once the construction phase has been completed the project is really only just beginning. This is the stage when many projects fail because they are considered to be finished and often insufficient thought and planning has been given to project operation. A well organised maintenance structure is required for smooth operation. However this structure does not exist in Malawi at present. This chapter sets out to propose a new maintenance organisation, which is currently being initiated in the Integrated Projects. There are still several gaps to be filled in giving details of actual maintenance as pumps are still being developed and the organisational structure is dependent on these. 1983 will be a crucial year for the evaluation and further development of this new maintenance structure.

1. EXISTING MAINTENANCE STRUCTURE

1.1.1. At present the responsibility for maintenance of boreholes, protected dug wells and their pumps rests entirely on the Government.

1.1.2. The borehole maintenance network has been long established and operates at regional and district level with supervision from Central Headquarters. The structure comprises a Senior Borehole Maintenance Officer and his deputy Borehole Maintenance Officer at Headquarters level; these are the only staff who have any formal training in pump operation and maintenance. There are a total of four foremen at regional level (two for the Southern Region because of the greater densities of population and handpumps) and 20 Maintenance Units at district level. The Maintenance Units have a supervisor (who is actually classified as a driver) and five to six workmen in the crew and each Unit is equipped with a 5/7 ton truck with hand-operated winches and a retractable mast. The staff know how to install and remove handpumps and carry out field repairs (generally replacement of components), but have little technical knowledge nor appreciation of the importance of preventive maintenance. Many of them do, however, have a very considerable amount of experience. Four new Maintenance Units are planned.

1.1.3. There are at present about 5,000 boreholes which are each visited several times per year.

1.1.4. A maintenance system for protected shallow wells has not been properly established. The construction programme is only operational in relatively few districts (Dowa, Kasungu, Ntchisi, Mzimba, Lilongwe, Ngabu, Dedza and Ntcheu) and at present the maintenance is organised and carried out by staff also responsible for construction. There are two Maintenance Assistants (at Nambuma and Kasungu) and 21 Project Assistants who all use bicycles for transport. Spare parts for repairs are supplied from Headquarters by a 1½ or 5 ton pick up.

1.1.5. There are about 2,000 protected shallow wells. On average the existing pumps (mostly Malawi Mark V shallow handpumps) require repairs once every 6 - 12 months. Attention is usually required to the plunger, footvalve, bushes or adapter unions. One Project Assistant together with one or two labourers from the village can attend to repairs without the use of heavy vehicles. Repairs

would usually take one to two hours.

1.1.6. A satisfactory maintenance system for protected shallow wells needs to be set up to cope with the large number of wells which will be constructed in future Integrated Projects. With the development of a strong shallow lift handpump (with a pump head compatible with the new Malawi deep pump) which can be easily maintained at village level, it is proposed that the maintenance of both boreholes and wells can be combined as described in Sections 5.2. - 5.9.

1.2. DRAWBACKS OF THE EXISTING BOREHOLE MAINTENANCE SYSTEM

1.2.1. Repairs are required very frequently largely due to the very poor old borehole design. The use of crushed roadstone (instead of a correctly graded sand) as a pack results in silt and sand being drawn into the borehole. This is enhanced by the very low open area of the torch or hack-saw slotted steel lining and the frequent casing-out of productive layers in the weathered zone which causes high entrance velocities of water and allows sand to be carried into the borehole. As a direct consequence of pumping sand the pump components (particularly cup leathers and cylinders) are damaged and need frequent replacement. On average cup leathers need changing two or three times each year, but more frequently in alluvial areas (up to eight times a year) where the silting problem is worse than in boreholes tapping the weathered basement aquifer. The feasibility study for the Upper Livulezi Project is showing that good borehole design leads to significantly fewer repairs being required. No cup leathers have needed replacement in any of twenty boreholes over 16 - 19 months of pump operation (October 1982).

1.2.2. Drawing in of silt and sand also means that the boreholes tend to fill up in time, giving lower yields and eventually needing to be cleaned or even abandoned. About half of the boreholes in the country have silted up by over 3 m and 20% by over 10m; some 250 have been abandoned due to complete silting and need expensive rehabilitation if they are to be used again.

1.2.3. The high frequency of breakdowns and length of time required for each repair means that the Borehole Maintenance Units can only cope with breakdowns, although the desirability of preventive maintenance is realised.

1.2.4. The existing borehole handpumps in use in Malawi are inappropriate and both difficult and costly to maintain. A heavy vehicle with a winch is used to lift the pump, before even the most basic repairs can be carried out on the downhole components. The pumps are heavy and require a crew of five to six men to remove or replace them - an operation which can take several hours. On average the pumps need to be lifted at about half of the visits. Only minor attention to the pumphead or lubrication is required on other occasions.

1.2.5. The cost of borehole maintenance is very high (about K200 per borehole per year at 1982 prices). A breakdown of these costs reveals that transport costs are the major component (60%) with staff costs (20%) and materials and office expenses (20%) being relatively low proportions of the total cost. The very high and increasing vehicle running costs has led to escalation of maintenance costs. The use of the 5 or 7 ton trucks for those visits where the pump does not require lifting (which account for over half of the transport costs) is clearly an unnecessary expense and lighter vehicles, even bicycles, would be more appropriate.

1.2.6. When pumps break down they are often out of operation for several weeks or months because of access problems for the heavy trucks and the unmanageable workload borne by each Maintenance Unit. If a breakdown occurs at the beginning of the rainy season the delay could be particularly severe and repairs may not be carried out until well into the dry season. All too often vehicle breakdowns can result in complete stoppage of maintenance activities in a district, sometimes for months.

1.2.7. The existing old pumps are too complicated to be maintained by the community; skilled workers and adequate workshops are needed. Spare parts are expensive and may be difficult to obtain from abroad when required.

1.2.8. The management problems of the existing maintenance structure are already daunting. The maintenance of 5,000 pumps currently requires two 1 ton vehicles, twenty 5/7 ton vehicles, about 160 staff and an annual budget of approaching K1 million per year. Nevertheless the organisation is so stretched that only a breakdown service is offered. Regular preventive maintenance is rarely undertaken. The prospect of a fivefold increase in the number of waterpoints (to about 25,000 if the rural population of Malawi is to be adequately served) and an equivalent increase in the size of the maintenance organisation is unthinkable. This would suggest an organisation of 700 staff, with 10 x 1 ton vehicles, 100 x 5/7 ton vehicles and an annual budget of K5 million at present prices! A new maintenance structure is clearly urgently required, if the Integrated Projects are to fulfill their promise.

2. PROPOSALS FOR NEW MAINTENANCE STRUCTURE

2.1. It is proposed that preventive maintenance and simple repairs be carried out as far as possible at village level by volunteers from the community. Government would be responsible for training, supervision, major repairs and distribution of spare parts.

2.2. AIMS

2.2.1. The prime aim is to create a system of maintenance that will keep 25,000 handpumps working, by ensuring that repairs are carried out as soon as possible. As stated in Section 1 the existing maintenance network is unable to keep 5,000 handpumps working effectively. The involvement of the community in preventive maintenance and repairs will relieve a considerable burden on Government.

2.2.2. The involvement of village volunteers will increase the feeling of community ownership and responsibility for the handpumps.

2.2.3. With the use of local volunteers the cost of operation and maintenance will be little more than at present even when there are Integrated Projects covering the whole country with considerably more handpumps requiring attention. Target annual costs for maintenance are about K50 per borehole and K25 per dug well, including pumphead reconditioning.

2.2.4. The new strong handpump design coupled with the new improved borehole designs should result in very few repairs being required, especially if preventive maintenance is carried out regularly.

2.2.5. The Malawi handpump is being developed with ease of maintenance as a major design criterion. It is intended that the designs will be simple enough for community maintenance using a few simple tools. It must be stressed that the success of village level caretaking is dependent on the development of suitable downhole pump components.

2.2.6. Heavy vehicles will not be required for repairs. One trained villager (possibly with the assistance of one untrained helper) will be able to carry out most repairs and will be able to carry all the tools he requires.

2.2.7. Regular servicing to increase handpump life will be ensured, and pump repairs are likely to be carried out more quickly.

2.2.8. It is felt that the community should be able to maintain the new Malawi pumps at village level and there is no easier or more effective way to make sure that the pumps are repaired, since it is in the villagers' own interest to do so. A justification for this approach is the widespread occurrence of bicycles in good working order within the rural areas. A bicycle has many working parts and there is usually someone in the village capable of repairs. In addition there are supplies of spare-parts which are readily available at village stores. The handpumps have only very few working parts and should require relatively little attention.

2.3. SOLUTIONS

2.3.1. The proposed national maintenance structure is organised in seven tiers as follows:-

1. Pump Committee..................Village volunteers
2. Village Caretaker...............Village volunteers
3. Group Village Repair Team.......Village volunteers
4. Project Maintenance Assistant...Government staff
5. District Team...................Government staff
6. Regional Centre.................Government staff
7. Headquarters....................Government staff

Key page E.1 shows a summary of the proposed network.

2.3.2. The maintenance structure is only at the inception stage and will need to be reviewed and modified as necessary as a result of lessons learned from preliminary trials of village level maintenance.

2.3.3. It is hoped to involve women in the caretaking as much as possible as it is they who collect the water and who suffer if the pump is not functioning properly. Men often do not know where the water comes from nor do they have the same incentives to maintain the pumps. This is clearly a pioneering concept as traditionally any repair work is considered to be a man's job. Some Group Village Headmen may be initially opposed to this idea in principle but most women seem to be willing, enthusiastic and quite capable of carrying

KEY PAGE E.1.

PROPOSED NATIONAL MAINTENANCE STRUCTURE

TIER

7. *Government Headquarters (ultimately about 25,000 pumps)*

6. *3 Government Regional Centres (ultimately about 8,000 pumps)*

5. *20 - 24 Government District Teams (ultimately about 1,000 pumps)*

4. *120 - 150 Government Project Maintenance Assistants (about 150 - 200 pumps)*

3. *500 - 600 Group Village Repair Teams (commonly 30 - 60 pumps, 10 - 20 villages, 1 repair man [or possibly woman] for every 3 - 5 villages)*

2. *6,000 - 8,000 Village Caretakers (1 woman [or man] responsible for commonly 2 - 5 pumps)*

1. *About 25,000 Pump Committees (3 women for each pump)*

out the preventive maintenance and possibly simple repairs once lighter downhole components are available.

2.3.4. Cross checks should be carried out at all levels in the maintenance network. This will ensure that the pumps last for as long as possible and are kept in good functioning order.

2.3.5. The first training sessions for repair teams and caretakers have been successfully held (October, 1982) in the Upper Livulezi Project [see Section 10]; concepts are being tested and new ideas are being developed all the time. A further section will need to be added to this Manual dealing with detailed repairs once suitable downhole components for the handpumps have been developed.

3. THE PUMP COMMITTEE

3.1. Each Pump Committee consists of three women volunteers chosen by the Village Water Committee at a public meeting. There is a separate Pump Committee for each handpump. The job could be rotated amongst the villagers with new volunteers perhaps every one or two years.

3.2. DUTIES OF THE PUMP COMMITTEE

3.2.1. *Care of Pump Surroundings*

a) Keep pump and pump surrounds clean and free from rubbish.

b) Keep animals away from the pump surrounds to avoid pollution and puddling the ground around the pump. In some cases, where there is a lot of stock, a sisal fence could be constructed around the water point.

c) Discourage villagers from spilling water off the concrete surrounds.

d) Ensure that water does not gather around the pump nor in puddles at the end of the drainage channel.

e) Ensure that excess water is channelled away and spread over a garden.

3.2.2. *Correct operation of pump*

The pump belongs to the village and the Pump Committee must make sure that everyone looks after it so that it lasts for a long time.

a) Do not allow children to play on the pump or block the outlet.

b) Try to stop villagers banging the stops when pumping.

c) Encourage long, slow strokes to give the pump a longer life. Short rapid strokes will lead to wear.

3.2.3. If there are any difficulties in pumping,or if the pump/pump surrounds require repairs inform the Village Caretaker or a member of the Group Village Repair Team promptly.

4. THE VILLAGE CARETAKER

4.1. One Village Caretaker will be chosen from each village to carry out preventive maintenance on all the pumps. If there are eight or more pumps in any larger community two volunteers should be chosen. The Village Water Committee in conjunction with the Village and Group Village Headman will be responsible for choosing the caretaker. It is hoped that wherever possible a woman should do this job since it is always women who use the pump and there is more incentive to keep it in good working order. Women are therefore likely to be more reliable in carrying out preventive maintenance and caring for the pump. Thorough preventive maintenance will guarantee maximum pump-head life, whilst poor preventive maintenance could result in rapid breakdown.

4.2. DUTIES OF THE VILLAGE CARETAKER

4.2.1. The handpumps should be inspected once a week to ensure that no break-downs have occurred. Preventive maintenance should be carried out once a month. It is suggested that all the pumps should be visited regularly every Monday (or another suitable day) and it is estimated that 10 minutes work (at maximum) will be required at each site. A pair of specially designed spanners[Figure E.4.1] will be given to each caretaker to check each month that all the nuts and bolts are tight.

4.2.2. For the Malawi (deep) handpump the following should be checked monthly:

a) The four flange bolts on the base of the pumphead should be tight.

b) The axle bolt should be tight (check using two spanners).

c) The cover plate can be opened by unscrewing the bolt and the hanger nuts inside should be tight (using two spanners).

d) The pump should be firm in its concrete setting.

4.2.3. The most suitable material and design for the axle bearings have not yet been finalised and tested. Plastic (polyacetal) bushes are being tried, and if these are used it is envisaged that these could be

rotated by the Village Caretaker through a half turn (180°) after a period of use. This will allow even wear before the bushes need replacement after one turn. The time scale after which rotation should take place has not yet been evaluated but is likely to be in the range of 6 - 12 months. If conventional sealed ball bearings (also being evaluated) are used, these will not be touched at village level.

4.2.4. The Malawi (shallow) handpump for dug wells has not yet been fully developed, however it is likely to require a similar type of preventive maintenance to the deep model using the same set of spanners. This will include tightening of nuts and bolts.

4.2.5. The Village Caretaker should make a record of his weekly pump visits and monthly inspections of nuts and bolts. It is intended that each Caretaker will be issued with a diary every year. This will be designed so that the weekly and monthly checks at each pump can be simply ticked off as done and space provided to note any repairs required and breakdowns reported. There will be a pictorial section in the introduction to serve as a reminder displaying the preventive maintenance which should be carried out for both deep and shallow handpump models. It would also be useful to include a section on health and sanitation in the introductory pages.
The diary would be inspected and signed by the Project Maintenance Assistant on his monthly visits.

4.2.6. A careful watch should be kept for any difficulties in pumping, for example:-

a) weak flow or no flow. When this is noted the Village Caretaker should determine whether this is the case *all* the time or only when pumping slowly.

b) delayed flow when no water is delivered for the initial eight complete strokes or more.

c) handle shaky even when the axle bolt has been tightened (Malawi deep pumphead).

4.2.7. If any of the above faults are noted or any other repairs are required a member of the Group Village Repair Team should be informed.

4.2.8. The Village Caretaker should check that the Pump Committee are keeping each water point and its surroundings clean, ensure that a garden is cultivated to use the drain water and that the pump is operated properly. This system of cross-checking should operate at all of the seven tiers.

4.2.9. If any part of the apron needs repairs the Village Caretaker should arrange with a local builder (perhaps the one who helped to construct the apron initially) to build up the surround as necessary and re-plaster over the repaired area. The community will have to organise themselves and pay for the repairs and materials (probably about K10 for labour and one bag of cement).

5. THE GROUP VILLAGE REPAIR TEAM

5.1.1. The Group Village Repair Team is chosen by the community at a meeting of the Village Water Committees and the Group Village Headman (usually the Village Caretakers would be chosen at the same meeting). The Repair Team is comprised of volunteers, one repair man from every 3 - 5 villages depending on location and traditional linking of communities. There will be at least two Repair Men to every Group Village (commonly 10 - 20 villages). Each Repair Man must be willing to carry out repairs at any pump within the Group Village, not only those within his nominal 3 - 5 villages.

5.1.2. It is likely that most of the Repair Team would be men. However, once lighter downhole components for the pumps have been fully developed and tested, it is hoped that women will be able and willing to carry out simple repairs. It may be difficult for the Headmen to accept this untraditional role for women but it should be encouraged because of the greater incentive women have to keep the pumps operating properly.

5.1.3. It is envisaged that a tool-box will be provided for each Group Village Repair Team to be stored by the Group Village Headman. This will contain lifting tools and spanners appropriate for the pumps. One Repair Man should be able to carry out most repairs single-handed or with one unskilled helper.

5.2. DUTIES OF THE REPAIR TEAM

5.2.1. Simple repairs should be carried out by a repair man as promptly as possible whenever they are reported. If help or advice is required another member of the Repair Team should be consulted. Procedures for repairs cannot be described in detail until the downhole components of the Malawi (deep) handpump and new designs for the Malawi (shallow) handpump have been developed and chosen for widespread installation. A further section will therefore need to be added to this Manual in due course.

5.2.2. For more difficult repairs the Project Maintenance Assistant should be asked for help.

5.2.3. Any spare parts can be obtained from the Maintenance Assistant. It is hoped that many of the small replaceable items (for example, foot valve, plunger, bushes, rod connectors) will in due course be made in Malawi (e.g. by injection moulding) and will be widely available in local stores. When this stage is eventually reached it is intended that the village communities will purchase their own spare parts. The villagers could perhaps use crops grown in their garden near the water point to collect money to pay for spare parts. Government will replace major items as and when they are necessary (for example a reconditioned pump head, rising main, etc.).

5.2.4. When the repair is completed the downhole components should be replaced carefully, nuts and bolts all tightened and the handpump tested. Water should be pumped until it is clear.

5.2.5. It is intended that diaries will be issued to each of the repair men to record when and where any repairs have been carried out. The introduction will include a "trouble-shooter's guide" to the type of repairs likely to arise and their remedies. This will be in pictorial form with the faults listed by number so that they can easily be referred to in the diary in case the repair man cannot write well. This will facilitate cross-checking by the next tier - the Project Maintenance Assistant.

6. THE PROJECT MAINTENANCE ASSISTANT

6.1. The Maintenance Assistant will be a Government employee (probably TA grade) and will be responsible for about 150 - 200 handpumps). He will live in the project area and will be provided with a bicycle. It is intended that a three roomed house and store will be built for each Maintenance Assistant using low-cost building techniques during the construction phase of the Integrated Project. It is desirable that the Maintenance Assistant has training at other completed projects and spends some time familiarising himself with his own project area and the rural community during the construction of water points.

6.2. DUTIES OF THE MAINTENANCE ASSISTANT

6.2.1. Monthly visits to each village will be required.

a) Each pump and pump surround should be visited to ensure that the village are looking after their water points and to ascertain if any major repairs are necessary. If the pump is not in good working order or the apron is dirty or needing repair the Maintenance Assistant should investigate the cause and try to find a remedy to the problem.

Perhaps 10 - 15 pumps (3 - 5 villages) could be visited per day, i.e. about 15 days would be required to fully cover his area.

b) Village Caretakers'diaries should be inspected and initialled to ensure the preventive maintenance is being carried out. This will be done at the same time as the pumps are visited.

c) A meeting with each Repair Team will be required to inspect and initial diaries and obtain details of any repairs which have been carried out. This would probably only take 1 - 2 days as each Maintenance Assistant would only have about 3 - 6 Group Village Repair Teams in his area.

6.2.2. The Maintenance Assistant should be available to give advice and help to the Repair Teams and Village Caretakers where necessary.

6.2.3. The store of spare parts should be looked after and an inventory maintained. Small replaceable items will be held in his stock and should be supplied to the village when required. It is hoped that foot valves and plungers will be available from village stores in due course. Some larger items might be stocked but most will need to be requisitioned from District Teams.

6.2.4. If major repairs are required the Maintenance Assistant will need to arrange for these to be carried out either from the District Team or the Regional Centre depending on the nature of the repair.

6.2.5. Records should be kept:-

a) Advance monthly work schedule.

b) Monthly work return.

c) Monthly report of repairs (date, waterpoint, pump number, nature of repair, materials used, depth to water (if known), depth of borehole/well (if known).

d) Inventory of spare parts in store and records of when and where any parts were used, and stores required.

6.2.6. Assistance will be required to organise and run training sessions and refresher courses for Pump Committees, Village Caretakers and Group Village Repair Teams. These will be organised through the Regional Offices and co-ordinated by the Headquarters Training Unit. The Maintenance Assistant will issue diaries each year to the Village Caretakers and Repair Teams, after filling in details of the handpumps for which they are responsible. [see Chapter D].

6.2.7. Liaison will be required with various district extension staff to encourage village meetings for advice on activities related to the water supplies [see Chapter D].

a) Health Surveillance Assistant and District Health Inspector for health education and sanitation.

b) Agricultural Field Assistant for small gardens using drain water from the pumps.

c) Building teams constructing model low-cost pit latrines.

7. THE DISTRICT TEAM

7.1. It is envisaged that District Teams could be established, perhaps using the existing 20 Maintenance Units and their stores as a basis. Each District Team would have one Senior Maintenance Assistant (STA grade), one storeman/clerk, one driver/mechanic and would be equipped with a 3/4 ton pickup. Each district would ultimately be responsible for about 1,000 pumps and supervising five to seven Maintenance Assistants.

7.2. RESPONSIBILITIES OF THE DISTRICT TEAM

7.2.1. Supervise Project Maintenance Assistants by regular (monthly) inspection visits and spot checks of Villager Caretaker's and Repair Team's diaries.

7.2.2. Supply stores to Project Maintenance Assistants. A stock of small replaceable spares could also be distributed whenever the District Maintenance pickup is required for a major repair. An inventory of the stores and details of their subsequent distribution will need to be kept.

7.2.3. Collect monthly returns from Project Maintenance Assistants and enter repair details on cardex [see Figure E.7.1.]. Summarise monthly repair information as monthly return to Regional Centre. Prepare advance monthly schedule of supervisory visits to Maintenance Assistants.

7.2.4. Give assistance to the Project Maintenance Assistant whenever a major repair is required, for example, a change of pumphead.

7.2.5. Arrange for pump reconditioning and supplies, vehicle servicing and borehole/well rehabilitation by the Regional Centre as necessary.

Figure E.7.1

Example of Format which could be used to record pump repairs on a cardex system

Borehole or Well Number:..

Handpump Number: 1) .... 2)........................

Village:............................ District..................

Map Sheet:.......................... Grid Reference:............

Date drilled/dug................... Drilled/dug depth (m).........

Date pump installation: 1)............... 2)....................

Test yield (l/min):..................

Static water level (at construction) (m):.........................

Date	Nature of Repair	Carried out by[1]	Spares Used	W.L.[2] (m)	Depth[3] (m)	remarks

[1] *Insert V for Village : MA for Maintenance Assistant*
D for District Team : R for Regional Centre

[2] *Water level below surface (if known)*

[3] *Depth of borehole/well below surface (if known)*

8. THE REGIONAL CENTRE

8.1. It is intended that Regional Centres would have a Senior Maintenance Officer (STO grade) supervising the Regional Store (storeman in charge) data store (STA in charge),the pump reconditioning and vehicle servicing workshop (TO in charge) and the borehole/well rehabilitation unit (TO in charge). The Regional Centre would be served by a 3/4 ton pickup, a 5/7 ton truck for delivery of materials, a 2½ ton truck for rehabilitation and two motorcycles for supervisory staff transport. The Regional Centre would ultimately be resonpsible for 6,000 - 10,000 pumps and 6 - 10 District Teams depending on the region.

8.2. RESPONSIBILITIES OF THE REGIONAL CENTRE

8.2.1. Supervise District Teams, through them the Project Maintenance Assistants. This will include monthly inspection visits.

8.2.2. The Central Region Store will also form the National Maintenance Store and will distribute to the Northern and Southern Regional Centres.

8.2.3. Recondition pumpheads as necessary (minor welding, reaming, respraying).

8.2.4. Service vehicles from Regional, District and Project levels.

8.2.5. Collect monthly returns of pump repairs from District Team and enter on cardex. The cardex format will be identical to that used by the District Team [Figure E.7.1]. A further record (probably a ledger) will be kept for each pump, to cross-refer and to record pumphead removal and overhaul. The Data Section at Headquarters level will need to use these records periodically to update the National Archives.

8.2.6. Carry out major repairs to boreholes/wells which cannot be done at district level - for example fishing for dropped pipe or rods.

8.2.7. Rehabilitation of boreholes and wells when required. This may include retesting and redevelopment of boreholes to remove infilling

of fine material in both borehole and pack. The frequency at which rehabilitation programmes would be required has not yet been evaluated. Retesting of the well-designed boreholes in the Upper Livulezi Feasibility Study is planned. The borehole performance after two years of operation compared with the initial performance will help to give some insight into the expected life before major rehabilitation and the techniques which may be required.

8.2.8. Training of Government maintenance staff at District and Project level. Refresher courses will be organised in conjunction with the Training Unit from Headquarters.

8.2.9. A summary of forms required for the proposed maintenance structure is given in Table E.8.1.

Table E.8.1.

Summary of Forms Required for Proposed Maintenance Structure

Project Maintenance Assistant

1. Advance monthly work schedule
2. Monthly work return
3. Monthly report of repairs
4. Stores inventory and requisitions

District Team

1. Advance monthly schedule of supervisory visits
2. Monthly report of repairs
3. Stores inventory and requisitions
4. Waterpoint cardex system

Regional Centre

1. Stores inventory and requisitions
2. Waterpoint cardex system
3. Pumphead cardex system (to record pumphead manufacture, overhaul, location)

9. MAINTENANCE AT HEADQUARTERS LEVEL

9.1. At Directorate level it is proposed that the maintenance programme would be the overall responsibility of the Head of Groundwater. The Chief Maintenance Supervisor (CTO grade) would be in charge of a Training Unit (with an STO and two TOs) and a Research and Development Workshop (with an STO and TO as Workshop Supervisors). Vehicles would include a 4 WD Station Wagon, two motor cycles for supervisory staff and two specially equipped 4 WD vehicles for maintenance training. Eventually Headquarters could be responsible for some 25,000 handpumps.

9.2. RESPONSIBILITIES OF HEADQUARTERS

9.2.1. Supervision of National Maintenance Network at all levels to ensure smooth operation.

9.2.2. The Training Unit will organise initial courses and refresher courses for Village Level Maintenance in conjunction with Project Maintenance Assistants [see Section 10]. Training sessions should also be arranged for Government maintenance staff at Regional, District and Project levels [see Section 11 and Chapter F].

9.2.3. The Research and Development Workshop will test and develop new ideas to improve handpumps and horehole/dug well construction techniques.

10. VILLAGE LEVEL MAINTENANCE TRAINING

10.1. Training courses and refresher courses will be needed for all levels of community maintenance. It is intended that these will be organised by the Training Unit from Government Headquarters in conjunction with the Project Maintenance Assistant.

10.2.1. The Integrated Project Logo should be used as an education aid [see Figure E.10.1]. This can be used to explain the following:-

a) Shallow lift direct action pumps are used in the valleys (dambos) where the depth to water is shallow, and boreholes with lever handle pumps are used where the water is deeper.

b) There are three main layers in the ground where the wells and boreholes are situated. In upland areas, nearest to the ground surface clays are found. Under them is soft, sandy weathered rock and last of all hard, unweathered rock. In lakeshore areas interlayered clays and sands are found overlying hard bedrock.

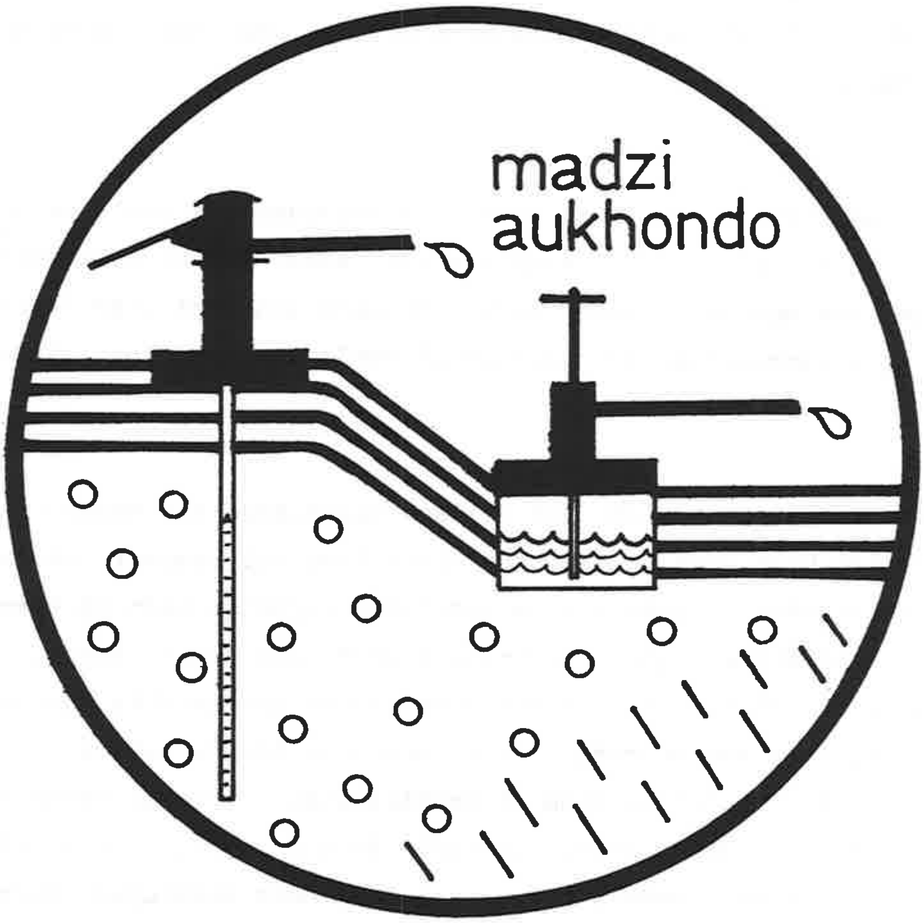
c) The boreholes penetrate the weathered rock from which the water supplies are derived. The dug wells are shallow and have a larger diameter with more storage for water as they often remain within the clays. Little water can be obtained from the hard rock.

10.2.2. It is intended that the logo will be widely displayed for a variety of uses - signs designating project areas; as transfers on vehicles, maintenance stores etc.; posters in schools and rural health centres; on the covers of Village Caretaker and Repair Team diaries; on T shirts, badges, hats, biros etc. to be handed out to Project staff, Maintenance Assistants, Village Caretakers and Group Village Repair Teams - perhaps a different item at each refresher course. The designs and logistics for production of the education aids are being investigated.

10.3. A trainers guide has been produced to help with the planning of training courses for village volunteers [see end of Section 10]. This guide was based on the flipchart for maintenance of the India Mark II handpump but modified for Malawi. Those responsible for training can extract the relevant Chichewa captions for duplication to hand out to the villagers

Figure E.10.1

Integrated Project Logo



being trained. This will serve as a reminder of their duties. The drawings with Chichewa captions have also been produced at poster size as a flipchart and were used as visual aids in the first training courses; these might need to be redrawn for other project areas.

10.4. It is intended that a film will be made showing the concepts behind Integrated Groundwater Projects, the involvement of the community during the construction phase and the subsequent maintenance required at village level. This could be shown in local clinics or schools at the start of any project and possibly again on completion when the community is required to take over the operation and maintenance.

10.5. It is hoped that the Training Unit from Headquarters would be equipped with two to three vehicles, possibly with audio visual equipment to transport the education aids discussed above together with demonstration pumps, pump components and examples of tools required for maintenance.

10.6. The first training sessions for Village Caretakers and Group Village Repair Teams have been held in the Upper Livulezi Project, and were highly successful. There was an excellent response both in terms of numbers of volunteers and the interest which was self-evident. The enthusiasm and willingness of the women to be involved in maintenance was particularly encouraging. Women were also keenly taking an interest in the demonstrations of repairs with a view to ensuring that the Repair Teams carried out their jobs properly! It is clear that once suitable downhole components have been developed women could be involved with repairs as well.

10.7. TRAINING OF THE PUMP COMMITTEE AND VILLAGERS

10.7.1. The Pump Committee and all the villagers will be instructed on the importance of protected water supplies and cleanliness of pump surroundings by the project staff during water point construction. It is intended that a short talk will be given to everyone by a Health Surveillance Assistant on health education and sanitation at

Figure E.10.4. Training Session for Village Caretakers

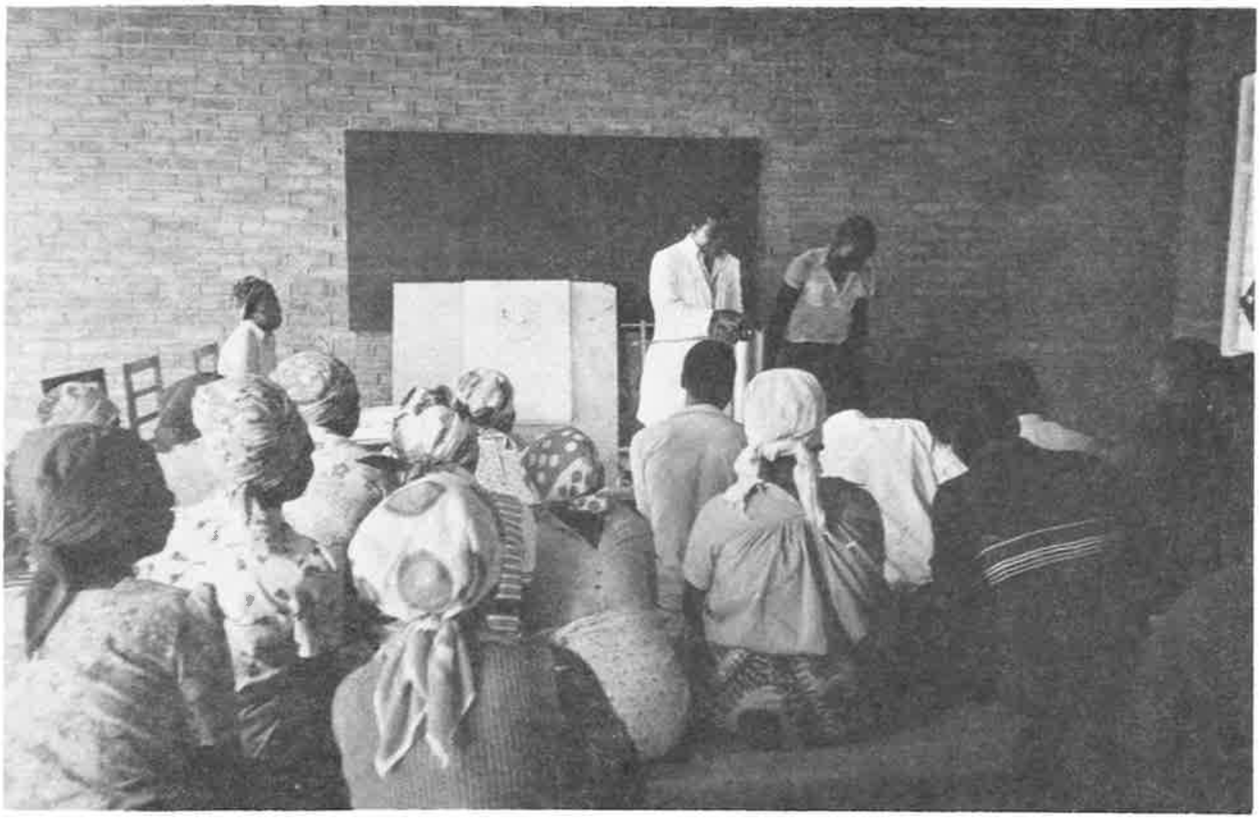


Figure E.10.5. Demonstration of Preventive Maintenance

preventive maintenance to be carried out. It is important that each volunteer has the chance to experiment with the tightening of the nuts and bolts on the handpump during the training session and is happy using the pair of spanners which is provided for each village. Village Caretaker diaries and a summary in Chichewa of points covered in the course (taken from the Trainers Guide) should also be handed out.

10.8.3. The course should include a session on health and sanitation dealing with disease transmission by insects and water, the importance of protected water supplies, personal hygiene, pit latrines and rubbish disposal. The importance of cleanliness in the collection, storage and use of water should also be emphasised. The District Health Inspector is probably best qualified and used to giving such talks.

10.8.4. Activities associated with the provision of water and health improvement could also be encouraged at this point, for example demonstration of low-cost pit latrines. It is envisaged that all Care-takers could be offered help with construction of a pit latrine if they provided the necessary locally available materials (sisal, bricks, crushed stones etc.). This would then serve as a model both of low-cost building methods and improved sanitation [see Chapter D].

10.8.5. The demonstration of a garden using drain water from a handpump should help to encourage production of similar gardens throughout the project area.

10.8.6. Refresher courses will need to be held perhaps every one to two years.

10.9. TRAINING OF THE GROUP VILLAGE REPAIR TEAM

10.9.1. A full day course will be required for training the Group Village Repair Teams (preferably not more than 15 people at a time. will be as for the Village Caretakers with an additional session explaining the mechanism of handpumps and simple repairs [see Figure E.10.3].

the handpump opening ceremony. At the same time the Maintenance Assistant can instruct the Pump Committee in their duties. He can then check that the pump surrounds are being kept clean and tidy whenever he has an inspection visit. If this is not being done he can try to find out the reasons - perhaps a volunteer has moved away from the village - then help to sort out a solution to the problem.

10.7.2. Talks on Health Education and care of water in the home can also be held at local schools and rural health centres. Posters showing the Integrated Project logo should be displayed in prominent positions in these buildings. In the long run it will be best to have a group of trained staff who are specifically attached to water projects to educate the villagers in the relationship between water and health. This is being planned in a joint programme with Ministry of Health.

10.8. TRAINING OF THE VILLAGE CARETAKER

10.8.1. A half day course will be required for training Village Caretakers (preferably 20 - 40 at a time). This could take place at the Project Camp, in a local school, dispensary,court or suitable place where there is a nearby example of both shallow and deep handpumps. The volunteers should be informed at least two weeks in advance and preferably offered an alternative date for the course as a contingency plan to allow for funerals or other occasions which preclude the caretakers from attending. The volunteers could be collected from suitable pick-up-points if it is too long a distance to walk. The course will take approximately three to four hours and an example itinerary in both English and Chichewa is given [Figure E.10.2]. It is felt that lunch should be provided.

10.8.2. The course is probably best organised by the Project Maintenance Assistants in conjunction with Training Staff from Headquarters using the Trainers Guide for Village Level Maintenance of Malawi Handpumps [end of Section 10]. This includes an introduction to the occurrence of the water,simple details of pump operation and an explanation of the maintenance system at village level. The duties of the Village Caretaker should be explained in detail together with a field demonstration of correct handpump operation and of the

Figure E.10.2

PROGRAMME FOR VILLAGE CARETAKER TRAINING

15 OCTOBER 1982 : HELD AT KANDEU DISPENSARY

0700 :	Collect volunteers from main road Livulezi (44 villagers from 3 group villages).	Kutenga anthu okonza mapampu m'malo awo.
0830 :	Introduction session - explanation of logo - explanation of village level maintenance structure and duties involved.	Mau oyamba Kulongosola chithunzi chamitundu iwiri yazitsime ndi mapampu ake. Kalongosoledwe ka udindo wa anthu okonza mapampu.
0900 :	- demonstration of correct pump operation in field (Kandeu Camp) - field demonstration of weekly pump inspection and monthly preventive maintenance for Malawi (deep) hand pump - defects to watch for.	Chionetsero chakagwiritsidwe nchito koyenera kamapampu. Kalongosoledwe kazoyenera kuona pa pampu mulunga ulionse ndinso zoyenera kukonza mwezi uli wonse pa pampu yamtundu wachogwirira chachitali. Zoonongeka zoyenera kuyang'anidwa.
1000 :	Health Education Session by District Health Inspector - disease transmission by water and insects - importance of protected water supplies - importance of pit latrines and sanitation, rubbish disposal.	Maphunziro azaumoyo matenda ochokera ku nchenche ndi madzi, kufunika kwa zimbudzi, ukhondo ndi maenje a zinyalala
1100 :	-Care and cleanliness of borehole/well surround -Care of water in the home - Personal hygiene	Kasamalidwe kamalo ozungulira chitsime ndi madzi muzinyumba Ukhondo

	- small scale agricultural gardens using drain water (demonstration of model garden in Kandeu Camp).	Kalongosoledwe kakagwiritsidwe ntchito ka madzi wotaikira pachitsime; kuthilira madimba (chionetsero chadimba lachitsanzo lapa Kandeu. kampu)
1200 :	Lunch	Chakudya cha masana

Figure E.10.3

PROGRAMME FOR REPAIR TEAM TRAINING : 14 OCTOBER 1982 : HELD AT KANDEU DISPENSARY

0700 :	Collect repairs volunteers from main road Livulezi (13 volunteers	Kutenga anthu okonza mapampu m'malo awo.
0830 :	Introduction session: - explanation of logo - explanation of village level maintenance structure and duties involved.	Mau oyamba. Kulongoso chithunzi chamitundu iwiri yazitsime ndi mapampu ake. Kalongosoledwe ka udindo wa anthu okonza mapampu.
0900 :	Notation of Malawi (deep) hand-pump components, - simple details of mechanism - demonstration of all parts and tools required for maintenance and repairs.	Kufotokoza za zipangizo za pampu ndim'mene igwirira ntchito. Dongosolo la logo kasamatidwe ka mudzi ndi ntchito zake
1000 :	Demonstration of correct pump operation in field (Kandeu Camp) - demonstration of preventive maintenance - removal of downhole components - explanation of mechanism of componsents and tightening of nuts. - defects to watch for - demonstration of dug well pumps (shallow) and Consallen/ India pumps found in Livulezi Valley.	Chionetsero chakagwiritsidwe nchito koyenera kamapampu. Chionetsero cha kakonzedwe ka pampu ndi kumanga manati ndi mabunti. Zoonongeka zoyenera kuyang'anidwa Chionetsero cha mapampu amitundu osiyana-siyana.
1200 :	Lunch	Chakudya cha masana
1300 :	Health Education session by District Health Inspector - disease transmission by water and insects - importance of protected water supplies	Maphunziro a Zaumoyo matenda ochokera ku Nchenche ndi madzi, Kufunika kwa zimbudzi, ukhondo ndi maenje a zinyalala

	- importance of pit latrines and sanitation, rubbish disposal	
1500 :	- Care and cleanliness of borehole/well surrounds	- Kufunika kosamalira pa chitsime
	- Care of water in the home	- Kasamalidwe ka madzi akumwa
	- Personal hygiene	
	- Small scale agricultural gardens using drain water (demonstration of model garden in Kandeu Camp)	- Kalongosoledwe kakagwiritsidwe ntchito ka madzi wotaikira pachitsime; kuthilira madimba (chionetsero chadimba lachitsanzo lapa Kandeu kampu)

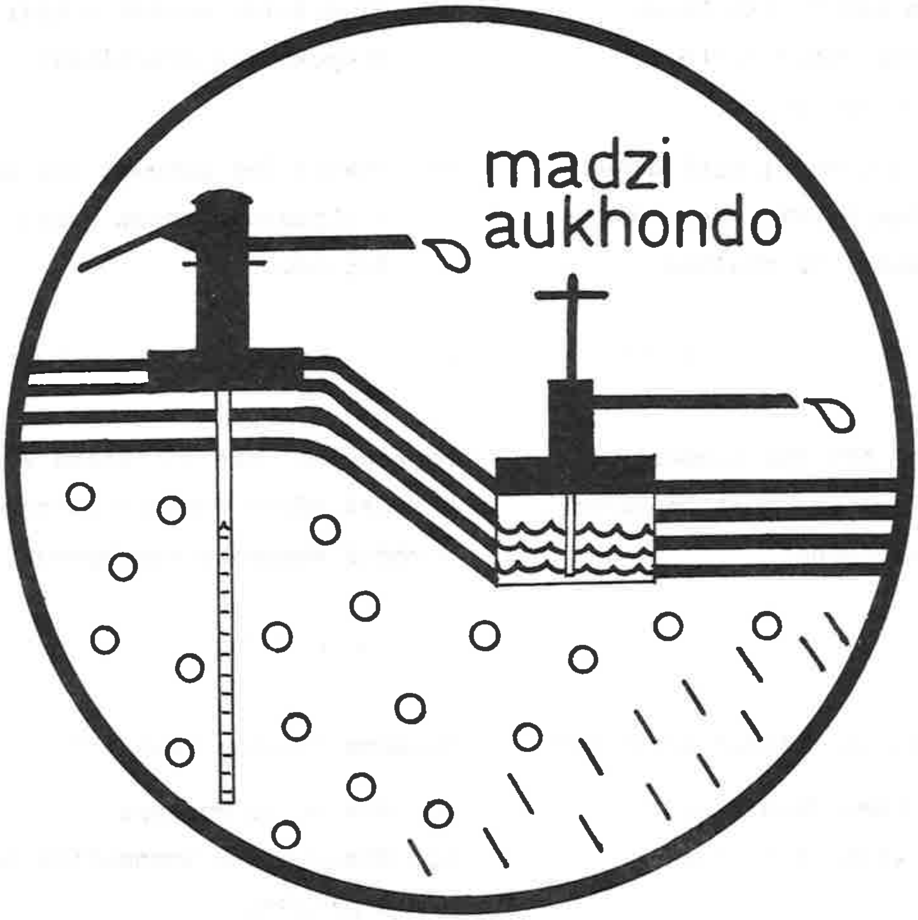
10.9.2. A demonstration of all the components of the handpump should be given aided by the flip-chart, together with an explanation of how each working part operates. Examples of each component and tools required for maintenance and repairs should be available for examination. The duties of the Repair Team will be explained, followed by practical field demonstrations of the removal of pumpheads and down-hole components for both deep and shallow models of handpump. The volunteers should all be actively involved in pulling out the pump rods etc. The mechanism of the pump can be demonstrated once more, and procedures for changing replaceable parts explained. Diagnosis of the repairs required to correct various faults should be discussed in detail. The Repair Team should also be familiar with the preferred methods of pump operation and the duties of the Village Caretakers.

10.9.3. The course will otherwise cover the same points as that for the Village Caretaker [Section 10.8]. A handout serving as a reminder of the duties and a diary should be given to each repair man and they will also be offered help with construction of a model pit latrine. A tool box will be given to each Repair Team to be kept by the Group Village Headman.

10.9.4. Refresher courses should be held perhaps every one to two years with extra guidance given by the Maintenance Assistant where and whenever requested.

Trainers Guide for Village level Maintenance of Malawi Handpumps

Dongosolo lothandiza a phunzitsi a zakasamalidwe ka M'jigo wa (pampu ya) mtundu wa Malawi Pampu pamudzi.


madzi
aukhondo

HANDPUMPS AND THOSE WHO LOOK AFTER THEM

There are two models of the Malawi handpump:

a) deep model with lever handle where depth to water is deep

b) shallow model with direct action handle where depth to water is shallow

The pumps are the property of the village and must be cared for by everyone.

The pumps are looked after by:

a) The Pump Committee
b) The Village Caretaker
c) The Group Village Repair Team
d) The Government Maintenance Team

All these people are doing very important jobs. By carrying out their duties they provide the village with a safe, clean continuous supply of water.

MAPAMPU (MIJIGO) NDI ANTHU OWANG'ANIRA (MAPAMPUWO)

Mapampu (mijigo) a mtundu wa Malawi Pampu alipo a mitundu iwiri:

a) Chazitsime zozama - chiri ndi chopukusira chachitali

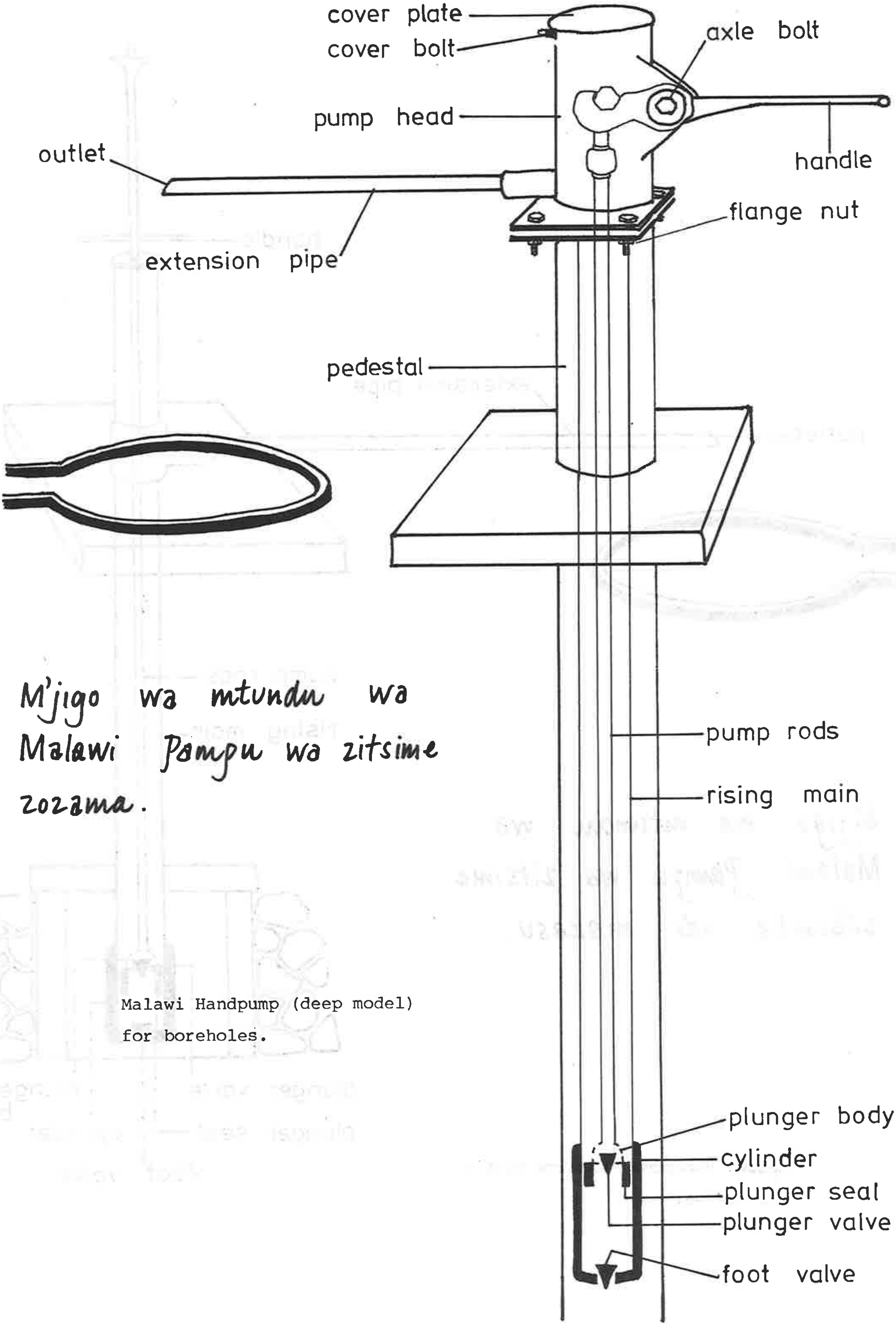
b) Chazitsime zokumba ndi makasu - chopukusa monga ngati kusinja.

Mapampu eni ake ndi anthu a m'mudzi ndiye choncho anthuwo ayenera kusamala mapampuwo.

Mapampu amasamalidwa ndi:

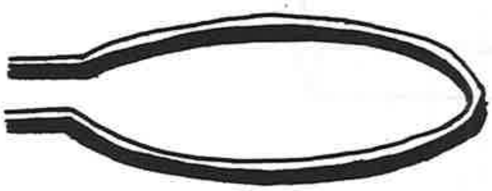
a) Bungwe la mapampu
b) Wosankhidwa wosamalira mapampu a m'mudzi
c) Timu lokonza mapampu a m'dera la mfumu yaing'ono
d) Wantchito wa Boma wosamalira ndi kukonza mapampu

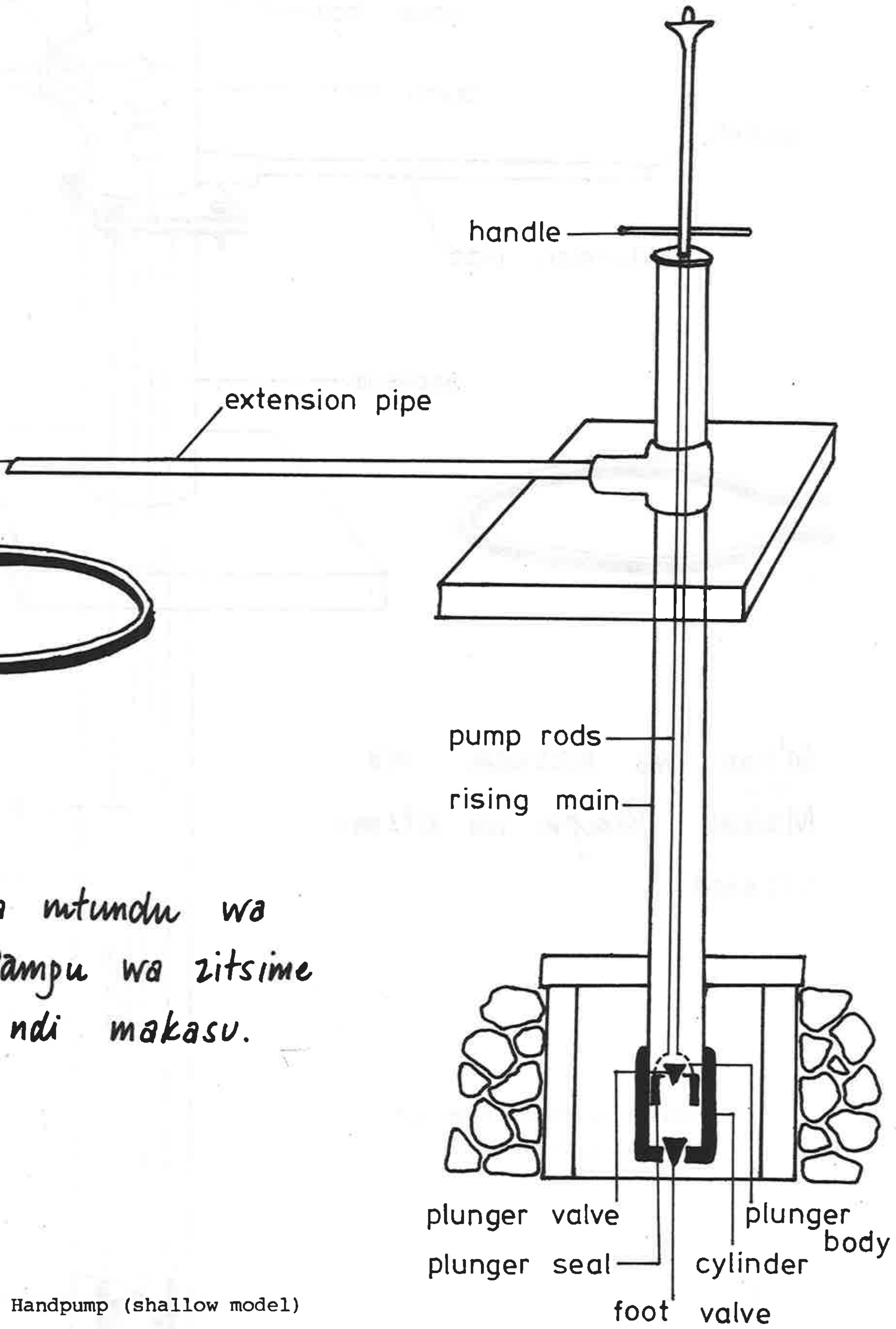
Anthu oyang'anira zitsime ndi anthu ofunika kwambiri chifukwa pakutero iwo akuthandiza kuti anthu ali m'mudzi akhale ndi madzi aukhondo nthawi zonse.



M'jigo wa mtundu wa Malawi Pampu wa zitsime zozama.

Malawi Handpump (deep model) for boreholes.





Mjigo wa mtundu wa Malawi Pampu wa zitsime zokumba ndi makasu.

Malawi Handpump (shallow model) for dug wells.

Each pump has a Pump Committee of three women volunteers who must keep the pump and pump surroundings clean, dry and free from rubbish.

Pampu liri lonse limasamalidwa ndi amai atatu wodzipereka, omwe ntchito yao ndi kuchotsa zinyalala ndi zina zoipa. Iyi ndi ntchito yopanda malipiro.

Each village has a volunteer Village Caretaker who carries out regular preventive maintenance on <u>all</u> the pumps in the village.

Mudzi uli wonse uli ndi munthu wodzipereka yemwe amaonetsetsa kuti mapampu a m'mudzimo akugwira bwino ntchito yache.

Each Group Village has a Repair Team composed of repair men. Every 3 - 5 villages has a volunteer repair man who carries out simple pump repairs when necessary. There are at least two repair men in each Group Village Repair Team.

M'dera la mfumu yaing'ono muli monse muli bungwe (la anthu atatu) lokonza mapampu. Midzi itatu, inai kapena isanu iriyonse imakhala ndi munthu wodzipereka amene amakonza mapampu akaongeka. M'bungwe liri lonse lokonza mapampu muyenera kukhala wanthu wosachepera awiri.

All the pumps in the area will be inspected regularly by the Maintenance Assistant who works for the Government. He will be available to give help with more difficult repairs if he is needed.

Mapampu amayenderedwa pa nthawi yake ndi watchito wa Boma yamwe amaona kasamalidwe ka mapampuwo. Atha, ngati atafunidwa kubwera kudzatha ndiza okonza mapampu ngati patakhala bvuto la likulu.

DUTIES OF THE PUMP COMMITTEE

NTCHITO ZA BUNGWE LOONA MAPAMPU

Care of pump surroundings

Keep the pump and pump surroundings clean.

Kasamalidwe ka malo a pampu(Chitsime)

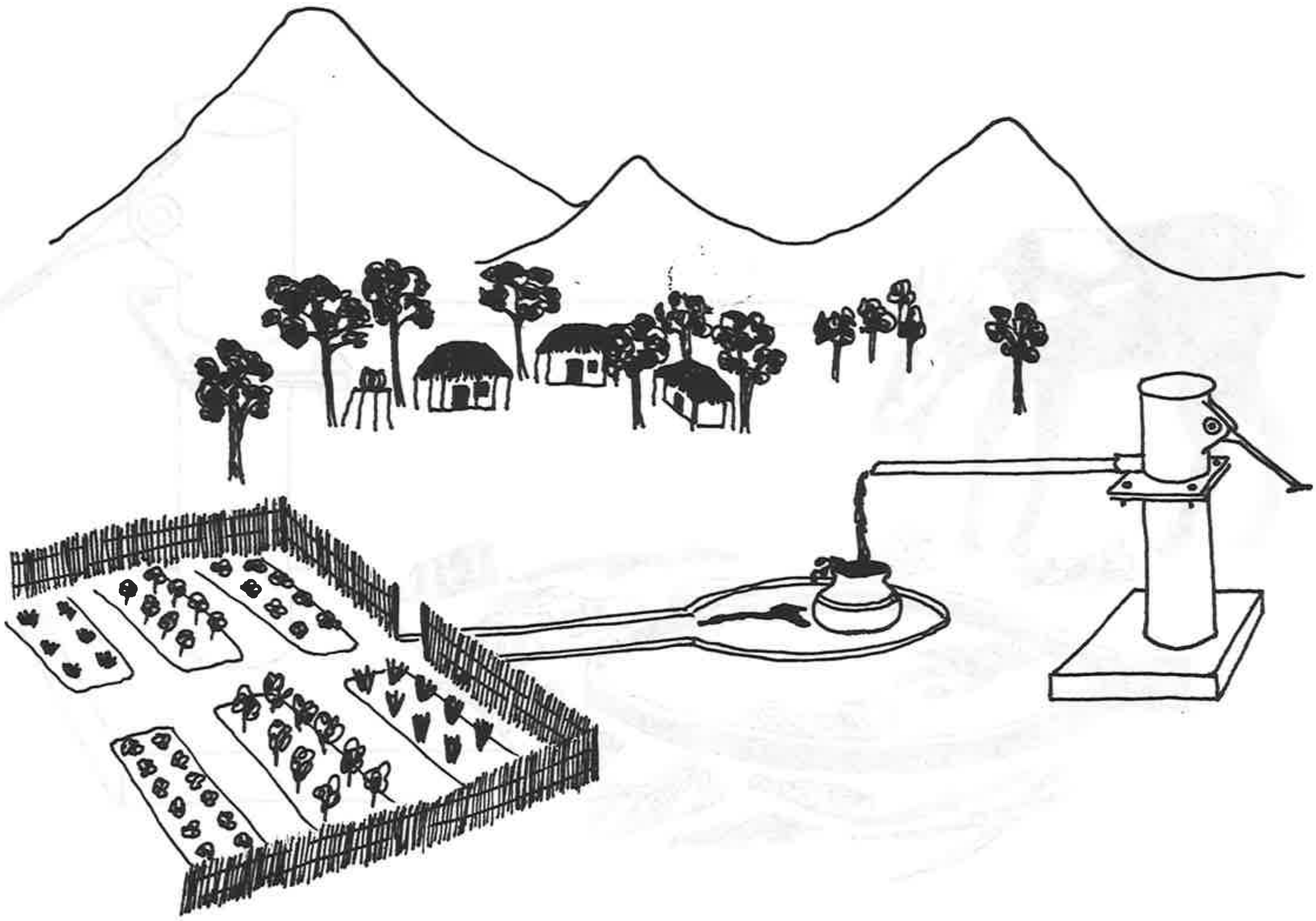
Onetsetsani kuti pampu ili yonse ikusamalidwa bwino pamodzi ndi malo ozungulira chitsimecho.

Keep animals away from the pump surroundings. If necessary build a sisal fence around the pump.

Ziweto zisamafike pafupi ndi pampu. Ngati nkofunika kuli bwino kubzala mpanda wa khonje kozungulira chitsimecho.

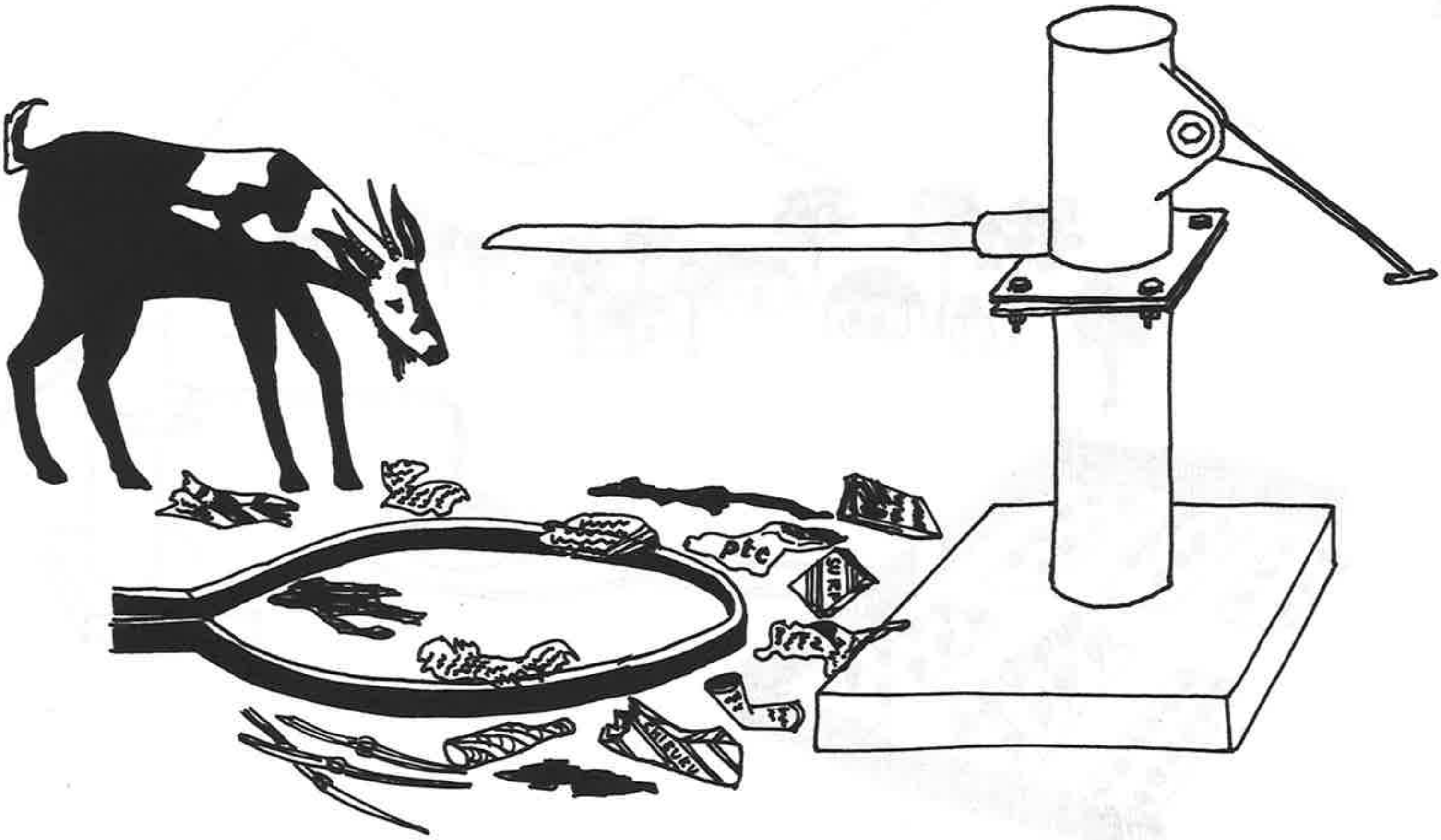
Keep the pump surroundings dry. Discourage villagers from spilling water off the concrete surrounds. Do not let excess drain water collect around the pump.

Pamalo pozungulira pampu pazikhala pouma. Anthu asamatayire madzi pa dothi ndiponso madzi asamadzale m'ngalande yozungulira pampu koma muwakonzere mopita pokalowa m'dimba.



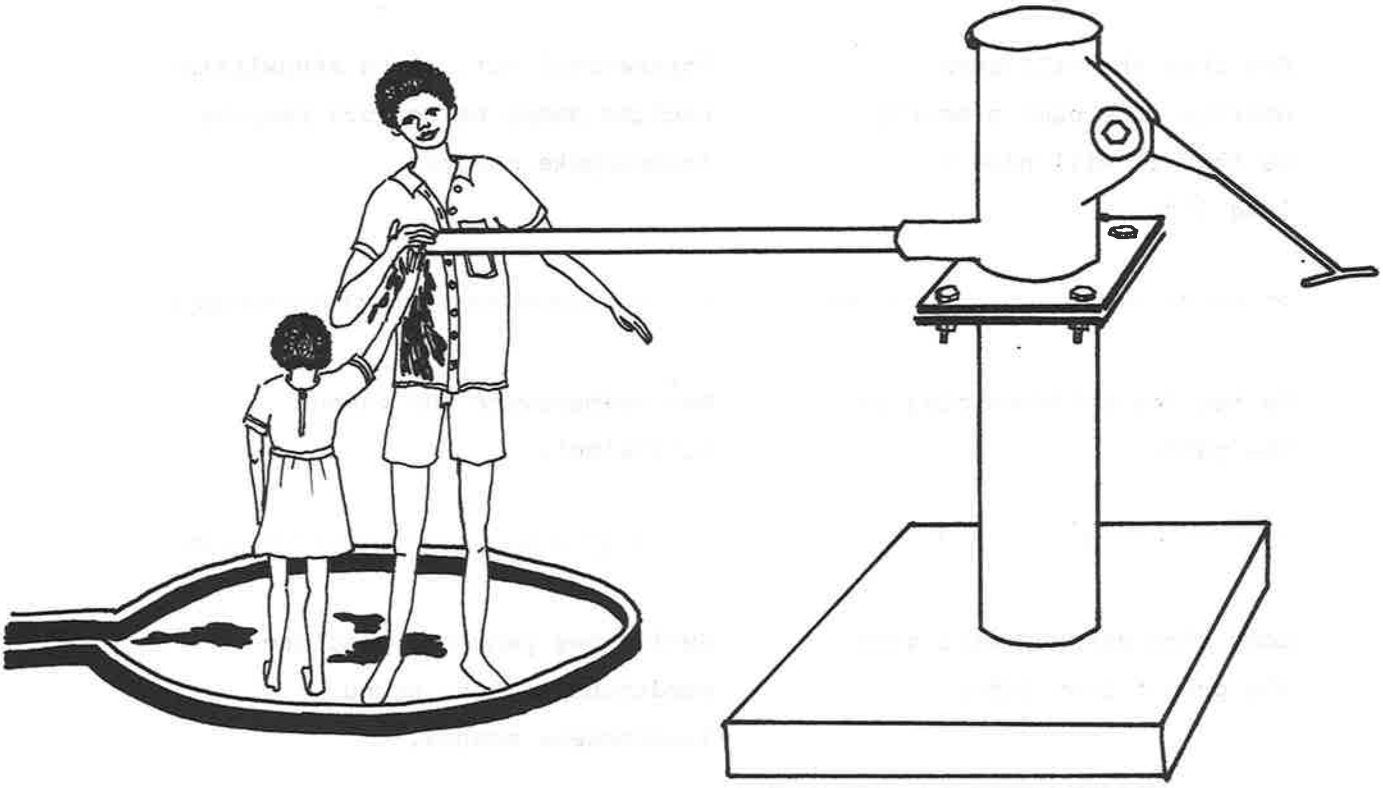
Konzani ngalande kuti madzi wotaika pa chitsime adzeremo polowa padimbo.

Channel drain water into a garden



Samalani malo ozungulira chitsime kuti akhale aukhondo wopanda zinyalala ndi nyama.

Keep the pump surroundings free from rubbish and animals



Chonde musatseka potulukira madzi pam'jigo.

Do not block the outlet.

Pump operation

See that the villagers operate the pump properly so that it will have a long life.

Do not let children play on the pump.

Long slow strokes will give the pump a long life.

If there are difficulties with pumping or the pump breaks down, report it promptly to the Village Caretaker.

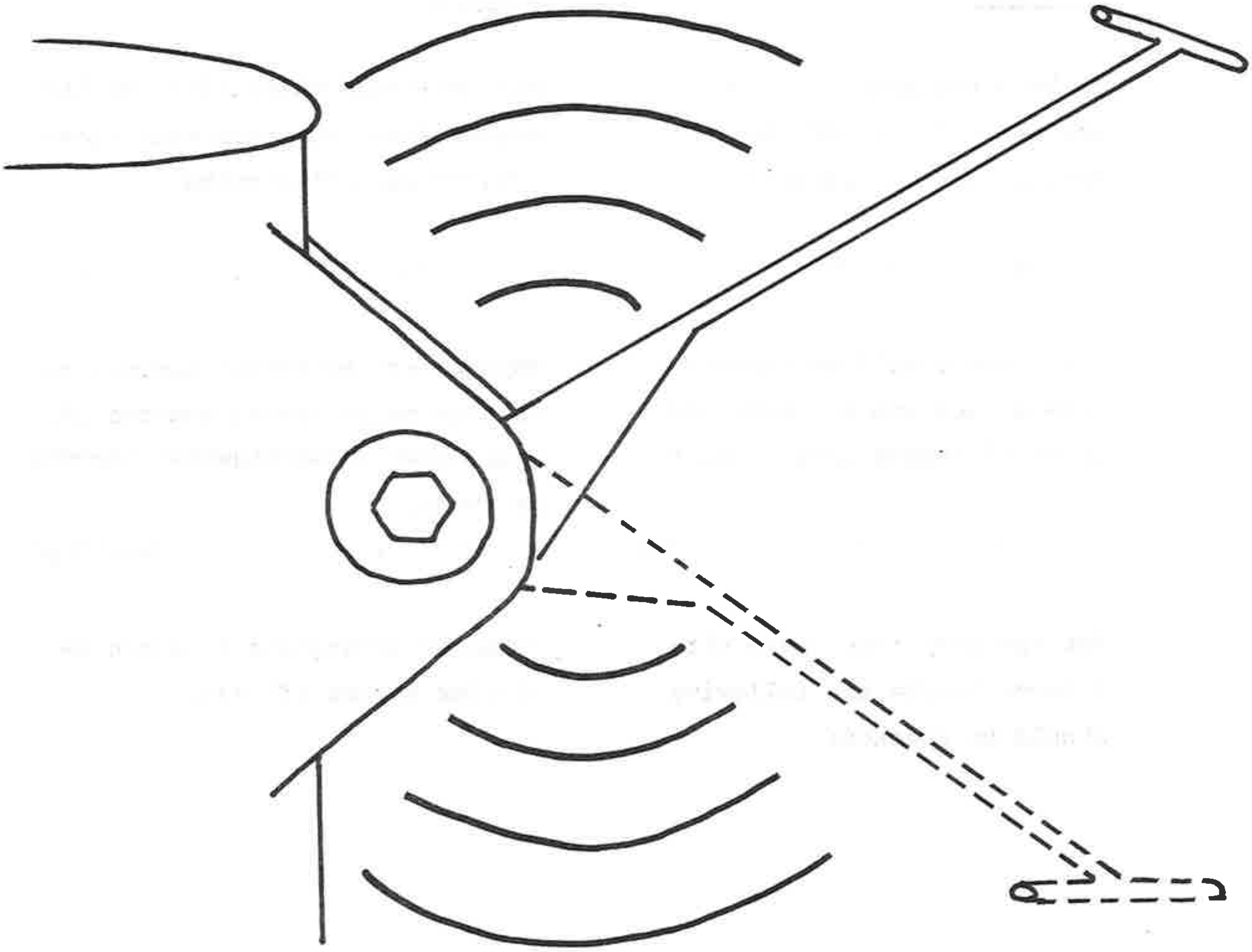
M'mene pampu igwirila ntchito

Onetsetsani kuti anthu akugwiritsa ntchito pampu bwino kuti pampuyo isaonongeke msanga.

Ana asamasewere ndi pampu (chitsime).

Kujiga mwa pang'ono pang'ono kumathandiza kuti pampu isaonongeke msanga.

Ngati pali mabvuto popopa kapena pampu yaonongeka nenani msanga kwa amene amaona kagwiritsidwe ka ntchito ka pampuyo.



Musamenyetse zoimitsira.

Do not hit the stops.

DUTIES OF THE VILLAGE CARETAKER

NTCHITO ZA WOSAMALA ZITSIME M'MUDZI

To keep the pumps in good working order - preventive maintenance is essential.

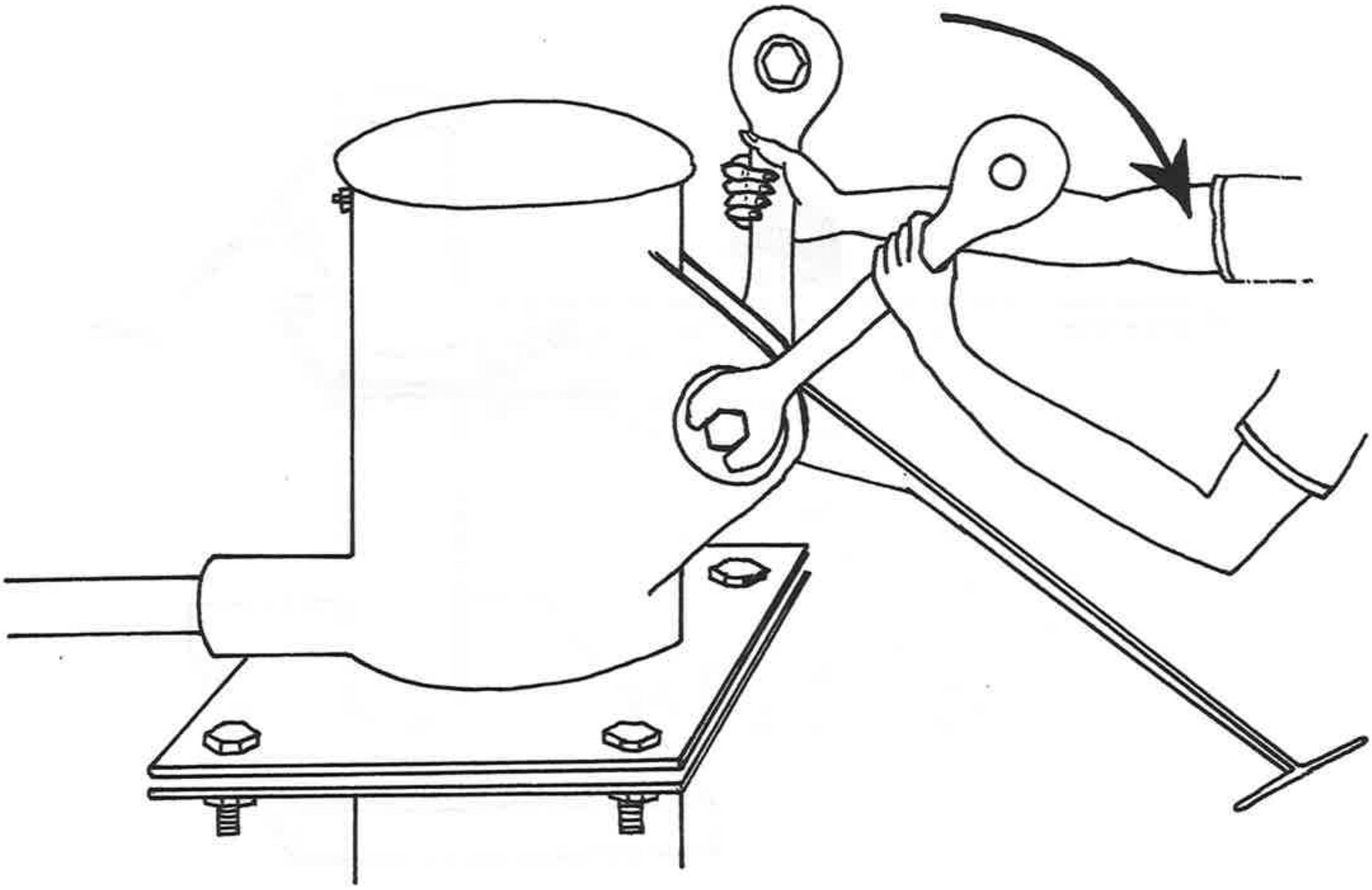
Kuti chitsime chizigwira ntchito nthawi zonse-kuteteza kuonongeka kwachitsime ndikofunika.

The pumps should be inspected once a week and the nuts and bolts tightened once a month.

Mapampu aziyenderedwa kamodzi pa mulungu ndipo manati ang'ono ndi akulu omwe azimangidwanso kamodzi pa mwezi.

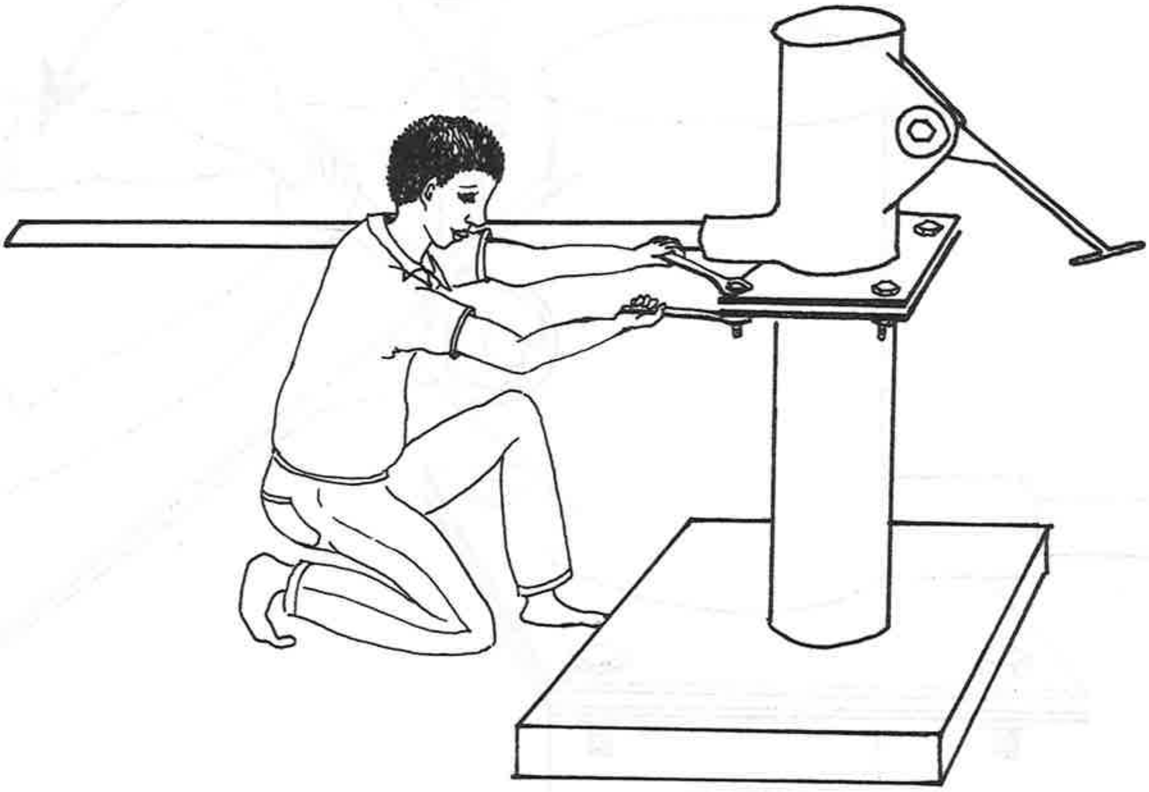
For the deep model pump with a lever handle the following should be checked:

Zoyenera kuyang'ana pa pampu ya zitsime zozama ndi izi:



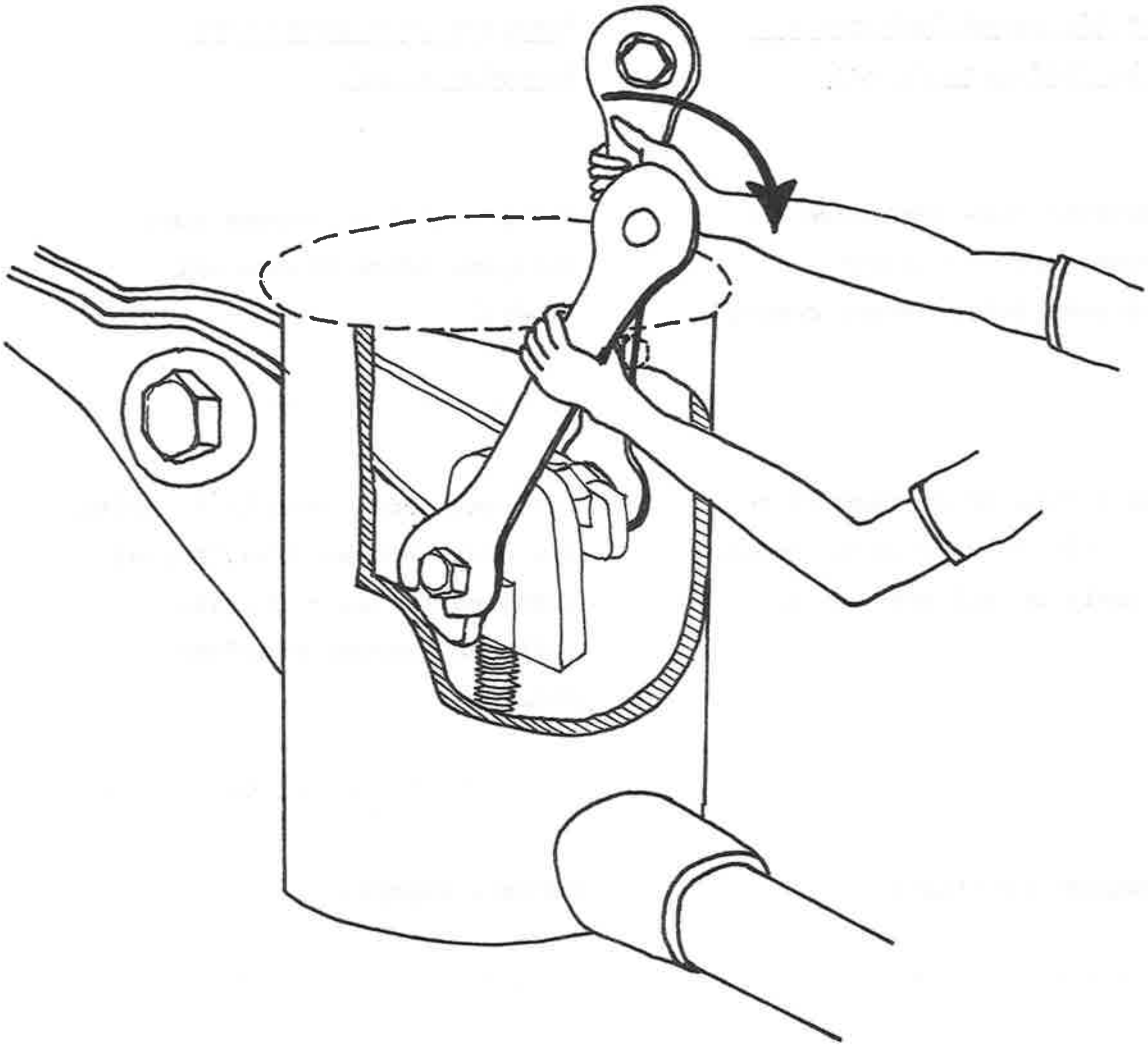
Kodi bauti la pakhosi (lolumikizira chopukisira) pochedwa pa akiselo ndilomanga mokwanira?

Is the axle bolt tight?



Kodi manati ndi mabauti anai a patsinde pa m'jigo (pampu) ndiwomangra mokwanira?

Are the four (4) flange bolts tight?



Tsegulani chitsekero cha pamutu pa m'jigo pomasula bauti lochigwirizira ku m'jigo. Kodi manati a m'kati mwa m'jigo udiwomanga bwino?

Open the cover plate by unscrewing the cover bolt. Are the hanger nuts tight?

On all pumps look out for the following defects:

Delayed flow (you have to pump more than eight strokes before water comes).

Weak flow or no flow (note if this is only when pumping slowly or all the time).

Pumping difficult

Handle shaky (even when you have tightened axle bolt if it is a lever handle).

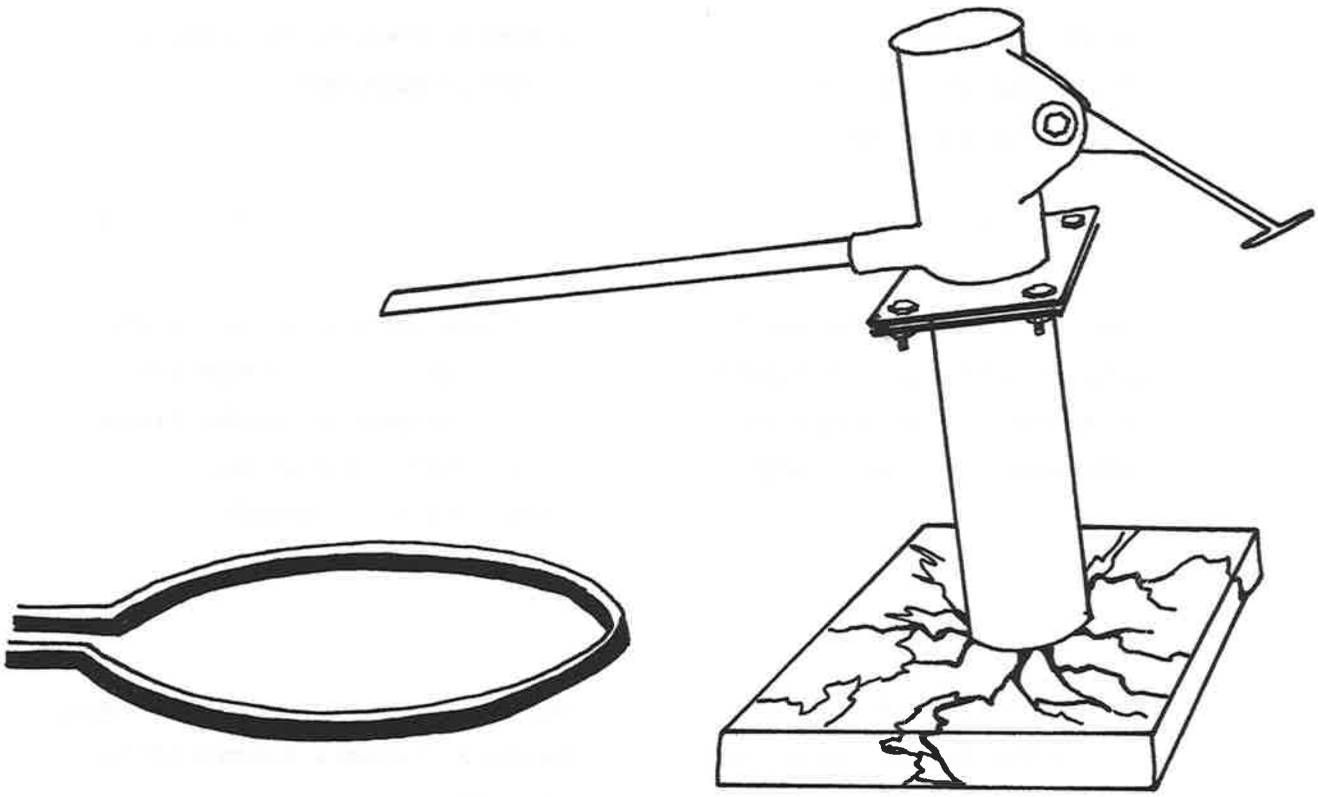
Pamapamu onse yang'anani zoonongeka izi:

Madzi osatuluka msanga koma mutapopa njira zisanu ndi imodzi.

Kutuluka madzi "mwaulesi" mwina osatuluka nkomwe (Yang'anitsitsani ngati izi zichitika chifukwa chopopa pang'ono pang'ono)

Kubvuta kupopa.

Chopopela ndichogwedera - nkana mutamangitsa mabauti akulu.



Kodi tsinde la m'jigo mu simenti
yo foundeshoni ndilogwedezeka?

Is the pump loose in its foundation?

If any repairs are necessary they should be reported promptly to one of the repair men in the Group Village Repair Team.

Ngati pali zofunika kukonza dziwitsani m'modzi mwa anthu a bungwe lokonza chitsime a m'mudzi mwachangu.

Keep a record of the weekly pump inspections and monthly preventive maintenance and breakdowns in your diary.

Muzisunga dongosolo la sabata liri lonse ndinso zosamalira ndi zoonongeka mu bukhu limene m'malembedwa zochitika za tsiku ndi tsiku m'mudzi.

The diary will be inspected by the Maintenance Assistant on his regular visits.

Woyendera wa boma adzafuna kuona bukhulo akabwera kudzayendera mapampu.

If the pump surrounds need any repairs arrange for a local builder to repair as neccesary.

Ngati simenti ya faundeshoni yagamuka kapenanso kung'ambika, chitani chotheka kupeza m'misiri wa zomangamanga msanga kuti akonze moonongekamo.

DUTIES OF THE GROUP VILLAGE REPAIR TEAM

If a pump is reported to be out of order, visit the site promptly to determine the cause.

Carry out repairs where possible. Ask another repair man or labourer to help if necessary.

Any spare parts which are required can be obtained from the Maintenance Assistant.

If any help or advice is required for more difficult repairs ask the Maintenance Assistant.

NTCHITO ZA TIMU LOKONZA MAPAMPU LA M'MUDZI

Ngati mudzidwa kuti pampu yaonongeka pitani msanga kuti mukaone chimene chabvuta.

Konzani pamene mungathe. Funsani wina wokonza kapena wothandiza kuti akuthandizeni ngati kulikofunika.

Zukonzera zofunikira mungazipeze kuchokera kwa wosamalira mapampu wa Boma wa m'dera lanu.

Chithandizo chitafunika pa zinthu zobvuta kukonza muyenera kumufunsa woyang'anira wa Boma kuti akuthandizeni.

When the repair is complete:

Kukonza kukatha:

Replace the downhole components of the pump carefully.

Bwezerani zinthu mosamala.

Ensure all the nuts and bolts on the pumphead are tight.

Onetsetsani kuti manati ang'ono-ang'ono ndi akulu omwe pa pampu-hedi ndiwomanga mokwanira.

Check that the pump is working and pump until the water is clear.

Muonetsetse kuti pampu ikugwira bwino ntchito ndipo "mujige" mpaka madzi woyera atabwera.

Keep a record of the repair in your diary.

Dongosolo la zokonzedwa lilembedwe mu bukhu lache moyenera.

The diary will be inspected by the Maintenance Assistant on his regular visits.

Woyendera wa boma adzafuna kuona bukhulo akadzabwera kudzayandera.

IMPORTANCE OF HEALTHY WATER

Good health begins with good water.

A handpump is a protected source of water. The water is pure, clean, healthy and safe to drink.

Water from the pump may taste strange to begin with, but you will get used to the taste and should use the safe water, not unprotected polluted sources like ponds or a river.

The pump gives a continuous supply of safe water near to the houses and does not dry up.

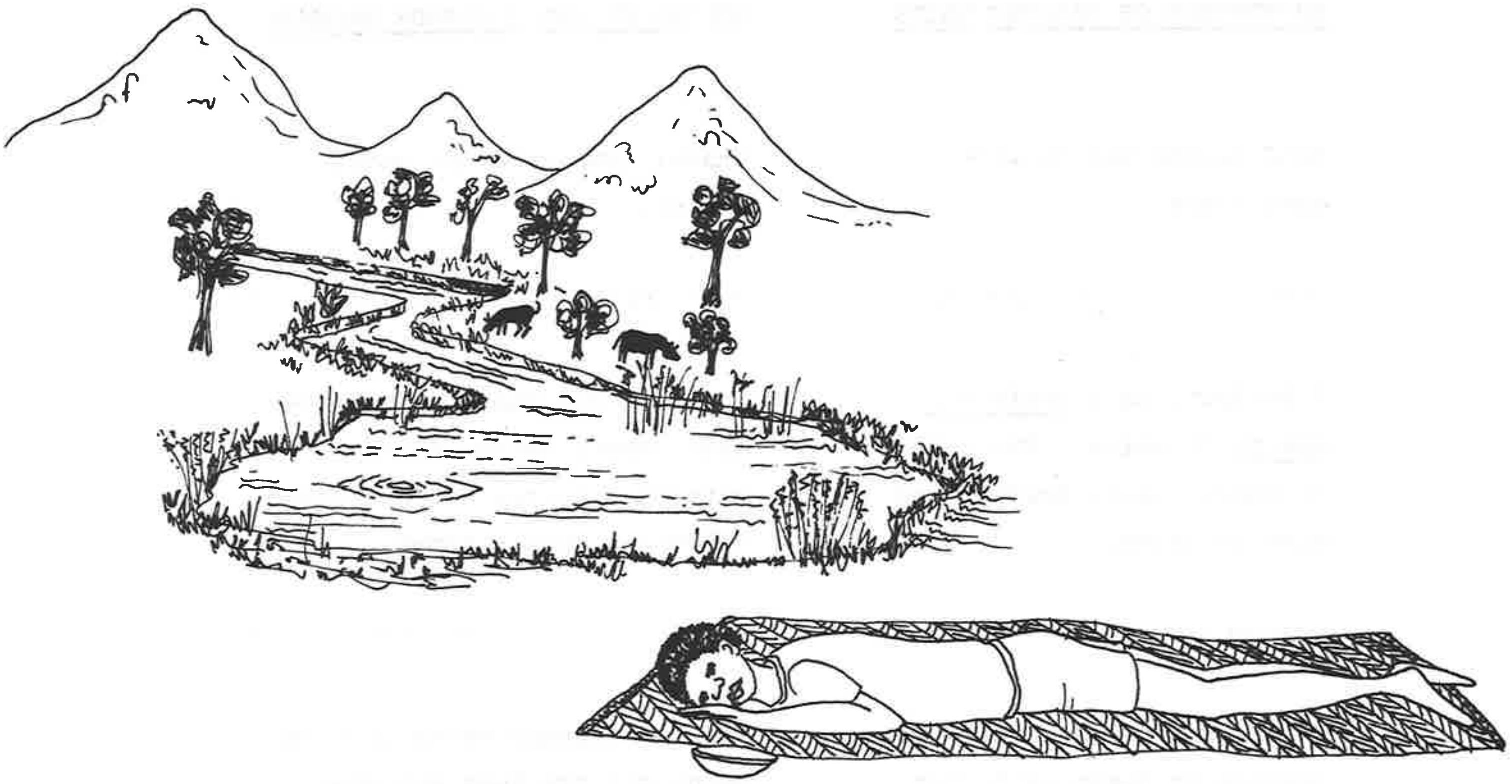
UBWINO WA MADZI OPANDA MATENDA

Thanzi limayamba ndi madzi abwino.

Chitsime cha pampu chimapereka madzi oyera bwino, opanda zitsotso, opanda matenda ndipo sadetsa nkhawa pokumwa.

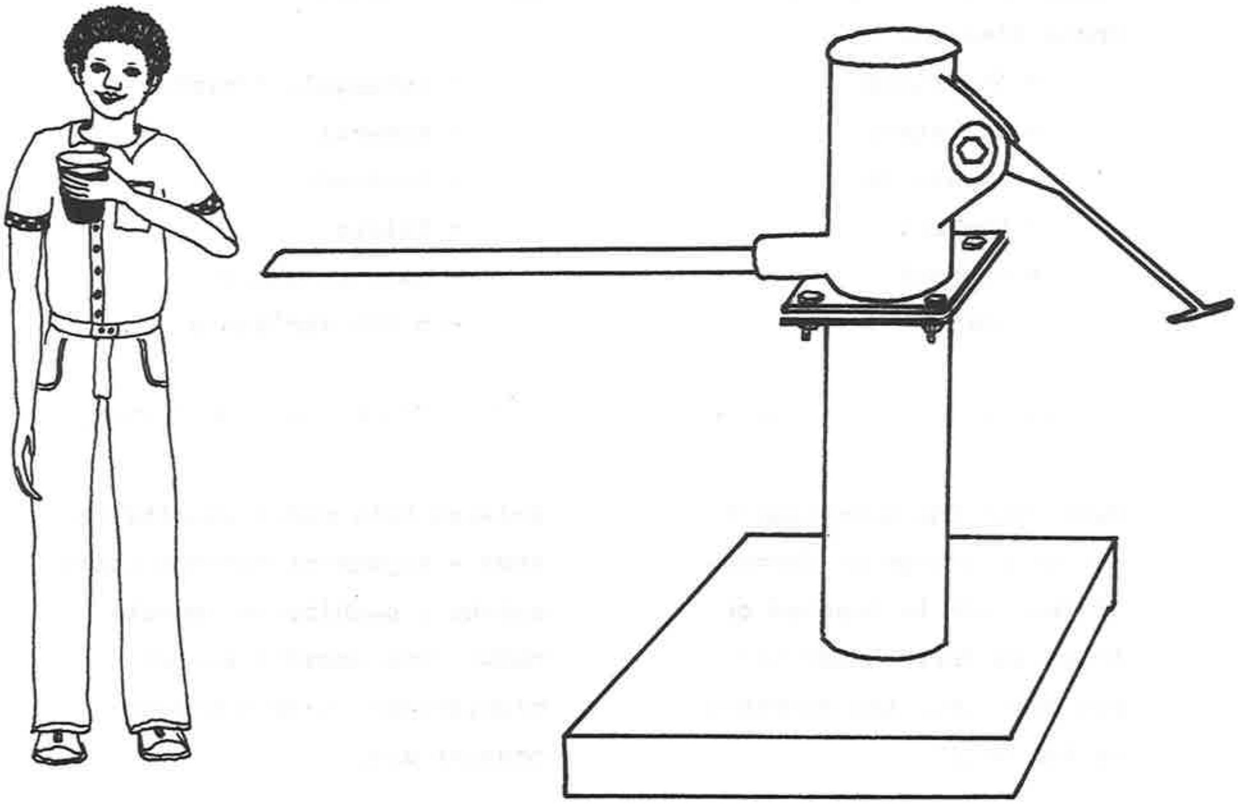
Madzi a mupampu mwina sakhala bwino poyamba koma amazolo-weleka ndiye kuli bwino kumwa madzi amupampu kusiyani kumwa madzi ochokera muzithaphwi.

Pampa imapereka madzi opanda matenda nthawi ili yonse pafupi ndi nyumba ndiponso sauma ngati m'mene zimachitira zitsime kaya m'mitsinje.



Madzi wochokera mum'tsinje ndiso pachitophwi (wosatetezedwa) angathe kukupatsani matenda.

Water from a river or pond (unprotected source) may lead to sickness.



Madzi wotetezedwa (a m'chitsime cha m'jigo) ndi aukhondo wopanda matenda.

Water from a handpump (protected source) leads to good health.

If people drink unprotected water they risk getting these diseases:

- diarrhoea
- dysentery
- hepatitis
- cholera
- typhoid
- worms

Anthu akamwa madzi osatetezedwa matenda monga:

- kutsegula m'mimba
- kamwazi
- chikasso
- kolera
- malungo akulu
- njoka zam'mimba

Note that the pump itself can be a source of disease if the base is cracked or loose so dirty water can run back into the borehole or dug well.

Dziwani kuti madzi amuzitsime anga - kupatseni matenda ngati maziko a pachitsime agumuka. Madzi oipa angathe kulowa m'chitsimemo kuzela m'malo ogumuka aja.

If the area around a pump is not clean it can contaminate the water below.

Ngati malo ozungulira chitsime ali osasamalidwa odzala ndizin-yalala angathe kulowetsa matenda m'madzi a pansi pa dziko.

Diseases can also be carried by insects so:

Matenda atha kutengedwa ndi tizolombo tating'ono-ting'ono choncho:

Make sure excess water does not collect around the pump in order to stop insects from breeding.

Onetsetsani kuti madzi asapange chithaphwi kuzungulira pampu kuti ziwala nchenche ndi udzudzu usaswerane muchithaphwimo.

Bury household rubbish in a pit so that flies are less attracted.

Kwirirani zinyalala m'dzenje kuti nchench zisabwere pafupi.

Use pit latrines.

Gwiritsani ntchito zimbuzi.

COLLECTION, STORAGE AND USE OF WATER

KUTUNGA, KUSUNGA NDI KAGWIRITSIDWE KA NTCHITO KA MADZI

Always
Wash hands at the pump before washing out the collection bucket.

Sambani m'manja papampu musanatsuke ndowa kapenanso m'tsuko.

Wash the inside of the bucket every time before filling it with clean water from the pump.

Tsukani mkati mwachotengera madzi nthawi ili yonse musanatungiremo madzi abwino a m'pampu.

Clean the storage pots every time before they are refilled from the collecting bucket.

Mosungira madzi mudzitsukidwa nthawi ili yonse musanaikemo madzi atsopano.

Pour out the old water in the storage pot for drinking water and replace it with fresh clean water every day.

Khuthulirani madzi ogonetsa mu msuko osungiramo madzi ndi kuikamo madzi abwino tsiku ndi tsiku.

Do not drink directly from the dipping vessel but pour the water into a cup.

Osamwera m'chikho chotungira koma m'chomwera (kapu) chake choyenera.

Do not use the dipping vessel except to take water out of the drinking-water pot. Keep it clean and hang it up after use.

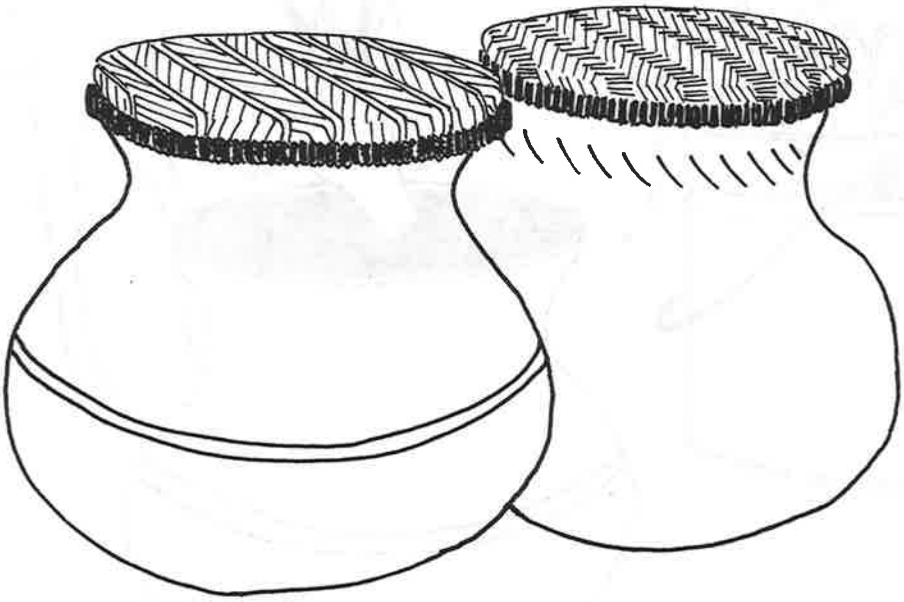
Osagwiritsa ntchito chotungira koma polhopokgapo pochotsera madzi mu msuko womwera. Chidzikhala choyera ndipo mukathera kugwiritsa ntchito muzichipachika.

Use a washing up dish rack.

Gwiritsani ntchito chithandala choyanikapo mbale.

Tetezani zotungira madzi ndi mbale (nsengwa) zodyeramo kuti ziweto zisamweremo madzi ndikunyambitamo.

Do not allow animals to drink from the storage pots or lick dirty dishes.



Brundikirani mitsuko yotungira ndi kusungiramo madzi kuti zoipa zisagweremo.

The water pots should be kept covered to protect them from animals, insects and dust.

The water supply from pumps is closer and more convenient so more water should be used for washing clothes on the washing slab, washing cooking and household utensils and for personal hygiene.

Madzi amumapampu ali pafupi kwambiri pa ichi madzi ambiri atha kugwiritsidwa ntchito monga kuchapa zobvala pochapila (washing slab), kutsukira ziwiya ndinso kusamba m'thupi.

Everybody should wash themselves and their clothes more frequently and keep their houses as clean as possible.

Ali yense ayenera kusamba ndi kuchapa zovala zake kawiri kawiri ndikusamala m'nyumba.

11. TRAINING OF GOVERNMENT STAFF IN THE MAINTENANCE NETWORK

11.1. Training of Government staff will be organised by the Headquarters Training Unit; courses should be held for Project Maintenance Assistants, staff in the District Teams and in the Regional Centres.

11.2. Training will include some or all of the following, depending on the tier in the maintenance structure:-

a) Familiarisation with all the working parts and theory of operation of the handpumps (both deep and shallow models).

b) Practical field demonstration of removal and replacement of the handpump on both boreholes and wells.

c) Demonstration of changing replaceable parts.

d) Trouble shooting to determine problems requiring attention for various breakdowns (one of several causes could be responsible for each pump failure).

e) Practical demonstration of stripping down and reconditioning of the different pumpheads.

f) Practical demonstration of borehole/well rehabilitation techniques.

g) Practical demonstration of pump apron construction in case rehabilitation of pump surrounds is required.

h) Explanation of the seven tier maintenance structure and procedures. for reporting breakdowns, repairs carried out and records of the history of each handpump.

i) Health Education including the importance of protected supplies, discussion of water borne disease, the need for cleanliness of the pump and surrounding area.

j) Training in community work.

Further details of the training programmes are given in Chapter F.

12. SUMMARY OF MAINTENANCE COSTS

12.1. EXISTING MAINTENANCE STRUCTURE

The existing maintenance system for 5,000 boreholes supplying about 1¼ million people requires:-

a) 160 staff (shortly increasing to 185)

b) 20 x 5/7 ton trucks (shortly increasing to 24)

c) 2 x 1 ton trucks

d) 4 motorcycles.

It costs approximately K1 million per annum to operate which represents K200 per borehole (1982 prices) and K0.80 per capita. Only a repair service can be provided and no preventive maintenance is carried out. There is no established maintenance system for dug wells at present.

12.2. PROPOSED MAINTENANCE STRUCTURE

12.2.1. The maintenance structure proposed in this Chapter would service approximately 17,000 boreholes and 8,000 dug wells supplying about 5¼ million people. The maintenance service would be greatly improved providing preventive maintenance, more frequent pump inspections and rapid repairs, training of staff and community volunteers, waterpoint rehabilitation and research for improved technology. The proposed system would require:-

a) 240 - 280 staff (1 x CTO, 5 x STO, 9 x TO, 25 - 30 x STA and 165 - 200 x TA)

b) 3 x 5/7 ton trucks for stores

c) 3 x 2½ ton pickups for rehabilitation

d) approximately 25 x ¾ ton 4WD pickups for District Teams and Regional Maintenance Officers

e) 3 x 4WD station wagons for training teams and the Superintendant

f) 8 motorcycles for supervisory visits from Headquarters and Regional Centres

g) 120 - 150 bicycles for the Maintenance Assistants. Government purchase of loans and monthly maintenance allowances would be provided.

12.2.2. The estimated annual cost (1982 prices) of the proposed system is shown in Table E.12.1.

Table E.12.1.

	Government (K)	Local Community (K)	Total (K)
Salaries (+ allowances and pensions)	400,000		
Vehicle running costs	310,000		
Pump spare parts		210,000	
Pumphead reconditioning*	135,000		
Ancillaries (office expenses etc.)	65,000		
Total	905,000	210,000	1,115,000
Cost per borehole	43	10	53
Cost per dug well	22	5	27
Cost per capita	0.18	0.04	0.22

* Major reconditioning every 5 years at 25% of replacement cost.

The annual cost to the Government of maintaining the system may also be expressed in constant prices as 2.9% of the capital construction costs. This percentage may be used in future years to calculate the current-price maintenance costs relative to inflating capital costs.

12.2.3. The annual cost to Government is approximately the same as under the present borehole maintenance system, although staffing levels would rise by 50%. Under the proposed system the number of pumps maintained would be five times greater and a more efficient and complete service would be provided. The cost of easily-replaceable down-hole components will be borne by the community; it is estimated that this will be less than one fifth of the total maintenance costs.

12.3. <u>A FURTHER SIMPLIFIED MAINTENANCE STRUCTURE</u>

12.3.1. It is possible that the maintenance structure could operate at a reduced scale, but the success of a maintenance system with a lower backup from Government will depend on the following:

a) the ease of repair and reliability of the Malawi handpumps

b) the reliability of preventive maintenance carried out at village level

c) the village capability for pump repairs.

12.3.2. A possible adaptation of the maintenance structure could then result in:

a) reduction in Government presence at district level to one STA with a motorcycle

b) additional stores (pumpheads, pipes, rods, etc.) kept by the Maintenance Assistants which would be supplied directly from the Regional Centre

c) a specialised Maintenance Team at the Regional Centre for difficult repairs(e.g. fishing for dropped pipes).

The small delays for major repairs which might result would be acceptable because of the improved level of service offered by the larger number of waterpoints.

12.3.3. With this reduced maintenance structure the requirements could come down to:

a) 200 - 230 staff

b) 3 x 5/7 ton trucks

c) 3 x 2½ ton pickups

d) 3 x ¾ ton 4WD pickups

e) 3 x 4WD station wagons

f) approximately 30 motorcycles

g) 120 - 150 bicycles.

The annual cost to Government would be K690,000 - K740,000 (1982 prices). This represents a cost of about K34 per borehole, K17 per dug well, K0.14 per capita and 2.3% of capital construction costs.

The cost to the community would remain as shown in Table E.12.1. Thus the total cost of maintenance would be K44 per borehole and K22 per dug well and K0.18 per capita.

12.3.4. It should be noted that all costs in this Chapter are 1982 prices. Where possible maintenance costs are also given as a percentage of capital costs, so as to facilitate calculation of future recurrent expenditure.

CHAPTER F

TRAINING

TRAINING

Since the reorganisation of the Groundwater Section in 1980, the Section has expanded considerably and the role which it plays has already changed significantly and continues to change. With the shift of emphasis to Integrated Groundwater Projects from the dispersed borehole programme, and the obvious need for reorganisation of the Maintenance Structure,the staff and training requirements will be revised. Whilst the vital importance of training is recognised, a full breakdown of requirements cannot be given at present. This Section of the Manual will be written when the structure of the Groundwater Section and its training needs are better defined. This task is now seen as a major priority.

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DAILY DRILLING REPORT

OFFICE OF THE PRESIDENT AND CABINET
DEPARTMENT OF LANDS, VALUATION AND WATER
(GROUND WATER SECTION)

Project..........
Date.......... Drill Headman.......... Borehole Nº..........
Location.......... Rig Number.......... Drill Supervisor..........

1. BEFORE DRILLING Static water level (m)..........
Hole depth (m).......... Hole diam. (mm)..........
Casing depth.......... Casing diam. (mm)..........

2. OPERATIONS (give times)
A.M. Drilling: From.......... To..........
Other operations Nature..........
From.......... To..........
P.M. Drilling From.......... To..........
Other operations Nature..........
From.......... To..........
Water struck (m).......... Rising to (m)..........

3. AFTER DRILLING Static water level (m)..........
Hole depth (m).......... Hole dia. (m)..........
Casing depth (mm).......... Casing dia. (mm)..........
EC of bailed sample.......... μs/cm..........

4. HOURLY DRILLING LOG

Time	Depth (m)	Notes

5. BAILER TEST RESULTS

Nº	Hole Depth (m)	Temp Casing (m)	RWL (m)	Number of bailers	Time (min)	WL Immediately after Test (m)
1						
2						
3						
4						
5						

6. CASING RECORD

Nº (From bottom)	1	2	3	4	5	6	7	8	TOTAL
Exact length (m)									

7. DAILY RECORD OF STRATA

From (m)	To (m)	Description

8. DRILL SUPERVISOR'S SIGNATURE

....

GOVERNMENT OF
UNDP/WORLD BANK
GLOBAL HANDPUMP PROJECT

HANDPUMP DATA FORM HDF 1 (INSTALLATION)

Copy 1: field project Copy 2: country HQ Copy 3 UNDP/WB

A. REFERENCE

1 Pump Code	
2 Waterpoint code	
3 Installation foreman	
4 Recorded by	
5 Checked by	

B. LOCATION

1 Country	
2 Project	
3 District	
4 Village name	
5 Map sheet & grid ref.	

C. WATERPOINT

1 Well type (tick) a) drilled		b) dug	
2 Construction dates a) from		b) to	
3 a) Diameter (give units)		b) depth	m
4 Static water level a) below ground	m	b) date	
5 Rock type			

	diameter (mm) v) inter	w) exter	setting x) from (m)	y) to (m)	z) material
6 Plain lining a)					
b)					
7 Slotted lining a)					
b)					

8 Slotted lining a) slot size	mm	b) open area	%
9 Gravel pack a) d_{50}	mm	b) volume	m^3
10 Development a) method		b) duration	hrs
c) sand free discharge (tick)		Yes	No
11 Pump test a) duration	hrs	b) yield	l/sec
c) final pumping water level (below ground			m
12 Water quality a) conductivity	µS	b) pH	

D PUMP

1 Pumphead a) manufacturer		b) model	
2 Installation a) date		b) time taken	hrs
c) ease (tick) easy		average	difficult

	v) material	diameter (mm) v) inter	w) exter	y) unit length (m)	z) no. of length
3 Rising main					
4 Rods					
5 Cylinder					

6 Geometry a) max. stroke	mm	b) max swept vol	l

7 'Performance' (no. of full strokes to give 20 l at 30 strokes/min)

a) 'theoretical'	b) 'actual'	c) efficency a/b	%

DRILLED/DUG WELL SKETCH

depth ↓ dia. →

ground

mark a) depth (vertical) scale
b) diameter (horizontal) scale
c) hole depth and diameter
d) lining depth and diameter
e) location of plain & slotted lining
f) rising main depth and diameter
g) rods
h) cylinder location
i) static water level (swl)

REF	B1	/ HDF 1 /	A1

HDF1 (side 2)

E PUMP SURROUND

1 Apron (tick) Yes ☐ No ☐

2 Washing slab (tick) Yes ☐ No ☐

3 Soakaway pit a)(tick) Yes ☐ No ☐

b) if no describe drainage ______

4 Construction by (tick) Agency ☐ community ☐ mixture ☐

APRON SKETCH mark: approx. scale

F VILLAGE

1 Approximate population ______

2 Approximate size ___ km x ___ km

3 Number of protected water points

	existing	planned
a) drilled wells with handpumps		
b) dug wells with handpumps		
d) taps		
c) other (specify in G 4)		

4 Estimate of no of people using pump ______

5 Village pump caretaker (s) (tick) Yes ☐ No ☐

VILLAGE SKETCH mark: approx. scale

o dug well × drilled well

G NOTES

1 Pump: modifications / special features

2 Pump: installation problems

3 Pump: observed faults

4 Other: (full chemical analysis etc)

REF	B1	/ HDF 1 /	A1

GOVERNMENT OF
UNDP/WORLD BANK

GLOBAL HANDPUMP PROJECT

HANDPUMP DATA FORM HDF 2 (MONITORING)

Copy 1 : field project Copy 2: UNDP/WB

A. REFERENCE							
1 Country		3 Pump code		5 Pump model		7 "Theoretical Performance"	
2 Project		4 Water point code		6 Pump install. date		(see HDF 1, D7a)	

B. MONITORING – Record all visits to pump (routine checking, preventive maintenance, minor repair, breakdown repair)

	a) date	b) static water level (m)	c) well depth (m)	d) monitor reading	e) "performance check" +	f) efficiency [% A7/Be]	condition of g) pump	condition of h) surround	i) preventive maintenance	j) repair (details on HDF 3)	k) cause (details on HDF 3)	l) user comments	m) observer
1	Installation												
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
13													
14													
15													
16											A1		A3

+ number of full strokes to give 20l at 30 strokes per minute

REF | | /HDF 2/ |

GOVERNMENT OF
UNDP/WORLD BANK
GLOBAL HANDPUMP PROJECT

HANDPUMP DATA FORM HDF 3 (BREAKDOWN / REPAIR)

Copy 1. field project Copy 2 UNDP/WB

A REFERENCE

1 Country		4 Repair code		7 Pump installation date	
2 Project		5 Pump code		8 Original static w. level	m
3 Pump model		6 Waterpoint code		9 Original well depth	m

B BREAKDOWN / REPAIR

1 Dates a) breakdown occurred ____ c) breakdown inspected ____

b) breakdown reported ____ d) repair completed ____

2 Breakdown reported a) by whom ____ b) to whom ____

3 Breakdown cause ____

4 Parts repaired ____

5 Parts replaced ____

6 Tools used ____

7 Time taken to carry out actual repairs ____ days / hours (delete)

8 Subjective ease of repair (tick) easy ____ average ____ difficult ____

9 Repair carried out by ____

10 Assistance from village caretaker(s) (tick) Yes ____ No ____

11 Do you think trained village caretaker(s) could have carried out repair Yes ____ No ____

12 Dug / Drilled well a) static water level ____ m b) depth ____ m

13 Notes (problems, difficulties, observations)

14 If component(s) corroded, damaged or broken describe in detail and sketch (or photograph) if possible

15 Recorded by ____

REF	A1	/ HDF 3/	A5	/	A4

LEDGER

ITEM:..

UNITS:...

REORDER LEVEL.......................... Sheet number................

DATE	Received from or issued to	Signature:	RECEIPTS	ISSUES	BALANCE
	Balance brought forward———				
	Balance carried forward———				

MONTHLY STOCK SHEET

MONTH:.....................

ITEM	UNIT	OPENING BALANCE	RECEIPTS	ISSUES	CLOSING BALANCE	REMARKS

MONTHLY ANALYSIS OF MATERIALS ISSUED

MONTH:..................

ITEM	UNIT	TOTAL ISSUED	TO PROJECT CAMP	TO PROJECT TRANSPORT	TO RIGS				TO WELLS TEAMS			
					A	B	C	D	I	II	III	IV

FORM A1 front

WELL Nº..................

OFFICE OF THE PRESIDENT AND CABINET
DEPARTMENT OF LANDS, VALUATION AND WATER
(GROUND WATER SECTION)

DUG – WELL CONSTRUCTION REPORT

District..................................

T. A..................................

Locality..................................

Grid reference..................................

A. O. D..................................

Moved from..................................

Moving to..................................

Client..................................

Address..................................

Well supervisor..................Crew Nº..................

Digging started..................................

Digging finished..................................

Final completion..................................

1 DAILY RECORD

Date	Digging time	From (m)	To (m)	Other work (hrs)	Remarks

2. DETAILS FOR COSTING AND CHARGING

A. CONSTRUCTION DETAILS

Diam..............mm, from..................m, to..................m

Total depth..................................m

Rest water level..................................m

B. CONSTRUCTION MATERIALS USED

Concrete rings..................................no..................

Bottom slab..................................no..................

Top slab..................................no..................

110 mm guiding PVC pipe..................................m..................

63 mm PVC rising main pipe..................................m..................

25 mm PVC pump rod..................................m..................

Foot value..................................no..................

Plunger..................................no..................

Solvent cement..................................tin..................

Cleaning fluid..................................tin..................

Filter stones..................................sum..................

Cement..................................pkt..................

Pumphead..................................no..................

FORM A1 reverse

3. LINING DETAILS

Depth (m)		

FORM A2 front

JOB CHARGING SHEET

OFFICE OF THE PRESIDENT AND CABINET
DEPARTMENT OF LANDS, VALUATION AND WATER
(GROUND WATER SECTION)

DUG - WELL JOB CHARGING SHEET

WELLS SUPERVISOR ....

COSTED BY ....

Client / Project ....

Location ....

Grid reference ....

Deposit recieved .... date ....

Well Nº ....

Crew Nº ....

Digging started ....

Digging completed ....

Final completion ....

Ledger folio Nº ....

A SITING

Item	Price
Desk Study	
Siting	
Extra	
Vehicle km	
A SUB-TOTAL	

B. DIGGING

Depth (m)	Diam (m)	Unit Cost (per m)	TOTAL
		B. SUB-TOTAL	

C. OTHER OPERATIONS

Item	Unit	Unit cost	Nº	Item price
Moving between sites (min K35)	km			
Decamping and moving equipment	sum			
Rings and filter stone transport	km			
Rings and slabs installation	sum			
Cleaning and disinfecting	sum			
Mud plinth	sum			
Pump installation	sum			
C. SUB-TOTAL				

INVOICE TOTAL

Sub Total	Amount
A. Siting	
B. Digging	
C. Others	
D. Material	
FINAL TOTAL	

SUMMARY OF CONSTRUCTION DETAILS

Well depth (m)	
Rest water level (m)	

FORM A2 reverse

D. MATERIALS

ITEM	Unit	Unit cost	Nº	Item price	NOTES
Concrete Rings	no				
Bottom- slab	no				
Top slab	no				
110mm Guiding PVC pipe	m				
63mm PVC rising main pipe	m				
25 mm PVC pump rod	m				
Foot value	no				
Plunger	no				
Solvent cement	tin				
Cleaning fluid	tin				
Filter stones	sum				
Cement	pkts				
Pumphead	no				

D(1) Total material cost	
D(2) Material cost carried over (where different)	

FORM B1 (front)

OFFICE OF THE PRESIDENT AND CABINET
DEPARTMENT OF LANDS, VALUATION AND WATER
GROUNDWATER SECTION

Borehole Nº ....

BOREHOLE CONSTRUCTION REPORT

District .... Client / Project ....

T. A. .... Address ....

Locality .... Driller .... Rig Nº ....

Grid reference .... Drilling started ....

A.O.D. .... Drilling finished ....

Moved from .... Distance .... kms Construction completed ....

Moving to .... Distance .... kms Vehicle Nº .... Kms on hole ....

1. DAILY RECORD

Date	Hours Drilled	From (m)	To (m)	Other work (hrs)	W.L. at start (m)	Remarks

2. DETAILS FOR COSTING AND CHARGING

A. DRILLING DETAILS

.... mm, from .... m, to .... m

.... mm, from .... m, to .... m

.... mm, from .... m, to .... m

Nº of bailer tests ....

Hours cleaning and developing ....

Hours test pumping ....

Hours recovery measurement ....

B. CONSTRUCTION MATERIALS USED

(i) Plain casing .... mm, ... m

(ii) Slotted casing .... mm, ... m

(iii) Bottom cap ....

(iv) Centralisers ....

(v) Solvent cement .... tin

(vi) Cleaning fluid .... tin

(vii) Gravel pack .... m^3

(viii) Cement .... pkts

(x) Pumphead .... m

(xi) Rising main .... m

(xii) Pump rods .... m

(xiii) Cylinder ....

(xiv) Charcoal .... bag

FORM B1(reverse)

3. First water @..m

Rises to..m

Main supply from..................m to..................m

200mm casing..............m inserted at..............m

4 hr specific capacity..............................l/min/m

[yield ÷ drawdown at 4 hours]

4. PUMPING TEST

From.................................. hrs on..................................

To.................................. hrs on..................................

Cylinder size..........................set at....................m

Stroke length............mm/EC @ end..............μs/cm

DRAWDOWN				RECOVERY	
Elapsed Time	Level m	Strokes p.m.	Yield l.p.m.	Elapsed Time	Level m
0.00				0.00	
0.02				0.02	
0.04				0.04	
0.06				0.06	
0.08				0.08	
0.10				0.10	
0.12				0.12	
0.14				0.14	
0.16				0.16	
0.18				0.18	
0.20				0.20	
0.25				0.25	
0.30				0.30	
0.45				0.45	
1.00				1.00	
1.15				1.15	
1.30				1.30	
1.45				1.45	
2.00				2.00	
2.30				2.30	
3.00				3.00	
3.30				3.30	
4.00				4.00	
5.00				5.00	
6.00				6.00	
8.00				8.00	

5 CONSTRUCTION DETAILS

300mm 250mm 200mm 150mm 150mm 200mm 250mm 300mm

Ground

depth (metres)

5/10/15

10/20/30

15/30/45

20/40/60

25/50/75

FORM B2

JOB CHARGING SHEET (Front)

OFFICE OF THE PRESIDENT AND CABINET
DEPARTMENT OF LANDS, VALUATION AND WATER
(GROUND WATER SECTION)
BOREHOLE FUND JOB CHARGING SHEET

Client /Project...
Location ....
Grid Reference...
Deposit Received K.........date.....................

Driller...
Rig Nº...
Costed by

Borehole Nº...
Drilling Started...
Drilling Completed...
Final Completion...
Ledger Folio Nº...

A. SURVEY

Item	Price
Desk study	
Survey	
Detailed Survey	
Extra days	
Extra Vehicle km	
A. SUB TOTAL	

B. DRILLING

Depth (m)	Diam. (mm)	Unit Cost (per m)	Total
B. SUB TOTAL			

SUMMARY OF CONSTRUCTION DETAILS

Borehole depth (m)		
Rest water level (m)		
	Hour pump test yield (l/min)	
	Hour pump test pumping level (m)	

C. OTHER OPERATIONS

Item	Unit	Unit Cost	Nº	Item Price
Moving between sites (min K35)	km			
Rigging up and down	sum			
Bailer test	sum			
Cleaning and development	hr			
Test pumping, first 8 hours	hr			
Test pumping, subsquent hours	hr			
Recovery measurements	hr			
Analysis of test results	sum			
Slotting casing	m			
Cement grout and plinth	sum			
Operating vehicles	km			
C. SUB TOTAL				

INVOICE TO CLIENT

Sub-Total	Amount
A Survey	
B Drilling	
C Other	
D Materials	
(From over)	
E	
F	
G	
Remarks	
FINAL TOTAL	

FORM B2 reverse

JOB CHARGING SHEET

D. MATERIALS

Item	Unit	Unit Cost	Nº	Item Price	Notes
Plain casing	m				
Slotted casing	m				
Bottom cap	no				
Centralisers	no				
Solvent cement	tin				
Cleaning fluid	tin				
Gravel pack	m^3				
Cement	pocket				
Pumphead	no				
Rising main	m				
Pump rods	m				
Cylinder	no				
Charcoal	bag				

$D_{(1)}$ Total material cost	
$D_{(2)}$ Material cost carried over (where different)	

FORM D1

MONTHLY DIARY SHEET

PROJECT: ____________________ MONTH: ____________

Please indicate team title and supervisor :-

DRILLING TEAM: RIG Nº ________ DUG WELL TEAM Nº ________	APRON TEAM: Nº ______ PUMP TEAM: Nº ______	SUPERVISOR: ____________

DATE	DAY	MORNING ACTIVITY: *	WATERPOINT NUMBER**	AFTERNOON ACTIVITY: *	WATERPOINT NUMBER**
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
31					

SUMMARY OF MONTH'S ACTIVITIES

A. DIRECT COST TEAM DAYS

	Waterpoint number	Number of days
1		
2		
3		
4		
5		
6		
	TOTAL :	

B. INDIRECT COST TEAM DAYS

	ACTIVITY	NUMBER OF DAYS
1	Waiting for materials	
2	Waiting for repairs	
3	Moving between sites	
4	Working on abandoned waterpoint	
5	Funerals	
6	Other	
	TOTAL :	

* enter operation e.g. drilling, digging, moving between sites, waiting for materials, etc.

** insert waterpoint number for normal operations (direct cost) such as drilling, digging, casing, gravel packing, developing, testing, Insert 0 for all indirect cost operations as listed in B) above.

FORM D2

SUMMARY OF MONTHLY DIARY SHEETS

PROJECT__________ MONTH__________

A. DIRECT COST TEAM DAYS — BOREHOLES

RIG NUMBER							Sub Total 1							Sub Total 2
	1	2	3	4	5	6		1	2	3	4	5	6	
BOREHOLE NUMBER:														
NUMBER OF DAYS:														
RIG NUMBER:							Sub Total 3							Sub Total 4
	1	2	3	4	5	6		1	2	3	4	5	6	
BOREHOLE NUMBER:														
NUMBER OF DAYS:														

TOTAL DIRECT COST TEAM DAYS = SUBTOTALS 1 [ ] +2 [ ] +3 [ ] +4 [ ] = [ ]

B. DIRECT COST TEAM DAYS — DUG WELLS

WELL TEAM No:							Sub Total 1							Sub Total 2
	1	2	3	4	5	6		1	2	3	4	5	6	
DUG-WELL NUMBER:														
NUMBER OF DAYS:														
WELL TEAM Nº:							Sub Total 3							Sub Total 4
	1	2	3	4	5	6		1	2	3	4	5	6	
DUG-WELL NUMBER:														
NUMBER OF DAYS:														

TOTAL DIRECT COST TEAM DAYS = SUBTOTALS 1 [ ] +2 [ ] +3 [ ] +4 [ ] = [ ]

C. INDIRECT COST TEAM DAYS - BOREHOLES

	RIG NO:					
	ACTIVITY	No of days	No of days	No of days	No of days	TOTALS
1	AWAITING MATERIALS					
2	AWAITING REPAIRS					
3	MOVING BETWEEN SITES					
4	WORKING ON ABANDONED BORE HOLES					
5	FUNERALS					
6	OTHERS					
	TOTALS					

To Form C1 Table 6

D. INDIRECT COST TEAM DAYS — DUG WELLS

	WELL TEAM Nº					
	ACTIVITY					TOTALS
1	AWAITING MATERIALS					
2	AWAITING REPAIRS					
3	MOVING BETWEEN SITES					
4	WORKING ON ABANDONED DUG-WELLS					
5	FUNERALS					
6	OTHER					
	TOTALS					

To Form C1 Table 6

OVERHEADS ANALYSIS	PROJECT:	MONTH: YEAR:			FORM C1 (Front)

A PROJECT INDIRECT COSTS

CAMP:
1. LABOUR COSTS (from PSL) = [ ]
2. MATERIALS COSTS (from table 1) = [ ]
3. EXPENSES (from table 2) = [ ]
4. SUBTOTAL (1+2+3) [ ]

TRANSPORT
5. FUEL etc (table 3) = [ ]
6. EXPENSES (from table 4) = [ ]
7. NON-PROJECT VEHICLES COSTS (table 5) = [ ]
8. SUBTOTAL (5+6+7) [ ]
9. TOTAL PROJECT INDIRECT COSTS (4+8) = [ ]

B ALLOCATION OF TOTAL PROJECT INDIRECT COSTS

1. SHARE TO BOREHOLES A.9× [ ] table 9(d) = [ ] carry to C·8
2. SHARE TO DUG-WELLS A.9× [ ] table 9(e) = [ ] carry to C·8

C BOREHOLE / DUG WELLS INDIRECT COSTS

			BOREHOLES	DUG WELLS
LABOUR COSTS	1.	SUPERVISORS (from PSL)		
	2.	TEAMS (from table 6)		
	3.	FOOTAGE BONUS (abandoned holes)		
	4.	TOTAL LABOUR COSTS (1+2+3)		
MATERIALS COSTS	5.	(from table 7)		
EXPENSES	6.	(from table 8)		
	7.	TOTAL INDIRECT COSTS (4+5+6) =		
ADD	8.	SHARE OF PROJECT INDIRECT COSTS (From B) =		
	9.	TOTAL OVERHEADS (7+8) =		
	10.	DIVIDE BY Nº OF DIRECT COST TEAM DAYS (from monthly summary of diary sheets)		
	11.	RIG / WELL DAY-RATE =		

REMARKS

Table 1: PROJECT MATERIALS FORM C1 (reverse)

ITEM							
UNIT COST							
QUANTITY							
TOTAL COST							

carry to A2

Table 2: PROJECT EXPENSES (from PAR) (i.e. depreciation and maintenance of camp equipment)

ITEM							
MONTHLY CHARGE							

carry to A3

Table 3: TRANSPORT FUEL AND OTHER MATERIALS

ITEM	PETROL	DIESEL	OIL				
UNIT COST							
QUANTITY							
TOTAL COST							

carry to A5

Table 4: TRANSPORT EXPENSES [from PAR) (depreciation and maintenance of vehicles)

ITEM							
MONTHLY CHARGE							

carry to A6

Table 5: TRANSPORT COSTS (non-project vehicles) (i.e. delivery vehicles)

VEHICLE							
RATE/km							
kms							
TOTAL COST							

carry to A7

Table 6: INDIRECT COST TEAM DAYS boreholes/dug-wells

TOTALS	boreholes		std team day rate		=	carry to C2 (boreholes)
(from Form D2)	dug-wells		std team day rate		=	carry to C2 (wells)

Table 7: CONSTRUCTION OVERHEAD MATERIALS -boreholes / wells

ITEM							
UNIT COST							
QTY-BOREHOLES							
COST-BOREHOLES							
QTY - WELLS							
COST-WELLS							

carry to C3

carry to C3

Table 8: CONSTRUCTION OVERHEADS EXPENSES - boreholes

ITEM							
MONTHLY CHARGE							

carry to C6

wells

ITEM							
MONTHLY CHARGE							

carry to C6

Table 9: ALLOCATION OF PROJECT INDIRECT COSTS

Number of borehole teams ☐ × 2 = ☐ (a)

Number of dug-well teams ------------------ ☐ (b)

Total (a) + (b) = ☐ (c)

Share of indirect costs allocated to boreholes = (a) ÷ (c) = ☐ (d) carry to B1

Share of indirect costs allocated to dug-wells = (b) ÷ (c) = ☐ (e) carry to B2

WATER POINT COST SHEET MONTH / YEAR ____ / ____

PROJECT ____ RIG / TEAM Nº ____

BOREHOLE / WELL FORM C2

WATER POINT Nº ____ REF ____

SUPERVISOR: ____ CONSTRUCTION DATES ____ TO ____ NUMBER OF DIRECT COST TEAM DAYS ____ (From form D2)

A. LABOUR COST

Standard team - day - rate ____ X no. of days ____ = ____ add footage bonus ____ = Total labour cost ____

B. MATERIALS COST

ITEM																
PRICE																
QUANTITY																
COST																

Total materials cost: ____

C. OVERHEADS

____ days @ rig/well day - rate ____ = ____
____ days @ rig/well day - rate ____ = ____
} Total Overheads = ____

D. COST SUMMARY

Total Direct Costs = A + B = ____
Total Indirect Costs = C = ____
Full Cost = A+B+C = ____

E. INVOICE VALUE Carried from invoice no. ____ = ____

F. NET SURPLUS / DEFICIT = Invoice value – Full cost = ____

REMARKS

Compiled by: date: checked:

FORM WQPC - 2

DEPARTMENT OF LANDS, VALUATION AND WATER
WATER QUALITY AND POLLUTION CONTROL SECTION

REQUEST FOR ANALYTICAL SERVICES

1. NAME AND ADDRESS OF PERSON REQUESTING SERVICES ....
   ....
   ....

2. SAMPLE SOURCE*:- RIVER; STREAM; SPRING; DEEP BOREHOLE; SHALLOW BOREHOLE; WELL; EFFLUENT.

3. NAME OF RIVER ETC. ....

4. NO. OF BOREHOLE ....

5. METHOD OF COLLECTION*:- PUMPED; BAILED; SCOOPED; OTHER (SPECIFY)
   ....

6. TYPE OF SAMPLE *:- ACIDIFIED AND/OR UNACIDIFIED

7. DATE COLLECTED ....

8. LOCATION ....
   ....

9. DISTRICT ....

10. MAP SHEET (1:50,000) AND GRID REFERENCE ....

11. WATER RESOURCE UNIT ....

12. WATER USE *:- DRINKING WATER SUPPLY; IRRIGATION WATER; OTHER (SPECIFY) ....

13. WATER QUALITY PARAMETERS PARTICULARLY REQUIRED ....
    ....
    ....

14. ANY OTHER RELEVANT INFORMATION (e.g. field pH, EC, temperature etc) ....
    ....
    ....

**Please delete*

LABORATORY NO's............

Figure B.4.1. Cardex Record of Borehole Information

a) Front

BOREHOLE DATA FORM BDF1

DESCRIPTORS

Locality	Chisuzi Village
Grid Ref.	WIV 513 818
Map Sheet	1333 C2
Depth b.d. (m)	45.75
RWL (construction)(m)	9.15
Datum altitude AOD (m)	1128.5
RWL AOD (avg min)(m)	1119.5
RWL AOD (avg max)(m)	
District	Lilongwe
Client	LLDP

Detailed Geology

0 - 32.9 Colluvium

32.9 - 45.7 Basement gneiss

G.S Ref No	D P 1 1 1
Borehole No.	5 E 1 9 9

CONSTRUCTION

Driller/Contractor: WCL JOSIA

Drilling Method: Percussion

Start: 23 03 72 Drilling Finish: 05 04 72

Drilling	diam (mm)	from (m)	to (m)
1.	203	0.00	33.55
2.	152	33.55	45.75
3.			

Water Struck (m)		rising to	
1.	22.0	rising to	19.15
2.		rising to	
3.		rising to	

Casing		diam (mm)	from (m)	to (m)
Plain	1.	152	0.00	21.35
	2.			
Slotted	1.	152	21.35	33.55
	2.			

Casing Material: Plain MS Slotted MS

Slot Size (mm): — Open Area %: —

Pump: Type Climax Suction (m b.d) 37

Filter: quantity (m³) 1.5 d50 (mm) .95

Q	RWL bd	SC	EC		

PERFORMANCE

Driller's Pump Test

5 hour yield (l/min)	136.8
5 hour drawdown (m)	6.10
5 hour Spec. Cap (l/min/m)	22.4

Detailed pump test

Transmissivity (m²/d): —

Storativity: — x 10⁻

See file no. N/A

SITING

Geologist: D Pascall

Date: 06 03 72

CST Spacing interval (m) 22.9

(10 Ω m) Point resistivity 10.2

DP:		
ρ1 (10 Ω m)	114.0	6.1 m
ρ2	2.5	m
ρ3		

Recommended: drill to (m) 61.0

Figure B.4.1. Cardex Record of Borehole Information

b) Reverse

5	E	1	9	9	c

PLUMBED DEPTH and WATER LEVEL 1			PLUMBED DEPTH and WATER LEVEL 2		
Date	Depth (m)	W.L. (m)	Date	Depth (m)	W.L. (m)
07 04 72	45.75	9.15			
23 09 76	45.75	5.19			
11 11 76	45.75	8.54			
11 10 79	45.45	4.58			
13 03 80	45.45	3.66			
21 09 80	30.50	4.88			
09 11 80	30.50	3.36			
03 02 81	45.75	4.27			
16 05 81	44.23	3.66			
04 01 82	44.23	5.49			

CHEMISTRY

Date	10/72			Date	EC (μS)
Ion	mg/l	mg/l	mg/l		
Ca	30				
Mg	11				
Na	22				
K	3				
Fe	1.8				
HCO_3	152				
SO_4	70				
Cl	110				
NO_3	<1				
F					
TDS	268				
EC					
pH	6.0				
T°C	25.0				

NOTES

Checked. [illegible]