Small scale irrigation using collector wells pilot project - Zimbabwe

FINAL REPORT

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Executive summary

Throughout Africa, many communities rely on crystalline basement rocks as the primary source of water supply. Well yields are often low and shortage of water remains the principal constraint on development in many areas. Recent studies in southern Zimbabwe have focused on the water resource potential of the crystalline basement rocks and, in particular, on the potential for using collector wells to abstract sufficient water from the regolith aquifer for both domestic use and small-scale irrigation by rural communities.

This is the final report in the Government of Zimbabwe/British Overseas Development Administration - funded pilot project: "Small-scale irrigation using collector wells - Zimbabwe". The project has been implemented by the Zimbabwean Departments of Agricultural Technical and Extension Services (Agritex), Research and Specialist Services (R&SS) and Water Development (DWD), in collaboration with the Institute of Hydrology (IH) and the British Geological Survey (BGS). It has been completed in Masvingo Province, one of the driest parts of Zimbabwe, and has allowed implementation of one of the most comprehensive comparisons of alternative well designs and detailed assessments of social, economic, institutional and environmental viability of community-based irrigation ever undertaken in Africa.

Currently, groundwater in southern Zimbabwe is abstracted by dug wells or by deep boreholes sited using geophysics. Low yields are typified by a recent Drought Relief Programme - only 21 per cent of boreholes gave yields of 0.6 l/s or higher and 18 per cent were dry. A collector well is designed for use in crystalline basement rock. It is a large diameter well sited by exploratory drilling whose yield is enhanced by lateral drilling at the base to a distance of 30 metres in several directions. Results are presented of collector well performance at nine locations, and include the effect of lateral drilling on well yield, measured aquifer properties, and comparison of collector well performance with that of traditional dug wells, large diameter wells, boreholes screened in the regolith, and conventional deep boreholes cased in the regolith.

Exploratory drilling has been found to be vital to locate optimum well sites in this region as present geophysical methods do not have sufficient resolution in terrain of such high spatial variability. Rainfall and geology influence choice of well design and in southern Zimbabwe (average annual rainfall 400-800 mm) collector wells have been found to be well suited in areas of younger undifferentiated gneiss and intrusive granite, less suited in areas of Karoo basalt, and unsuitable in areas of older gneiss complex because either depth of saturated weathering was insufficient or depth of water table exceeded 15 metres. At all project sites, however, a consistently adequate supply of water for domestic use and small-scale irrigation has been obtained from the shallow regolith aquifer, both by large diameter wells (17.6 m^3/day, on average) and collector wells (25.9 m^3/day, on average). The increase in sustainable yield obtained by lateral drilling is variable but on average is significant at 38 per cent improvement.

Economic viability of siting deep boreholes to support community gardens depends entirely on success rate of drilling. Some screened regolith boreholes drilled by the project gave higher yields than existing deep boreholes. This is important, as it suggests that: a) siting deep boreholes by shallow exploratory drilling in the regolith to identify the greatest depth of saturated weathering may be a reasonable approach for helping to overcome the spatial

variability found in the deep aquifer, and b) boreholes in this region would generally be better if screened in the regolith rather than cased. The challenge for future groundwater development in the communal lands of southern Zimbabwe is suggested to lie in quick and cost effective selection of the appropriate well design and location in a given area. Practical examples illustrate that this can be achieved by rapid exploratory drilling, simple pump tests of exploratory holes and existing water points, and limited geophysical surveys, used in conjunction with a hydrogeological decision tree developed during the pilot project.

The results of comprehensive baseline surveys, routine monitoring and return-to-household surveys highlight the positive impact on rural economies and quality of life that small-scale irrigation using groundwater can have. They also highlight the importance of a range of human and institutional factors that can influence this type of development.

The schemes are highly valued by the communities both for their provision of reliable domestic water and sufficient irrigation water. An estimated 3882 people obtain their domestic water from the six project wells, consuming approximately 13 litres per person per day. The estimated population of households directly involved in the six community gardens is 4461 people with a mean income generated per member per year of Z$255.20. The schemes are economically viable and water use efficient, with an average IRR in 1994 of 19 per cent, average total gross margin per hectare per year of Z$24,000, and average gross margin per unit of water (Z$/ha/m) of $43,800 per scheme. They provide extensive marketing opportunities for the sale of dry season vegetables to surrounding townships and play an important role in improving the welfare of women and children by making more efficient use of labour time, improving nutrition, and providing an important source of disposable income for household items and school fees. In essence, the collector well gardens have reduced the period of scarcity of fresh vegetables that communities in the area face by four to five months, lowered the number of people who feel there is a period of fresh vegetable scarcity by about 25 per cent, and decreased the time during scarce periods that people miss out on eating fresh vegetables by about four days in every week. Price increases for plots in the gardens indicate the degree of welfare improvement the schemes are now bringing to members. Many people, originally disinterested are now wishing to join, to the extent that there is a willingness to pay up to 16 per cent of a years income from rainfed crops to join the schemes and benefit from the steady revenue they can provide.

It should be noted that the implementation of community-based development initiatives is not easy, and many factors can influence scheme performance. Local ownership of the resource is one vital ingredient. Local communities are much more likely to look after and pay for the upkeep of their water points and gardens if they know that they belong to them and not to another agency. An important corollary of this is that the community is involved at all stages of the resource development, from its inception, through planning and construction, to subsequent maintenance and management. An inter-disciplinary project team is vital to success, recognising that decision making at all stages is an inter-disciplinary process. Valuable lessons learnt at first schemes allowed key steps to be identified that help to promote full community involvement and ensure schemes that are more likely to be sustainable from a social perspective. Among these, an informal community contract considered prior to construction is a potent means of outlining obligations, clarifying misconceptions and creating sense of ownership.

Leadership remains the main social factor influencing scheme performance, principally because decision making in a community-based project is slow compared to a private or family-based project and more easily disrupted by leadership disputes. Whether these disputes can be overcome depends on whether the potential benefits of the development are sufficient to ensure that the community maintain interest in the development during a dispute and have sufficient incentive to overcome a dispute. Fortunately, group ownership of a resource is not new in Zimbabwe, potential benefits in this case are significant, and in most communities there appears to exist the necessary qualities of leadership, experience of gardening, and local institutional structures to make this type of community project successful. Where such qualities or structures are lacking or temporarily fail, trained facilitators can help enormously in resolving difficulties.

Specific environmental benefits of community gardens using groundwater include the reduction in pressure to cultivate marginal land, particularly streambanks, and the promotion of longer-term management strategies due to decreased risk and increased security of tenure that the schemes bring. There remains, however, a critical need to ensure that any new investment in water and garden facilities does not fail through failure to protect the ground water resource. Community participation in development of small-scale irrigation using groundwater can have the major benefit of providing the ideal springboard to improved resource management at the village or catchment scale. In many cases, it gives rural communities their first experience of the institutions needed to make community-based activities successful. Future development of wells and gardens should proceed hand-in-hand with programmes of community-based natural resource management, building on the opportunity and incentive that this initial type of water development project provides.

An increasing number of communities and agencies are requesting to replicate the pilot schemes. A steering committee has been formed to develop a framework for the next phase of work. Details of the proposed NGADI project: "Nutrition Gardens and Groundwater Development in Zimbabwe" are included here. Initially, the project will focus on the critical need to enhance institutional capacity in Zimbabwe to implement sustainable water points and community gardens. It will include programmes of village level training and permit extended monitoring required to confirm scheme viability. Later, as this initial form of project support is withdrawn, it will provide a sound basis for replication of schemes on a wider scale on behalf of local authorities and in response to community and NGO requests.

In summary, the pilot project: "Small-scale irrigation using collector wells" has been highly successful. The quantified benefits to rural communities recorded at pilot schemes and expected at future schemes, the anticipated benefits of enhanced institutional capacity to implement sustainable water points and community gardens in the future, and the far-reaching benefits of using this type of first water development project as a springboard to other community-focused projects in health, agriculture and the environment, may be considered sufficient to justify project replication on a wider scale. The development of community gardens using groundwater has little risk of negative consequences, while offering numerous additional positive externalities, such as improved productivity due to better nutrition and health (both to scheme members and surrounding populations), reduced demands on women's time and energy spent fetching water and in providing relish, the provision of employment and skills development at the local level, the development of community spirit and collective action, and the contribution to development of local institutional structures. For much of Zimbabwe and many parts of Africa underlain by basement rock, this offers a possible way in which communities threatened by aridity and land degradation can stabilise or improve living standards and quality of life.

Contents

1 Background

1.1 SEMI-ARID AREAS OF SOUTH-EAST ZIMBABWE

Communal areas of southern Zimbabwe typify the problems now facing people and the environment in many semi-arid parts of Africa. Population densities are high - up to 61 persons per square kilometre, and increasing at an average rate of 2.2 per cent per annum (CSO, 1993). The majority of people live in rural areas and depend on subsistence farming. They are struggling to survive on a poor and degrading resource base. Drought is recurrent and agricultural production is low and highly variable. Land degradation and desertification are taking place at an alarming rate.

The extent of land degradation in south-east Zimbabwe has been described and discussed in a number of reports (e.g. Whitlow 1983; Whitlow and Campbell 1989; Abel and Blaikie, 1989; Campbell *et al*, 1989; Tagwira, 1992; Scoones, 1992). The main processes of land degradation in the region are deforestation, overgrazing and soil erosion. These result from poor management of natural resources in a region characterised by high population growth, normally high livestock numbers, a lack of financial and manpower resources for sustainable land management and a land tenure system which promotes overgrazing (IIED, 1992). Since 1980, the Government of Zimbabwe has adopted policies aimed at improving the management of land resources in rural areas. However, the successful implementation of these policies remains elusive, as does the goal of sustainable agricultural development.

Prime constraints on sustainable development in south-east Zimbabwe are the low and erratic rainfall and the availability of ground and surface water resources. Rainfed crop production provides the main source of staple foodstuffs. However, increasing population and declining productivity of existing croplands have led to cultivation of more marginal terrain better suited to other less intensive forms of land use. Extension of cropland is often at the expense of grazing lands, thus placing even greater pressures on the remaining grazing land (Whitlow, 1989). It should be noted that there is no obvious evidence in south-east Zimbabwe of environmental recovery being promoted by increase in population as has been reported for some semi-arid areas of Kenya (Tiffen *et al* (1994).

In areas where sufficient water resources are available, large-scale irrigation projects have been and continue to be constructed. However, such schemes have often proven to be expensive, relatively inefficient and difficult to reconcile with traditional farming systems. Some large irrigation schemes have also caused a range of health-related and environmental problems and necessitated considerable social adjustments. In contrast, experience in the region has shown that informal or garden irrigation can be economically viable and appropriate to farmers, especially women farmers, for whom it is already a traditional component of the farming system.

The unavailability of reliable safe water is one of the main problems confronting rural populations in south-east Zimbabwe. In Masvingo Province for example, 32% of people still rely on relatively unsafe water from unprotected wells, rivers, streams and dams (CSO, 1993). There is a recorded density of only one protected water point (well or borehole) per 17 km^2. Of these, 40% are known to go dry during drought (Anon, 1992). For some communities the priority is for cleaner and more reliable sources of water. For many it is for sufficient water to allow vegetables to be grown.

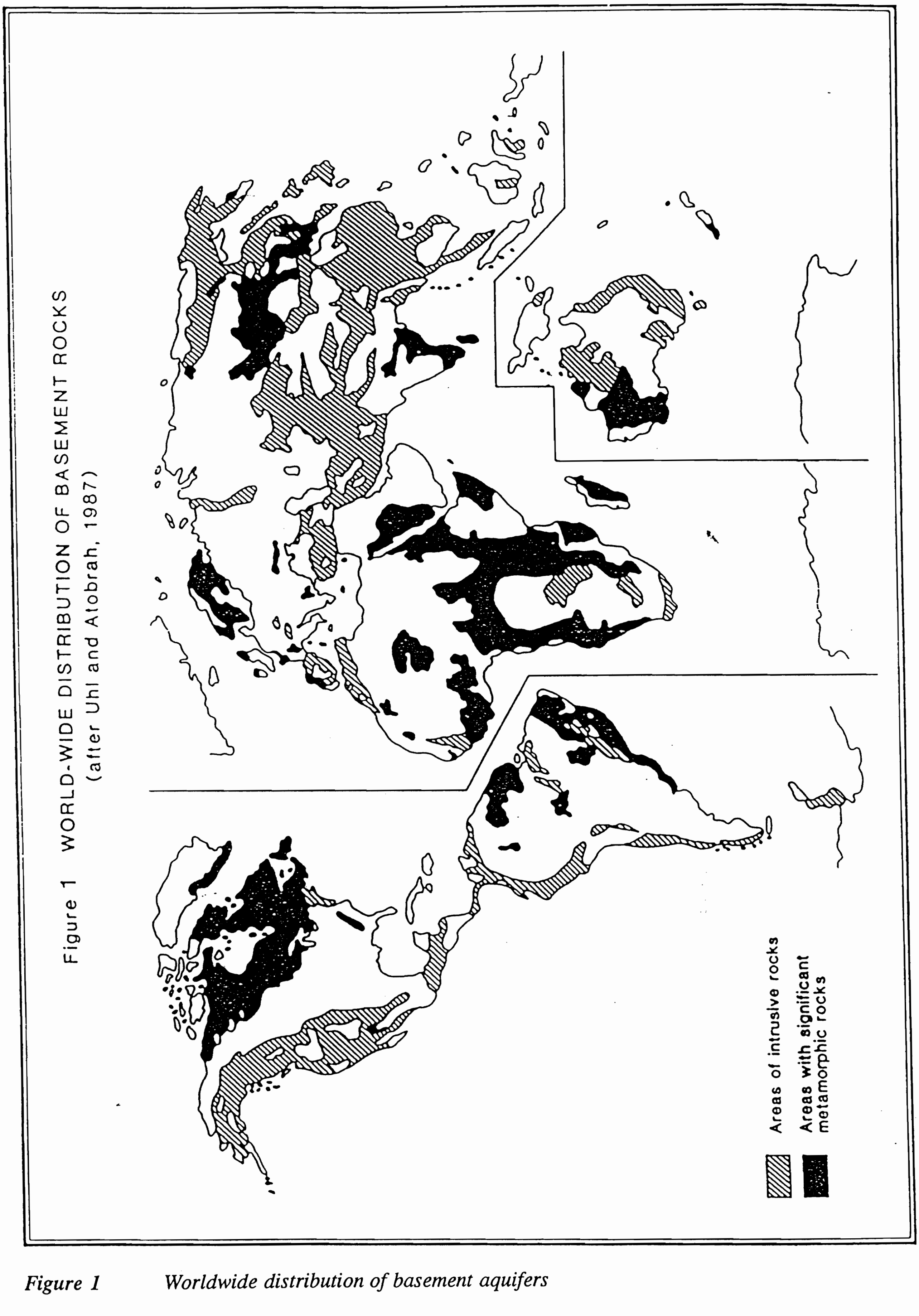


Figure 1 *Worldwide distribution of basement aquifers*

In conclusion, south-east Zimbabwe is typical of much of semi-arid Africa. The many attempts that have been made to alleviate the serious social and environmental problems in the area have met with only limited success. The reasons for this lack of success are varied and complex. Some interventions have been inappropriate, some have been introduced without the participation of stakeholders, and others have not been economically viable. Some interventions, although relatively successful, have been introduced at such an isolated and local scale that they have gone only a short way to alleviating the multiple problems of the local communities *let alone* the region as a whole. There is therefore, a fundamental need for the implementation of projects that are appropriate, economic, involve the participation of stakeholders, and address the problems of the people and the environment of the whole region. The pilot project described here has these wider objectives.

1.2 COLLECTOR WELL RESEARCH

Basement aquifers are of particular importance in tropical and sub-tropical regions because of their widespread extent and accessibility and because there is often no readily available alternative source of water supply, particularly for rural communities (Wright *et al*, 1989; Wright, 1992; Howard and Karundu, 1992; Howard *et al*, 1994). Figure 1 shows the extent of crystalline basement aquifers worldwide. In general, water in basement aquifers occurs within the weathered residual overburden (or regolith) and the fractured bedrock. In Zimbabwe, current development is generally by digging wells within the regolith or drilling boreholes to intercept fractures in the bedrock. However, work during the last twelve years has shown that collector wells can be used to increase groundwater abstraction from regolith aquifers (Wright, 1992; Anon, 1994). A collector well is a shallow, hand-dug well of large diameter with horizontal boreholes drilled radially from the bottom of the well to a distance of approximately 30 m (see Figure 2).

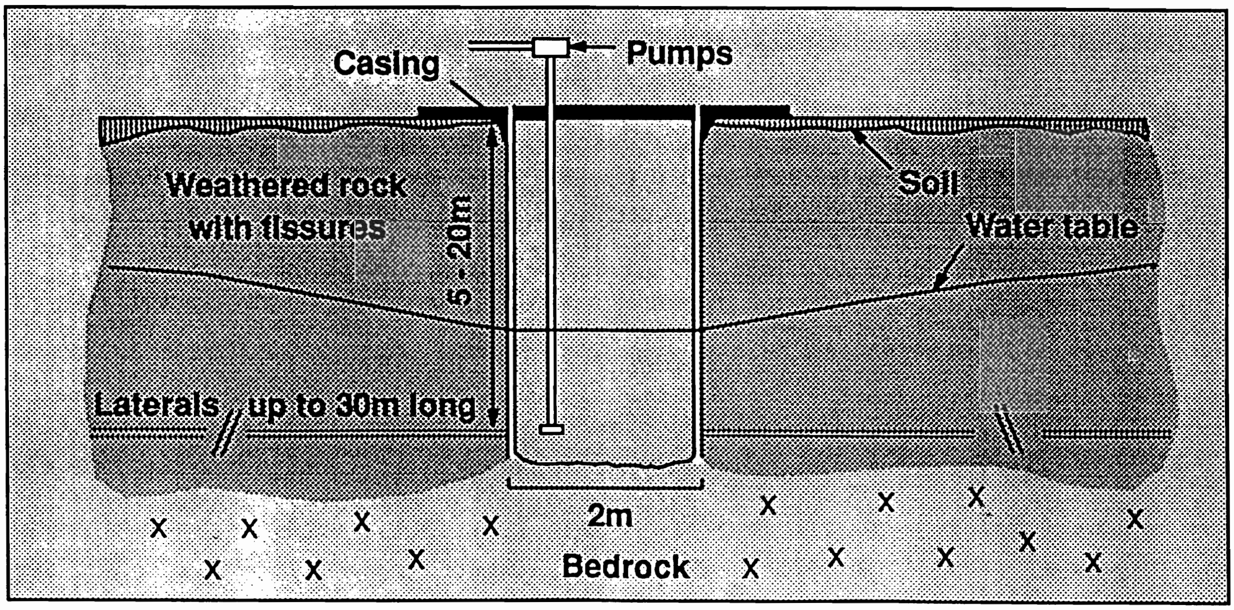


Figure 2 Schematic diagram of a Collector Well

It has been demonstrated that in some areas higher average yields can be obtained from collector wells than from slim boreholes with the added advantage of small drawdowns. Safe yields from eight wells in Zimbabwe and Malawi and 20 in Sri Lanka were calculated at 2.7 l/s^{-1} (ranges of 1.1-6.6 and 0.5-8 l/s^{-1} respectively) with drawdowns of 2-3 m, and were compared with typical yields in the range 0.1-0.7 l/s^{-1} for slim boreholes at pumping drawdowns in excess of 30 m (Wright, 1992).

1.3 FIRST COLLECTOR WELL GARDENS

In 1988, the Institute of Hydrology began a collaborative research project with the British Geological Survey and the Lowveld Research Stations. The main objectives of this project were to study the feasibility of using regolith aquifers as a source of water for small-scale irrigation and to compare and develop methods of low-cost, high efficiency irrigation which would be suitable for use on small irrigated gardens. In 1989, a collector well was constructed at the Chiredzi Research Station. Construction of laterals in this well led to a 150% improvement in yield (Chilton and Talbot, 1990). Water from this well has been used to irrigate a 1 ha demonstration garden that has been the location for a series of trials that have evaluated different approaches to improving irrigation efficiency for a range of crops. The results of these trials can be found in a series of interim reports (Batchelor *et al*, 1990; Lovell *et al*, 1990; Lovell *et al*, 1992; Murata *et al*, 1995).

In 1991, the collaborative research project completed the construction of a first off-station collector well garden at Romwe Catchment in Chivi District. Although the yield improvement due to laterals was relatively low at 10% (Chilton and Talbot, 1992), this well with its two handpumps was able to provide domestic water for over 1200 people and water for a 0.5 ha community garden. At the outset, 46 families had plots or allotments on this garden. The results of the first cropping seasons are presented in the interim reports listed above. After initial social and institutional "teething" problems this garden has flourished most notably during the 1991/92 drought when many boreholes and traditional dug wells dried up and when all irrigation schemes using surface water failed. The success of this collector well in providing domestic water and a valuable and continuous supply of vegetables during the 1991/92 drought went a long way to overcoming residual scepticism and was also instrumental in securing Government of Zimbabwe and British Overseas Development Administration support for the pilot project reported here.

2 The pilot project

2.1 WIDER OBJECTIVES

The pilot project "Small scale irrigation using collector wells -Zimbabwe" had the following wider objective:-

i) To improve the long term well being of rural communities and the rural environment by effective use of groundwater.

2.2 SPECIFIC OBJECTIVES

The project contained the following main elements:

i) selection of suitable sites and the installation of six small irrigation schemes using water from collector wells in south-east Zimbabwe;

ii) the assembly and collection of adequate baseline data and design of a monitoring system to facilitate the assessment required at iv below;

iii) the regular collection of data through the monitoring system;

iv) production of a final integrated report on the scheme's technical, economic, financial, institutional, social and environmental viability, with recommendations for future development.

Specific objectives of the project were:

i) to field test the validity of small scale irrigation and collector well research results obtained at the Lowveld Research Station (LVRS);

ii) to identify ways of improving the operation of the schemes, for example by identifying and overcoming constraints;

iii) to identify a basis for replicating the schemes on a wider scale.

(Ref. Project Data Sheet, BDDSA March 1992)

The project started on the 1 October 1992 and finished on 16 January 1996.

3 Project implementation

3.1 ACTIVITIES AND STAFFING

In order to fully evaluate collector well garden viability, monitoring of the initial scheme at Romwe continued during the pilot project, and the six new pilot project schemes were planned and sited to broaden the range of physical, social, economic and institutional settings considered. Practical constraints of distance and equipment available to construct and monitor all schemes in a limited period of time meant that, logistically, this objective was best achieved by siting the new schemes in Zaka District, on a line running north of Chiredzi Research Station and reasonably parallel to the main Buffalo Range - Zaka road. In this way, four principal geologies (younger mobile belt gneiss, older gneiss complex, paragneiss and younger intrusive granite) and corresponding terrain types likely to be important in future development could be studied. With success of the initial scheme at Romwe and increasing interest as first pilot project schemes were completed in Zaka District, two additional schemes were also requested and funded by Plan International in Chiredzi District. These schemes, at Machoka and Masekesa, enabled study of a further geology (basalt) and social setting (Shangaan, as opposed to Ndebele and Karanga at previous sites). Results from these two schemes are included here.

Figure 3 shows staff involved and key activities during the pilot project. Figure 4 shows regional geology and eventual location of the nine schemes completed during this pilot phase.

3.2 BASELINE DATA COLLECTION

Socio-economic aspects of the schemes funded by GoZ/ODA have received considerable attention. Comprehensive baseline data at each scheme has been collected in four parts:

i) Rapid rural appraisal to identify main characteristics and structure of each community, existing water and garden resources, community problems and aspirations;

ii) Formal surveys by questionnaire of 30 households randomly selected from the whole community to assess local institutions important at district and village level, key people and leadership patterns in the community, both modern (Vidco/Wadco) and traditional (Chief/Kraalhead), the range and pattern of income and expenditure, class structure and wealth present in the community, family circumstances including decision making, division of labour and problems faced, water sources past and present, current patterns of vegetable consumption, health, farming assets and practices; gardening activities past and present, contact with extension staff, experiences of development;

iii) Case studies of 4 households selected to represent different income groups and provide more detailed information on particular aspects such as income and expenditure, household budgets, savings and credit, patterns of vegetable consumption, decision making within the household and within the community, gender divisions and attitudes, and specific effects of the collector wells and gardens;

iv) Informal meetings with groups of women only and groups of men only to discuss issues of gender, equity, health, leadership and rural development.

Specific results of baseline data collection can be found in project progress reports (Lovell, 1993; Lovell *et al*, 1993b, 1994a and 1994c; Brown and Dube, 1994; Murata *et al*, 1994).

3.3 MONTHLY MONITORING

Following baseline data collection, regular data collection throughout the project has been achieved by monthly monitoring visits to all schemes. In this way, information has been obtained not only on well and garden performance but also on the dynamics of change that have occurred at each scheme. In particular, routine monitoring has been achieved in four main ways:

i) collection by garden committee secretaries at each scheme of routine data on inputs to and outputs from the gardens, including cropping patterns, irrigation and water use, crop protection, fertilisation, crop yields and market prices;

ii) collection by an appointed member of each garden committee of weekly data on well water levels and abstraction measured by a Munro Chart Recorder and two water meters fitted to each collector well;

iii) monthly visits by project staff to collect data (i) and (ii), observe progress and to discuss with members and extension staff issues that have included the role of local institutions and leadership patterns within the community and their impact on community efforts, and the degree and form of community efforts, problems, successes and failures and the differences and similarities between schemes;

iv) regular analysis of all data to provide detailed accounts of both financial performance and social dynamics at each scheme on a season by season basis (see project progress reports Lovell *et al*, 1995 and Mazhangara *et al*, 1995).

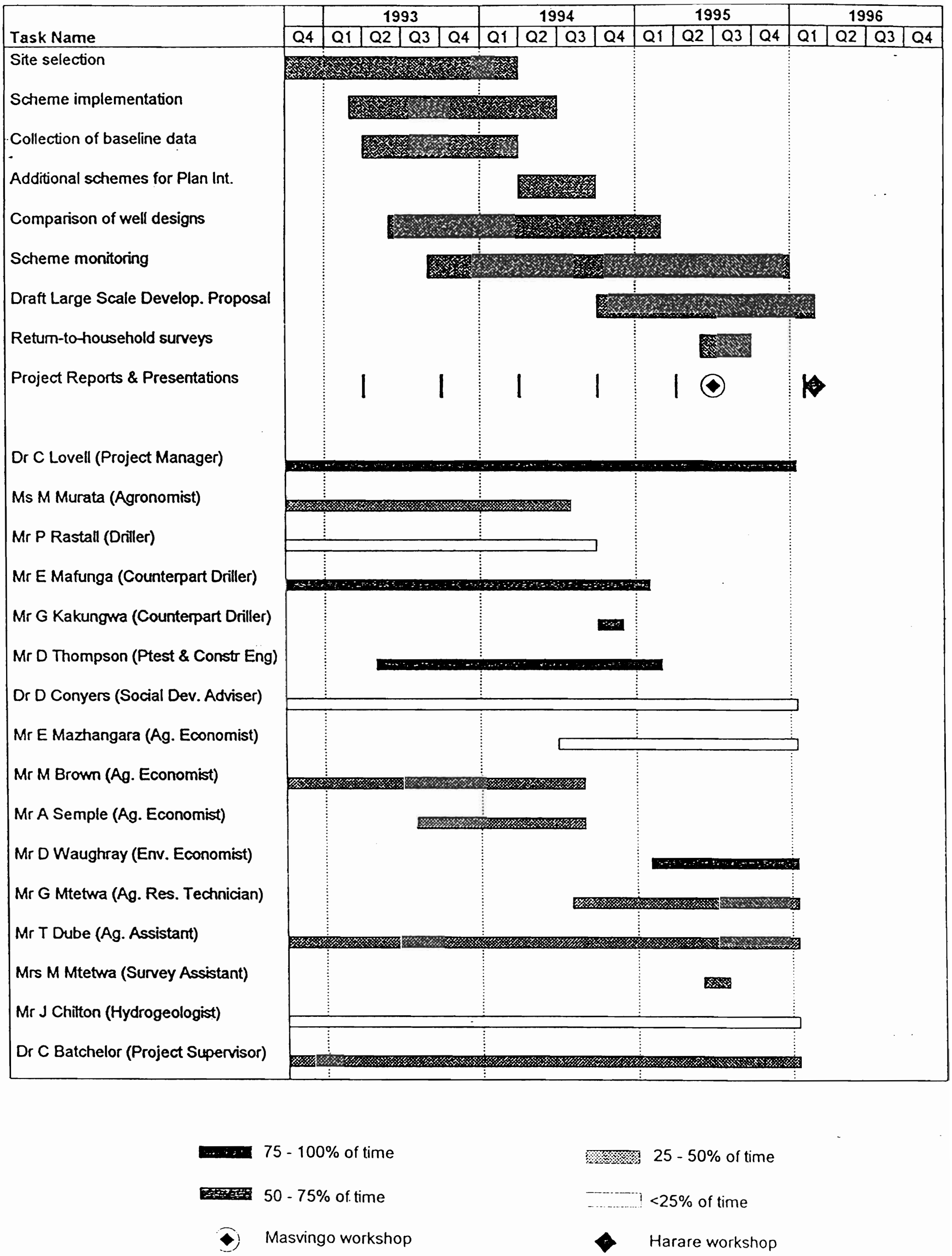


Figure 3 Key activities and staff involved in the pilot project

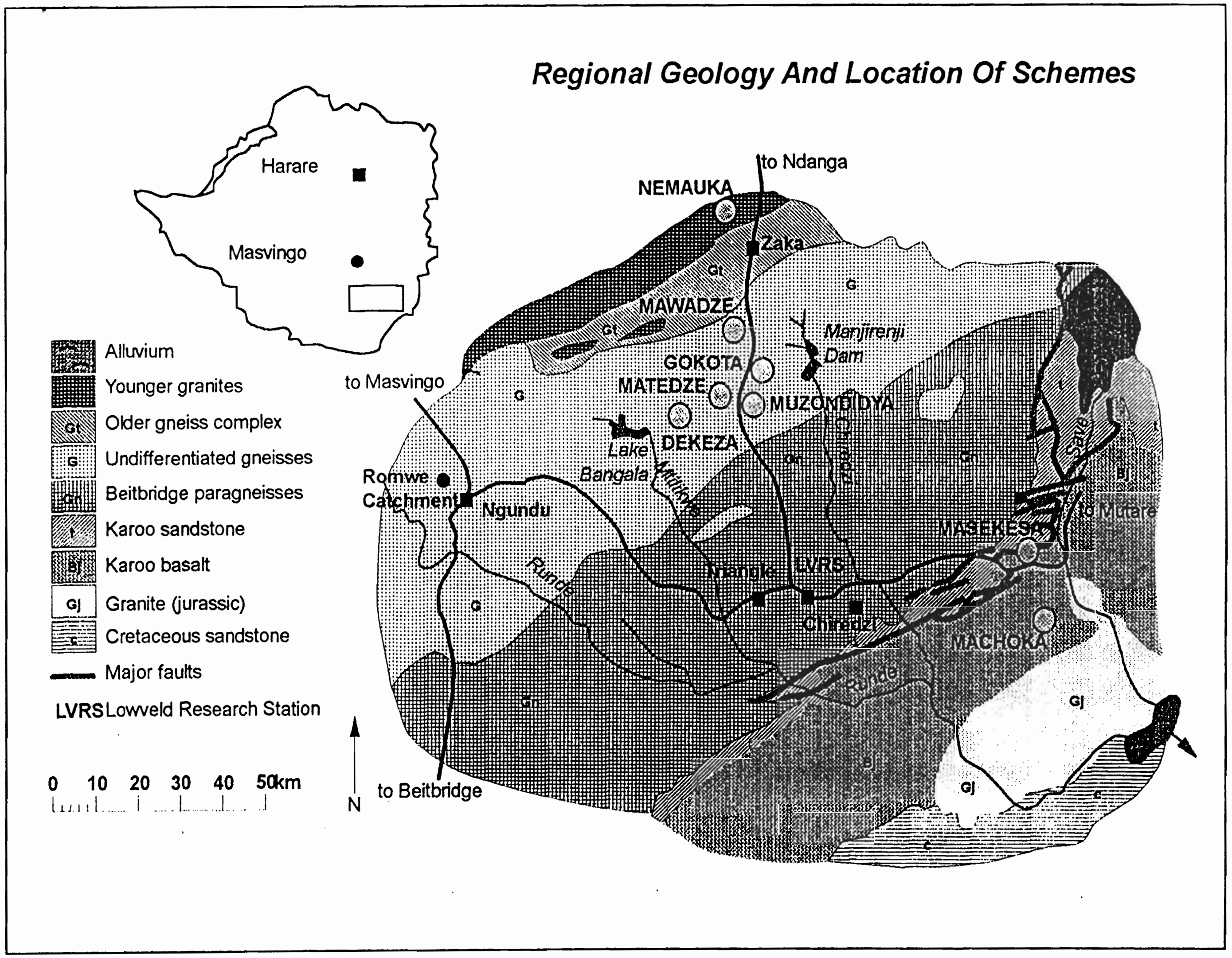


Figure 4 Regional geology and location of schemes

3.4 RETURN-TO-HOUSEHOLD SURVEYS

To help in overall evaluation of scheme impact on both members and non-members of each community, a socio-economic return-to-household survey was completed towards the end of the project in August 1995. Using a similar questionnaire to that used during baseline data collection, the 30 households at each scheme were revisited. As well as information listed in Section 3.2 (ii) above, emphasis was placed on:

i) issues of equity, particularly looking at who are and who are not members of the schemes and reasons why;

ii) willingness to join, using proxies for money in order to better assess the welfare improvement that the schemes bring;

iii) differences between vegetable availability and consumption and money spent on vegetables before and after the schemes;

iv) wealth breakdown of members and non-members, including the potential created by the schemes for employment and income generation and paying special attention to the money that women are now saving or using in revolving funds or generating from other new small scale income generation activities.

Full details of the survey are provided in Waughray *et al* (1995).

4 Scheme implementation

4.1 METHODS OF SITE SELECTION

During the first two years of the project, various methods of site selection were tried in order to represent ways in which site selection might be undertaken in a larger development programme.

4.1.1 Formal nomination by Agritex staff

Requests were made to Agritex staff at ward level to suggest potential areas for collector well gardens based upon geographical, hydrogeological, socio-economic and agricultural selection criteria shown in Annex 1.

A total of thirty-eight prospective sites were identified in this way and all were visited. Twelve were shortlisted but following a team visit only four were considered to satisfy most of the selection criteria. Table 1 provides an example of rapid rural appraisal data collected at this stage. Three of the sites were nominated for exploratory drilling. At the first (Chindondodza) saline water was found, at the second insufficient water, and at the third a successful site (Muzondidya) was located.

It should be noted that the beginning of the project coincided with the worst drought recorded in Zimbabwe. In the project area, rainfed crops had failed, surface water suplies had all but failed, and relief programmes of well drilling and well deepening were ongoing. The situation encountered at all sites visited was one of critical need first and foremost for adequate supplies of domestic water. Only if this could be supplied could people begin to consider the possibilities of garden irrigation. By formal Agritex nomination, numerous communities with dire need for water and with great enthusiasm for gardening could be identified. The value of local knowledge provided by the Agritex field staff could also not be bettered. But the problem remained at all sites to know whether groundwater of suitable quality and quantity existed at a depth and in weathering appropriate for collector wells or other well designs. Unfortunately, in many instances the hardships faced by the communities nominated were found to be directly related to unfavourable hydrogeological conditions in these areas.

4.1.2 Formal nomination by DDF staff

Hydrogeological records of completed wells and boreholes are kept by district and provincial offices of the District Development Fund (DDF) and Department of Water (DWD). Making use of these records and, in effect, considering only the geographical and hydrogeological criteria initially, eight potential areas were quickly identified. Following subsequent liaison with staff of Agritex and the local communities, this approach improved success rate. Of six areas with vehicular access, five were found hydrogeologically worthy of exploratory drilling and at the first selected, a successful site (Gokota) was located. It should be noted, however, that the more favourable hydrogeological conditions identified in this way meant that at several locations the communities were better off than communities visited by the previous method of site selection, at several locations the hydrogeological conditions found were different to those on record, and even at the site where hydrogeological evaluation was successful (Gokota) the location of the best exploratory hole was not in the immediate area of the existing DDF well but in a neighbouring valley, a finding that highlighted the extreme spatial variability of aquifer properties in this region that was to become a key factor throughout all subsequent exploratory drilling.

Table 1 Example of data collected during rapid rural appraisal of prospective sites

District (Communal land)	Zaka (Ndanga)
Ward (Chief)	34, Dzoro North (Bota)
Extension Worker (AEW)	Mr Makunde, Chivamba B/C
Placename	Muzondidya
Kraal(s)	Muzondidya, Gachiti, Maranele, Semende, Manyetu
VIDCO (Chairman)	1, Taivamunhamo (Mr V Semende)
Grid Reference	Map 2031C2; 366 176 31°26'E 20°38'S Alt.620m
Initial Site ID by:	AEW (Mr Maireva at that time)
Site Location	1km from main tar road Chiredzi - Zaka
Landform/Catchment	Large vlei, wide, low slopes, open land, at junction of small side vlei. RWL 5m.
Geology	Granulite gneiss; area devoid of faults
Community Structure	5 kraals around proposed site. Muzondidya Primary School and B/C within 2km.
Present Water: Domestic Gardening	Not critical: good B/hole at school provides whole community. Spring nearby until 1989. 2 NORAD wells at B/C, 1 on vlei give some water Serious. Underground stream 2km from potential site provides water for 10 individual gardens. Private land all around. Owner unwilling.
Previous Gardens	Cooperative garden for 30 families at Primary School, well now dry at 5m. 40 families at Chamuwonde downslope on vlei had garden, 3 beds/family for home consumption.
Present Vegetables	From existing gardens ?
Community Enthusiasm	Very good. Initial visit attended by many people including 3 kraal heads. Community proposed garden 100 families, community well RWL 4m but inadequate. Kraals have cooperated previously. Would select equally among 5 kraals wherever garden is sited.
To serve: Domestic Gardening	None 250 families
Land Allocation	Mr Chauke has offered land for the proposed community garden. Mr Marenele and Mr Gachiti would do same.
Market Opportunities	Appear excellent, main tar road close by.
Other factors	Much interest from menfolk of this community. Good spirit shown, active Master Farmers Club and VIDCO. VCW Mrs J Musikavanhu
Overall Impression	Distinct vlei landform, public, much interest, scheme primarily for gardening, excellent marketing opportunities. Convenient to LVRS.
Recommendation	High priority for exploratory drilling

4.1.3 Site selection by geology

The principal physical factors influencing choice of well design are geology and rainfall. These determine the relative positions of the base of the regolith (weathered zone) and the water table (Chilton and Foster, 1995). Depth of weathering is a complex function of geology and rainfall; in general the former determines the degree and type of weathering and the subsequent properties of the aquifer, and the latter may have the strongest influence on the depth of weathering. Geology and rainfall may also influence groundwater quality. Thus, only where geology and rainfall produce a saturated regolith that is relatively thick (greater than 5m) and a water table that is relatively shallow (less than 15 m below ground level) is a collector well likely to be viable.

Five principal geologies and corresponding terrain types are of importance in the communal lands of southern Zimbabwe, namely younger undifferentiated gneisses, younger granites, Beitbridge paragneiss, older gneiss complex and Karoo basalt (Figure 4). The first pilot project schemes at Muzondidya and Gokota and the initial scheme at Romwe were all successfully sited on the first of these geologies. Thereafter, attention was placed on siting schemes on the remaining geologies.

On younger granites, exploratory drilling was successful and one pilot project collector well was sited at Nemauka. On Beitbridge paragneiss, depth of weathering and rest water levels were generally found to be suitable for collector wells but reconnaissance of existing water points in the southern parts of Zaka District and Nyajena Communal Land revealed groundwater salinity to be a serious problem on this geology, consistent with the findings of first exploratory drilling at Chindondodza. Consequently, a scheme was not sited on this geology. On the older gneiss complex around Zaka, exploratory drilling revealed either small amounts of water in shallow depths of weathering on top of fresh rock, or no water present in depths of weathering often greater than 20 mbgl. Despite concerted effort, a suitable location for a collector well could not be found on older gneiss complex, although a number of locations suitable for deep conventional boreholes were identified and an ideal site for a collector well was subsequently identified at Mawadze on the transition between older and younger gneiss complexes.

4.1.4 Site selection by request

As first pilot project schemes came into operation, interest from neighbouring communities and from aid agencies working in the region increased. Members of the community at Dekeza, for example, made a request for a collector well garden through their Agritex Extension Worker when hearing of exploratory drilling at nearby Makwevere, and members of the community at Matedze made a request for a collector well garden through the Headman of one of their kraals after observing success of the scheme at Dekeza. Similarly, two additional schemes were requested and successfully sited (on basalt) for Plan International at Machoka and Masekesa in Sangwe Communal Land. Potential site identification in this way, based on initial interest expressed either by a community or by a donor on behalf of a community, is likely to occur again in a larger development programme particularly if work is concentrated on a ward-by-ward or district-by-district basis. Where well siting is found possible, this approach represents the best way to identify prospective locations because it creates a community sense of ownership of the project from the outset.

4.1.5 Site selection using geophysics

Geophysical methods have been extensively used in a wide range of hydrogeological environments to assist in the selection of optimum sites for borehole drilling. Indeed, in areas underlain by basement rocks, considerable reliance has been placed on such methods. Varying degrees of improvement in "success rate", have been claimed, but the published cases of comprehensive and thorough post-drilling comparison of geophysics and drilling success are few, and comparisons of different methods under the same conditions even rarer. It is, for example, not often easy to evaluate the additional benefits of geophysics, as it is rarely possible to compare on a site by site basis the "with" and "without" geophysics drilling result. In most rural water supply projects either one or other method is employed, and the best that can be expected is overall statistical comparisons of similar projects using different approaches in the same region.

Geophysical methods have been deployed in basement areas with three main objectives:

- To eliminate negative sites with hard bedrock at very shallow depth rather than waste time on unproductive drilling. Experience shows this can be achieved by a variety of geophysical methods.

- To locate simply, quickly and cheaply the precise spot where the weathering is of the optimum depth (usually maximum) for the type of abstraction point proposed, relatively permeable and where the water table is relatively shallow. This is much more difficult to achieve.

- To locate productive fractures in the unweathered bedrock, where the weathered zone is either very thin and/or is above the water table, and the bedrock is therefore the target for groundwater exploration.

It should be remembered that, to be effective, geophysical methods need strong contrasts in the physical properties of rocks, and need these to be closely related to hydrogeology and groundwater occurrence. Basement rocks, as will be apparent from the discussion in Chapter 5, are highly variable in both weathered and unweathered states, and many of these variations are gradational and small in scale. A great deal of effort over many years has been expended by the hydrogeological community in the development of instrumentation and field methods to address the three objectives outlined above. Although promising results have been reported, methods which are scientifically effective but easy and cheap to operate are not yet widely available. Extensive work has been carried out by BGS in Zimbabwe, including some field testing of the shallow seismic method in the present project. While it was able to delineate areas of shallow bedrock to be avoided, it was not able to pinpoint consistently preferential locations for shallow groundwater supplies (Davies, 1994). While further work on the development of geophysical methods is underway, its routine use in projects such as this one cannot be recommended as cost-effective at present.

4.2 METHODS OF SCHEME CONSTRUCTION

Originally it was envisaged that the project would identify and construct six collector well gardens during the first year (PDS, BDDSA 1992). In the event, this proved not to be possible if the schemes were to represent a range of physical, social, economic and insitutional settings. Instead, schemes were implemented two at a time. This had the added advantage that first schemes completed provided examples of problems that could occur and an adaptive approach to scheme implementation became possible.

4.2.1 Key steps identified

Valuable lessons were learnt at first schemes and these led to significant improvements in implementation of later schemes. The key steps now known to be important in development of community gardens using groundwater are shown in Figure 5. These are not intended as a prescription but rather as a checklist. The exact order and importance of the steps will vary to some extent between different areas and between different communities, but in southern Zimbabwe the sequence shown has been found to be helpful in promoting successful collaboration with communities and in implementing schemes more likely to be sustainable from a social perspective.

The importance of community meetings in this sequence cannot be overstated. They are the key to success. No work should be done in an area until local leaders have been consulted. Sufficient time must be allocated to allow these meetings to be well organised, attended by all leaders and interested members of the community. Sufficient time must also be allowed for reflection and consideration by both community and project staff.

In southern Zimbabwe it will be rare to meet a community that does not have need for or express interest in a community garden particularly as this will also offer a source of clean domestic water. Thus at the first community meeting it is important not to raise hopes too high. It should be explained from the outset that the scheme will be possible only if hydrogeological evaluation is positive, a step described in detail later in Section 5.10. If hydrogeological evaluation is successful, the second community meeting provides the venue for more detailed discussion of the prospective project.

4.2.2 Informal contract with community

Community problems which occurred at the first schemes could be linked primarily to a poorly developed sense of ownership of the project, lack of self-confidence, leadership problems, and misconceptions about the project regarding ownership, responsibility for management and maintenance, and distribution of benefits.

In order to help develop a sense of community ownership at the earliest opportunity and to avoid misconceptions, project staff introduced at the final two schemes (Mawadze and Matedze) an informal contract between the community and project staff. This was prepared in Shona and signed at the time of the second community meeting. A copy in English is shown at Annex 2. The contract outlines the potential project and stages of scheme construction, lists contributions expected from both parties, and recognises explicitly community ownership of the project and community responsibility for scheme management and maintenance.

Use of the contract was well received and proved to be successful at both locations. The people appreciated the clarification which the document provided. Well construction proceeded at record pace, with all work performed on a voluntary basis and in high spirits by teams of five men working for five days each under supervision of a project foreman. Similarly, completion of the gardens was undertaken voluntarily by both male and female members as a group activity. Most importantly, there has been increased reference to project ownership noted during interviews with case study families and the incidence to date of social teething problems has been less at these two sites.

Hypothetical Target: 250 farmer-managed community gardens in Southern Zimbabwe

Irrigated using groundwater. Each garden to be 0.5 ha or larger and to serve upward to 50 families. Each will require a minimum of 15 cubic metres of water per day (including domestic water) abstracted using the most appropriate well design determined for the area.

Define Programme Area eg. Masvingo Province

▼

Select one District at a time eg. Zaka

▼

Liaise with District Development Committee in order to:
- **Identify ongoing and proposed water development projects eg. dams, boreholes, irrigation schemes, water and sanitation programmes**
- **Avoid duplication of effort or possible conflict of interests**
- **Collate hydrogeological data for existing wells and boreholes**
- **Identify Wards where present programme would appear appropriate based on need, hydrogeology, viability of other types of surface water development project**

▼

Consider one Ward at a time eg. Bota South

▼

Liaise with WADCO and field staff of Agritex and DDF in order to:
- **Confirm status of water supplies and gardens in the Ward**
- **Identify potential communities or VIDCO's based on need and anticipated community interest**

▼

Visit selected communities or VIDCO's eg. Gondora.

▼

First Community Meeting and Site Visit to Assess:
- **Existing sources of water (visit plus hydrogeological records)**
- **Community need**
- **Community interest**
- **Community structure**

▼

Areas considered to show potential

▼

Hydrogeological Evaluation
(See separate reports)

▼

Area considered to show potential

▼

Second Community Meeting to:
- **Describe potential project to community**
- **List external contributions that can be made**
- **List community contributions that will be required**
- **Answer any questions from the community**
- **Clarify any misconceptions**
- **Confirm community commitments**
- **Define project community and placename**
- **Agree community contribution to construction**
- **Agree allocation of land for the project**
- **Agree programme of work**
- **Sign informal contract with the community**

▼

Begin work

▼

Figure 5 *Key steps to be taken in development of community gardens using groundwater*

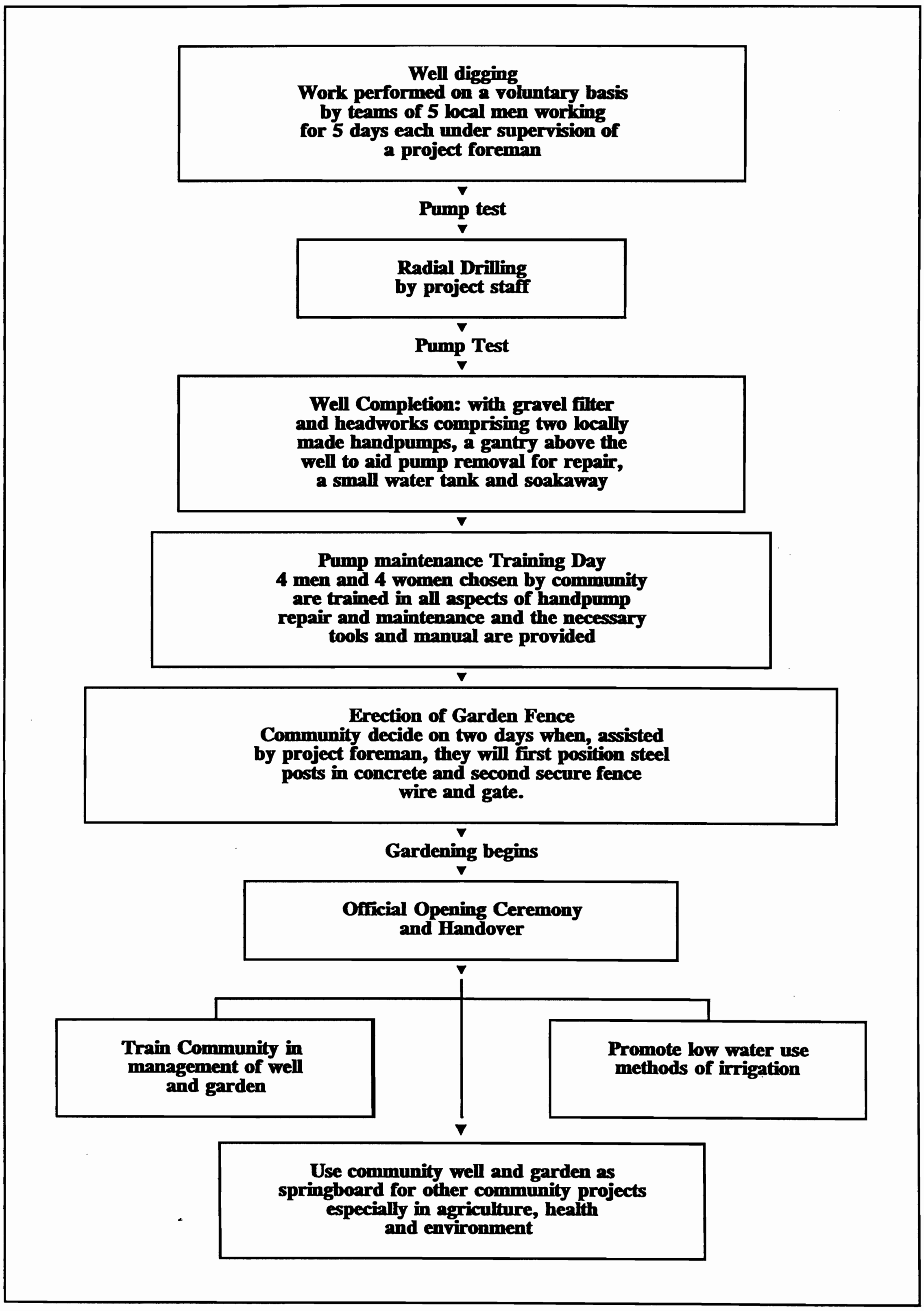


Figure 5 *Continued*

4.2.3 Garden membership

The pilot project has investigated a number of different social settings. This has involved garden membership being decided by communities in a number of different ways, with resulting differences both in the performance of the schemes and in non-equitable distribution of benefits between members and non-members. These aspects are considered further in Sections 6 and 8 below. Considerable amounts of data have been collected and scheme monitoring is continuing. The consensus made by project staff at this stage is that institutional structures are still evolving and it is too early to draw conclusions on the 'best' or preferred mechanisms by which scheme membership can and should be decided.

4.2.4 Pump maintenance

In a project designed to implement relatively high yielding water points and provide rural communities with water sufficient for both domestic use and irrigation, it is vital that appropriate, reliable and affordable components and sources of inputs are used in scheme design. Choice of pump type and pump maintenance thus become two key issues. In Zimbabwe, a locally manufactured type 'B' bushpump has proved to be robust and can be repaired at relatively low cost. During the project, two have been fitted per collector well. In addition to meeting the total pumping capacity required of 15-20 m^3/day, fitting two pumps has provided a safety net in the event of one pump breaking down. A steel gantry was fitted above each well to facilitate lifting of the pumps, and training days held for 8-10 members of each community at the time of pump installation when the necessary tools and repair manual were also donated. All schemes were also registered with DDF in order to benefit from the third tier of their maintenance system that provides assistance in cases of emergency.

This approach has worked well, and its success and popularity is illustrated by the continuing ability and willingness of project communities to repair not only their own pumps but also those of neighbouring communities. At one site (Mawadze), members have even gone to the extent of purchasing spare parts in anticipation of future breakdowns. However, it should be noted that problems can still arise for which a community and even DDF pump minders are not prepared (for example, dropping a pump cylinder down a well), or which can delay pump repair (for example, a pump minder or other key personality is absent). Furthermore, routine monitoring has indicated that daily wear and tear of even this robust design of pump is very high. The pumps do breakdown and presently their heavy (almost dangerous) weight represents a disincentive to community-based maintenance. While recommending that the general approach to community-based pump maintenance developed during the pilot project should continue in a larger development project, it is suggested that:

i) where conventional 'B' type bushpumps are used, a SIWIL pump lifter be provided with each collector well instead of steel gantry (as this was found to be safer and easier for communities to operate as well as being cheaper);

ii) trials be held of alternative pump types that ease community-based maintenance (for example, the recently developed "extractable" version of the Zimbabwe bush pump).

Use of a motorised pump is not advisable. It has higher running costs and difficulties of repair that can be beyond the means of poor rural villages. It also lacks the control against groundwater depletion inherent in the use of handpumps, an important consideration in these dry areas.

4.2.5 Community ownership

It has been found helpful upon completion of each scheme to hold an official opening ceremony and handover. This event can be attended by local and foreign dignitaries as appropriate. It helps to seal the sense of ownership felt by the community, it allows the community to show with pride what they have already achieved in their garden, and it is an appropriate time for a celebration. Community participation in development of small scale irrigation using groundwater also provides the ideal springboard to other community projects, especially in health, agriculture and the environment. Villagers given water in the present project are now beginning other projects that include keeping rabbits and growing fruit trees. Community workers in the area are now able to advise on nutrition at the new gardens. Agricultural extension staff and NGO's are providing advice on agronomy and garden management and are promoting low water use methods of irrigation. Perhaps most exciting is the opportunity this type of first water development project creates to initiate community-based management of soil and water resources in each small catchment considered. In this way, the people themselves become responsible for recharge to their well and the life of their scheme, and in so doing they also begin to address the problems of environmental degradation often too daunting when considered on a larger scale.

5 Technical and economic viability of collector wells

5.1 BACKGROUND

Appraisal of the first collector well garden completed in Romwe catchment in 1991 gave an indication of the economic viability of small scale vegetable production when water for irrigation could be made available to communities in this dry region (Brown and Dube,1992). Similar and even higher returns at pilot project schemes reported later in Section 6 confirm viability of gardening. However, this form of appraisal does not indicate whether a collector well is the **most** viable or cost-effective means of providing water to support this activity. No comparative studies of alternative well designs were possible at the time of the first scheme. In order to satisfy pilot project objectives and properly assess technical and economic viability of collector wells, a methodology has been developed and implemented in the present programme.

5.2 COLLECTOR WELL PERFORMANCE TO DATE

Figure 6 shows performance of the project wells to date, as well as the collector wells located in the Romwe Catchment and at the Lowveld Research Station. This monitoring confirms that the peak water required to irrigate a 0.5 ha garden and satisfy local domestic need is presently 14-15 m^3/day. However, the initial scheme at Romwe also demonstrates that a viable (if somewhat smaller) community garden is possible using 10-11 m^3/day.

Over the three year period 1993-95, a slight net fall in well water levels at sites 1-6 can be detected. However, the process of groundwater recharge in this region depends heavily on the pattern of rainfall distribution during any year, and results of the complimentary study of groundwater recharge ongoing in Romwe Catchment (Butterworth *et al*, 1995) indicate that 1994/95 was a particularly poor year. Recharge in this catchment during 1994/95 (total rainfall 735 mm) was very low due to an even distribution of rainfall (shown in Figure 6(g)) and significantly lower than during 1993/94 (total rainfall 661 mm) when consecutive heavy rains fell early in the season. It is encouraging therefore that all collector wells have provided a continuous supply of water even through years of low recharge, but it is also clearly important to monitor recharge and well performance over the longer-term.

The data set shown in Figure 6 probably represent one of the best ever collected on crystalline basement rock. It is recommended that monitoring be allowed to continue in order to assess the impact of prolonged well use and periods of low rainfall on both well performance and the groundwater resource.

Figure 6a & b Collector well performance to date

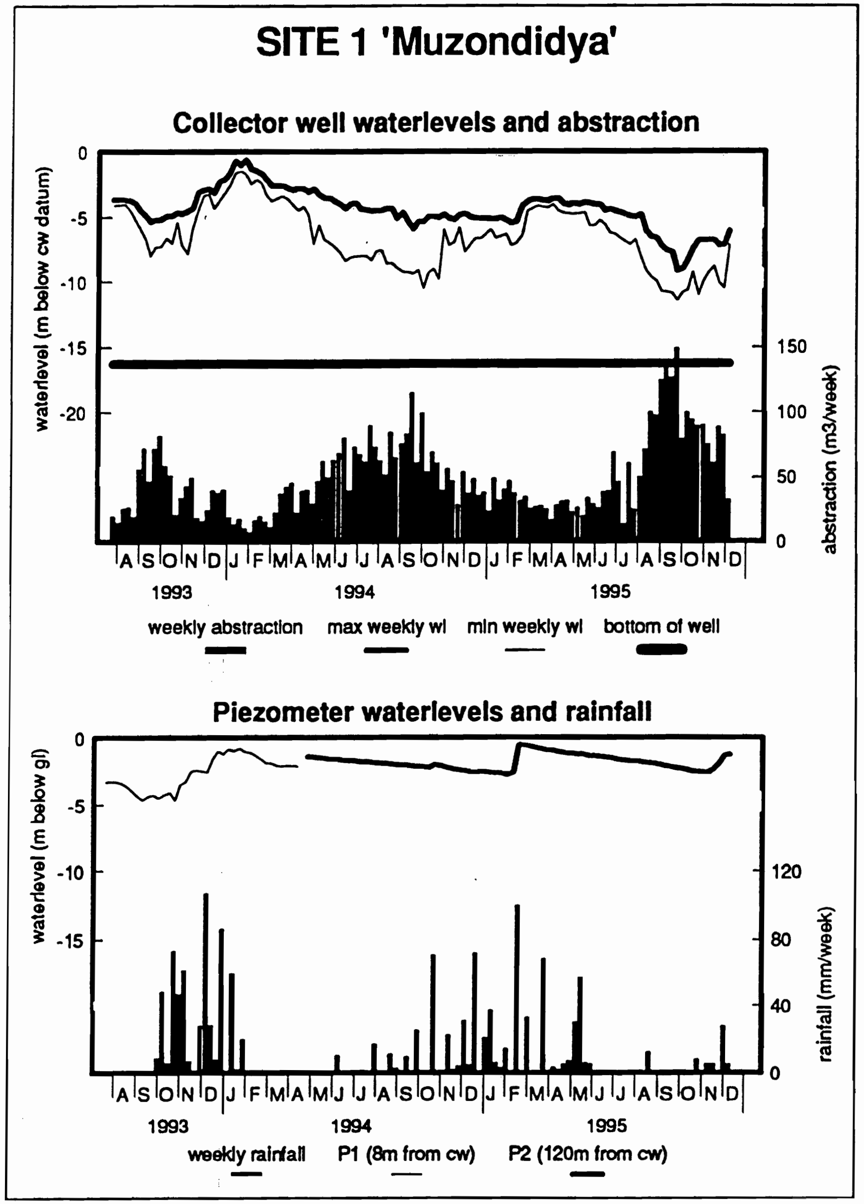


Figure 6(a). Muzondidya collector well performance

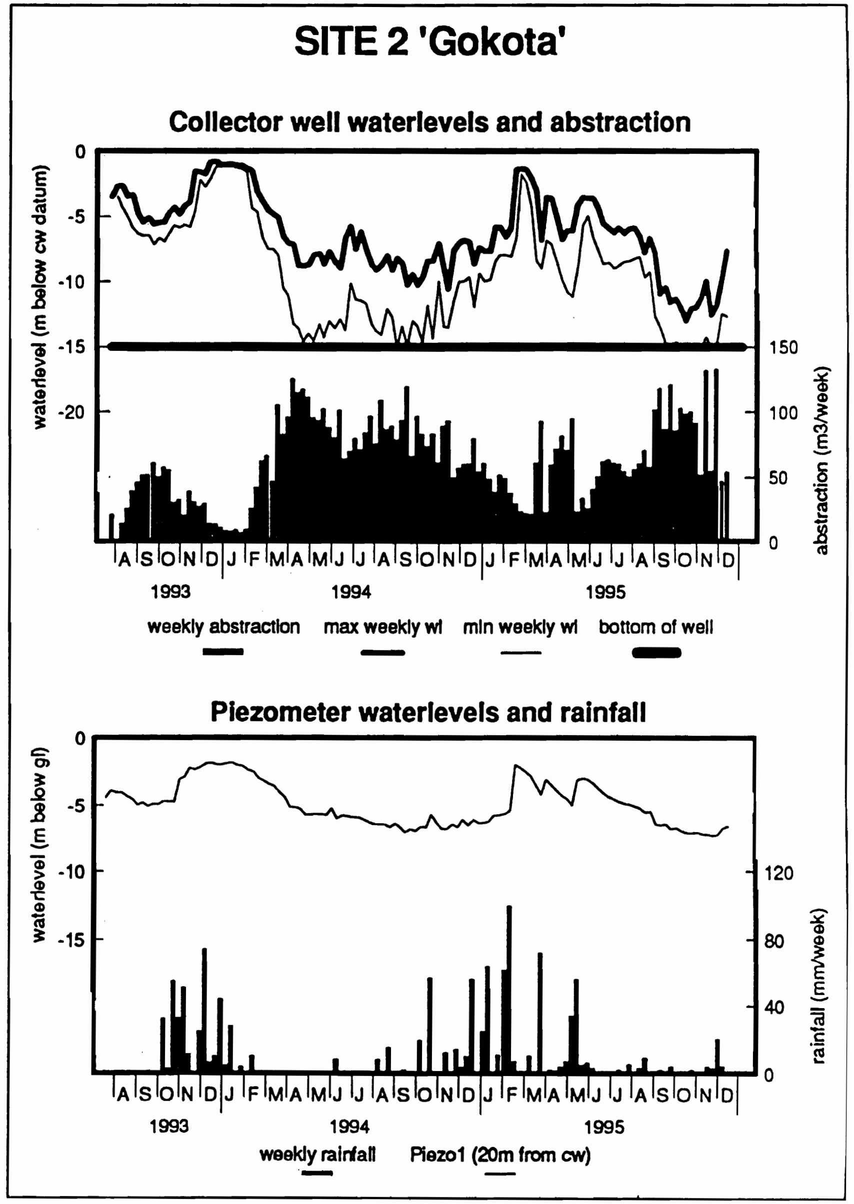


Figure 6(b). Gokota collector well performance

Figure 6c & d Collector well performance to date

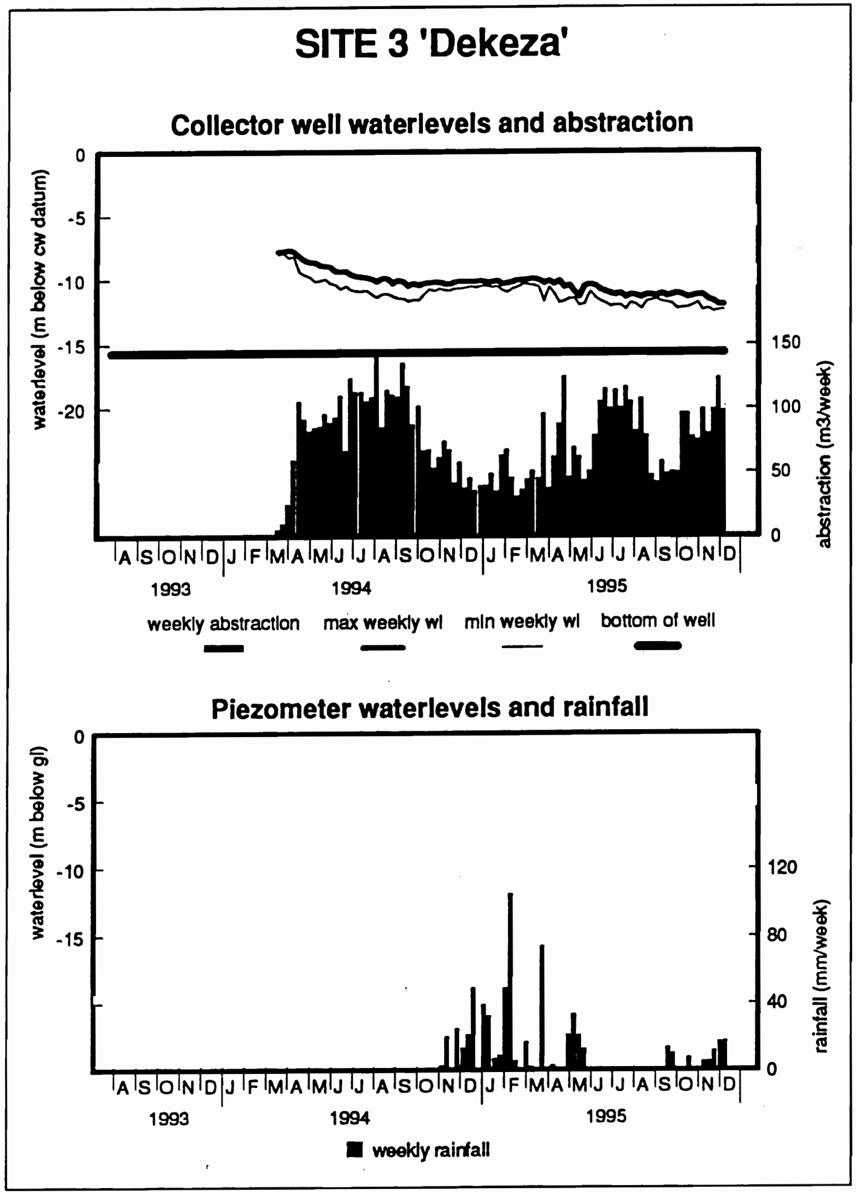


Figure 6(c). Dekeza collector well performance

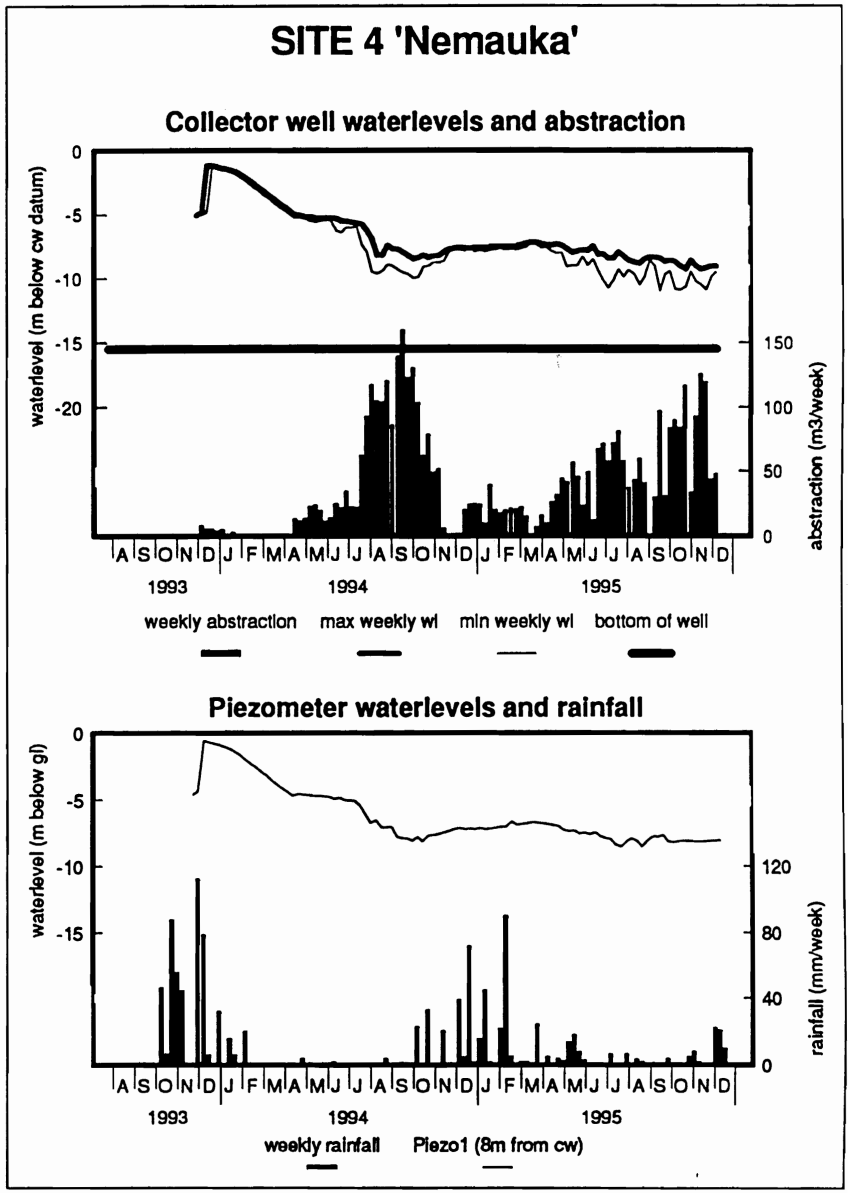


Figure 6(d). Nemauka collector well performance

Figure 6e & f Collector well performance to date

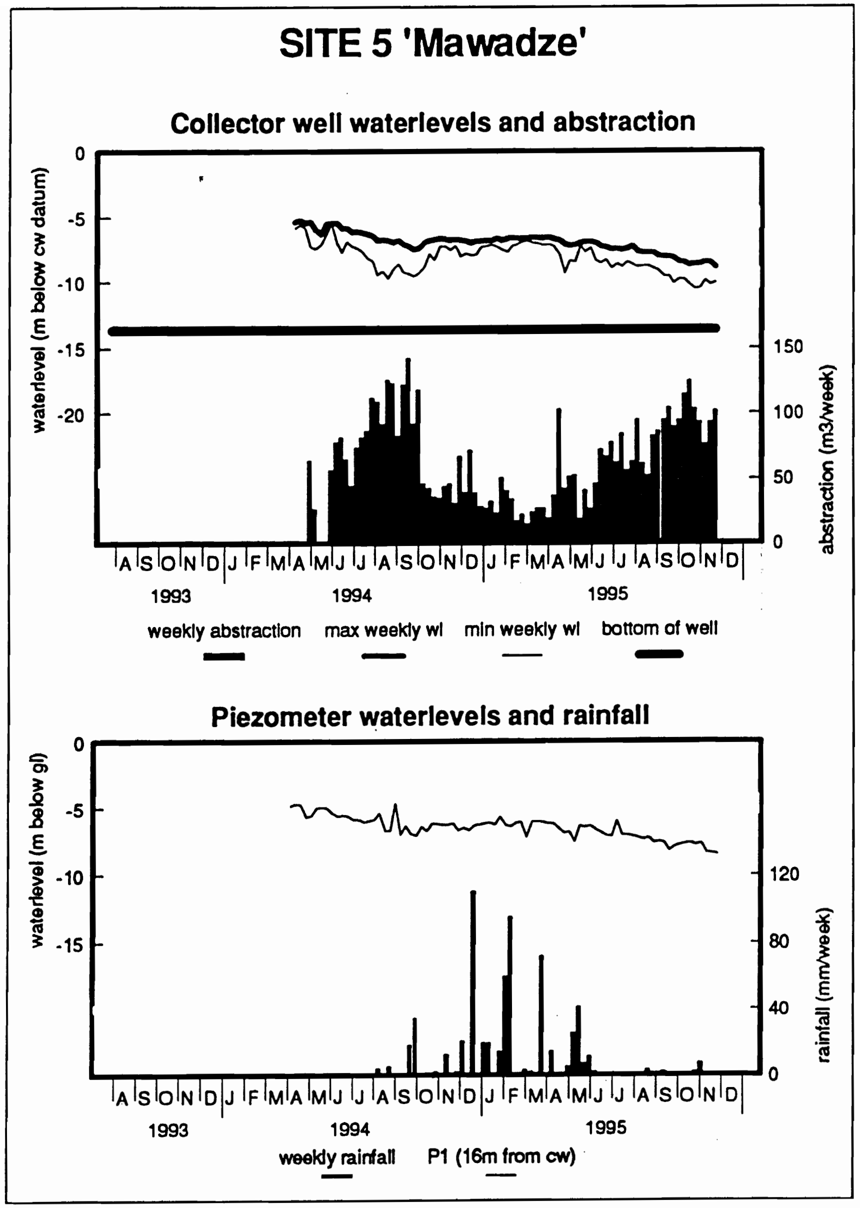


Figure 6(e). Mawadze collector well performance

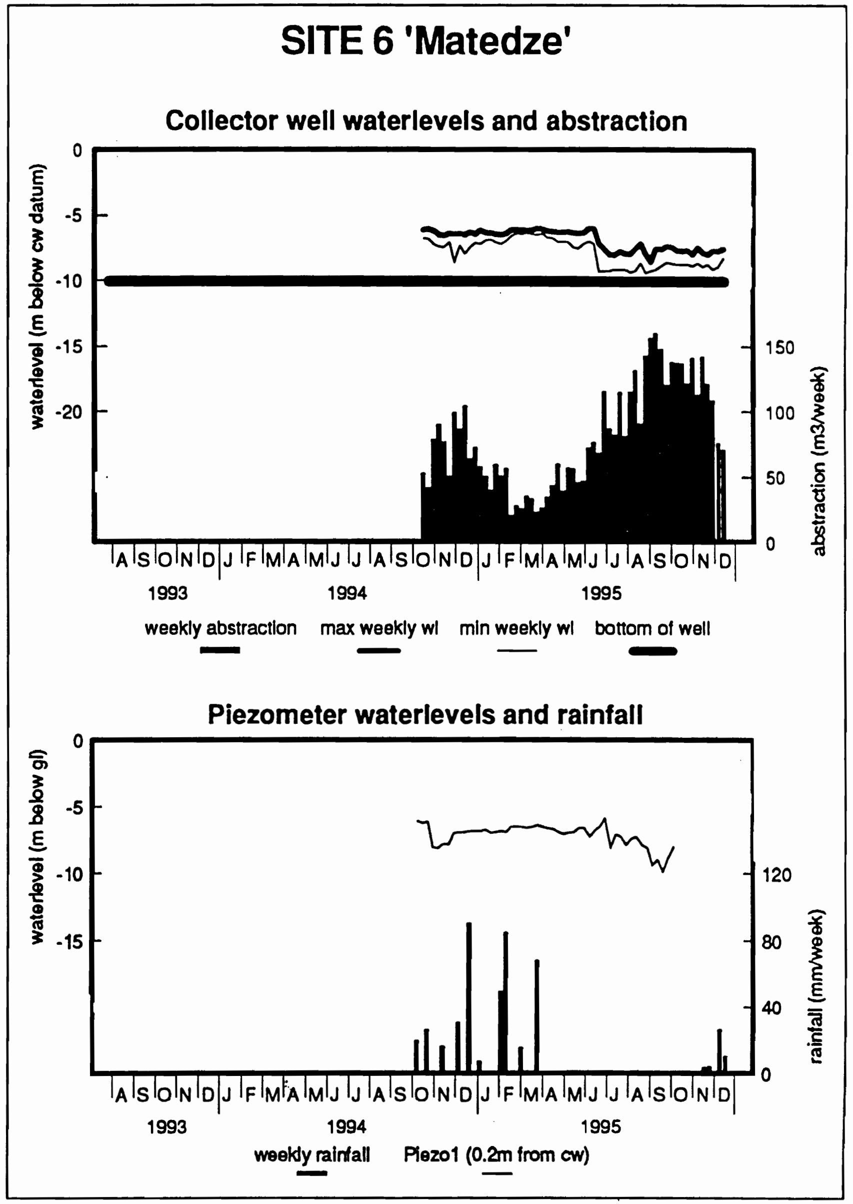


Figure 6(f). Matedze collector well performance

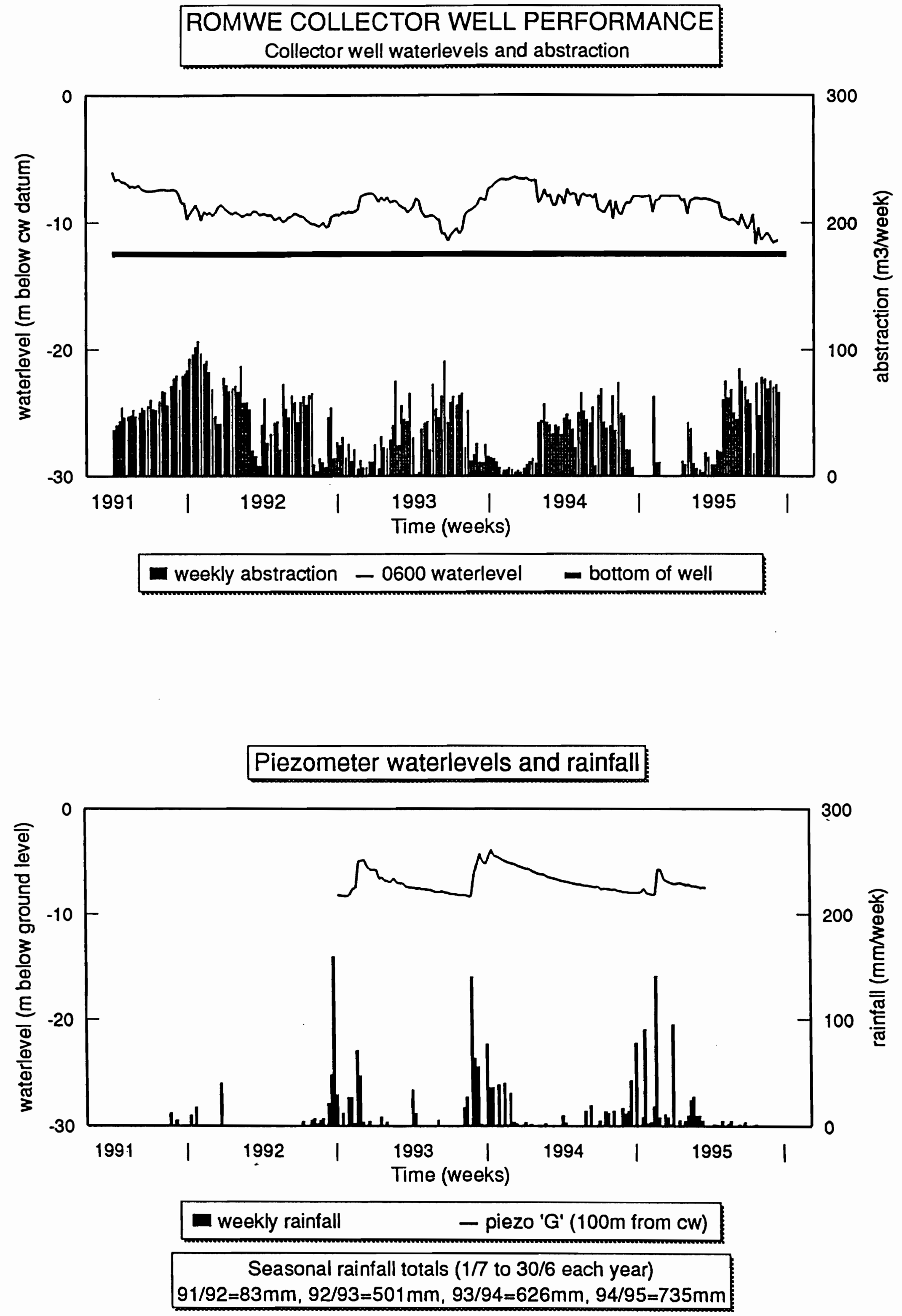
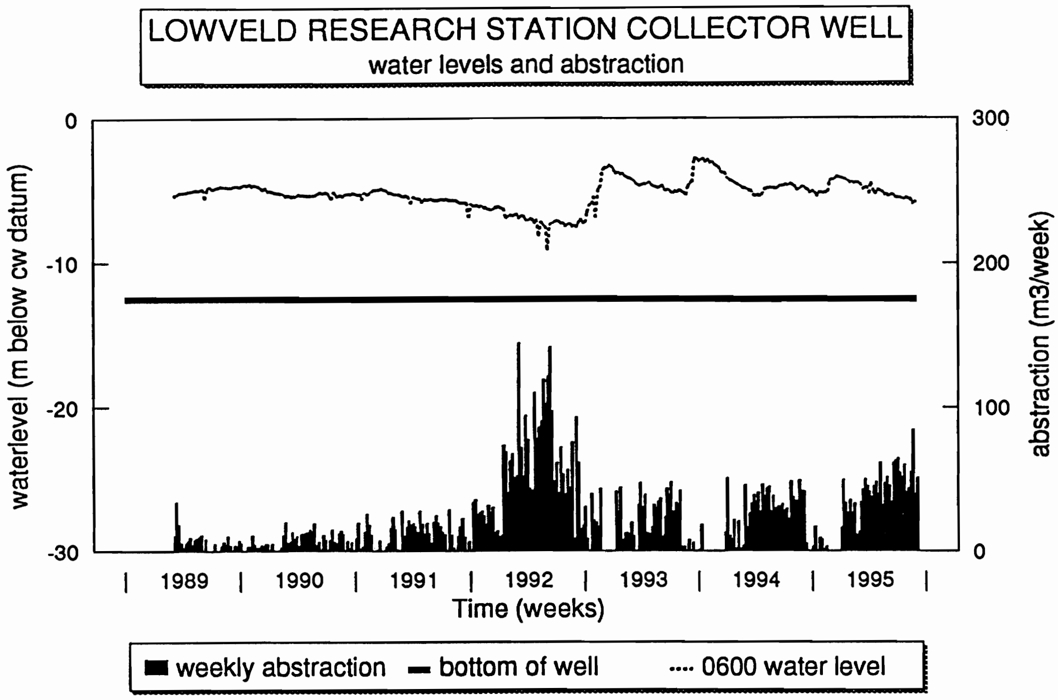


Figure 6g *Romwe collector well performance*



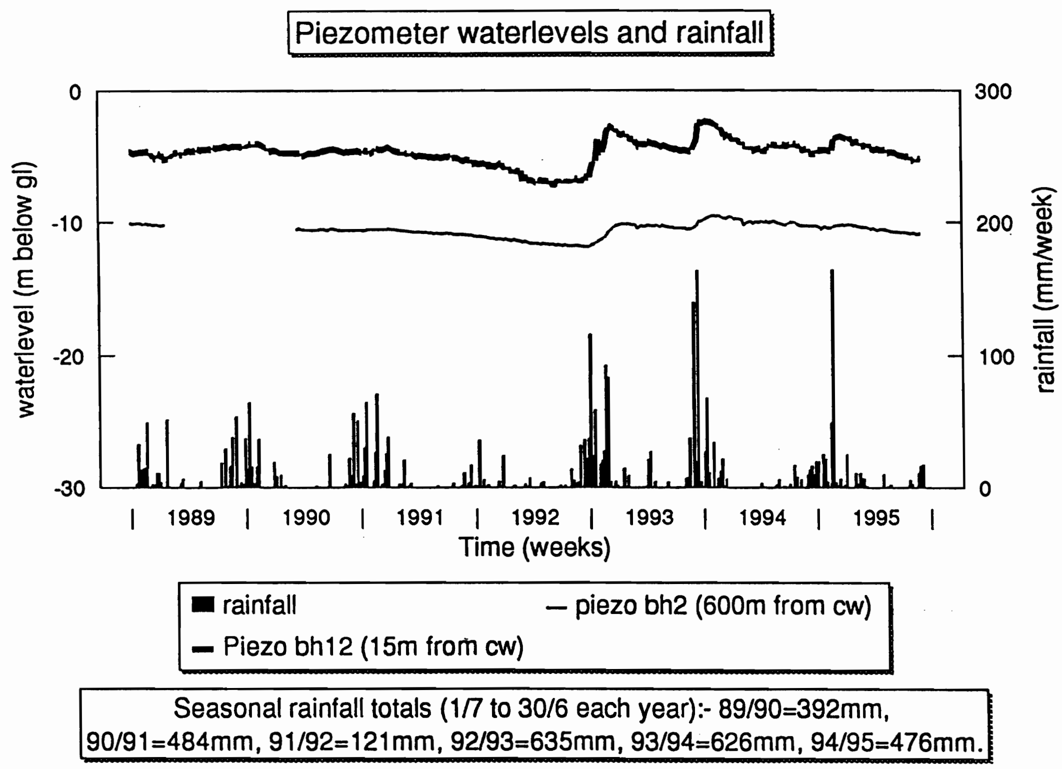


Figure 6h *Lowveld Research Station collector well peformance*

5.3 EFFECT OF LATERAL DRILLING

Figure 7 shows improved well recovery rates measured at the eight sites at which lateral drilling was completed. At the ninth site (Machoka), pumping tests of the large diameter well prior to laterals showed that it could satisfy the required target of 15 m^3 of water per day without drilling. Only small improvement in well yield by lateral drilling was recorded at site 2 (Gokota) and at Romwe. Despite this, the large diameter wells at these two sites have since proved able to support viable community gardens (Section 6). At the other sites, lateral drilling improved well yield significantly. On basement rock, for which the technique was originally designed, lateral drilling in this project has improved well yields by an average of 38 per cent. Where successful, it has the effect of reducing drawdown and increasing rate of recovery following abstraction from the well. In real terms, this improvement has converted relatively low yielding large diameter wells at sites 1 and 6 into collector wells that now satisfy the required target of 15 m^3/day, and at sites 3, 4 and 5, has converted satisfactory large diameter wells into relatively high yielding collector wells that could now support irrigated gardens larger than 0.5 ha.

5.4 COMPARISON WITH ALTERNATIVE WELL DESIGNS

Four other well designs are currently used to abstract groundwater in Zimbabwe and elsewhere and may be compared with collector wells. These different well designs are illustrated in Figure 8.

Traditional dug wells (TDW)

In Africa, the traditional source of groundwater is a dug well. Generally, these are dug by hand using chisels and picks and a bucket and windlass to remove the spoil but without the aid of a dewatering pump. They are usually 0.8-1.2 m in diameter. The level of abstraction sustained is generally low but can be sufficient to supply a family with water for domestic use and a small garden. Final depth of well is controlled primarily by the degree of weathering in the upper layers and by the water-table. The well cannot be dug much below this level without the aid of a dewatering pump and often will be deepened progressively during periods of low recharge as the water-table falls. With the occurrence of several dry years and increasing demands of a rising population, programmes of well deepening (often using explosives into the hard rock) are being undertaken in Zimbabwe. These so called 'deep wells' are included under this category.

Large diameter wells (LDW)

Like a traditional well, a large diameter well is constructed in the weathered zone of basement rock. Again it is dug by hand but with the use of hand tools that can include a pneumatic jackhammer and de-watering pump to allow construction below the water table. It is lined either with rocks, bricks, concrete or steel and is usually 2-3 m in diameter. Final depth is controlled by weathering and the required volume of water, digging usually stopping when fresh rock is encountered. Abstraction sustained can be higher than a traditional dug well due to the greater volume of storage provided and the greater wetted surface area giving increased inflow (Figure 8). At present large diameter wells are not common in Zimbabwe but are important elsewhere, for example,'agro-wells' in Sri Lanka (Shah, 1990). For the purposes of this comparison, large diameter wells tested at each site were those constructed prior to lateral drilling to create collector wells.

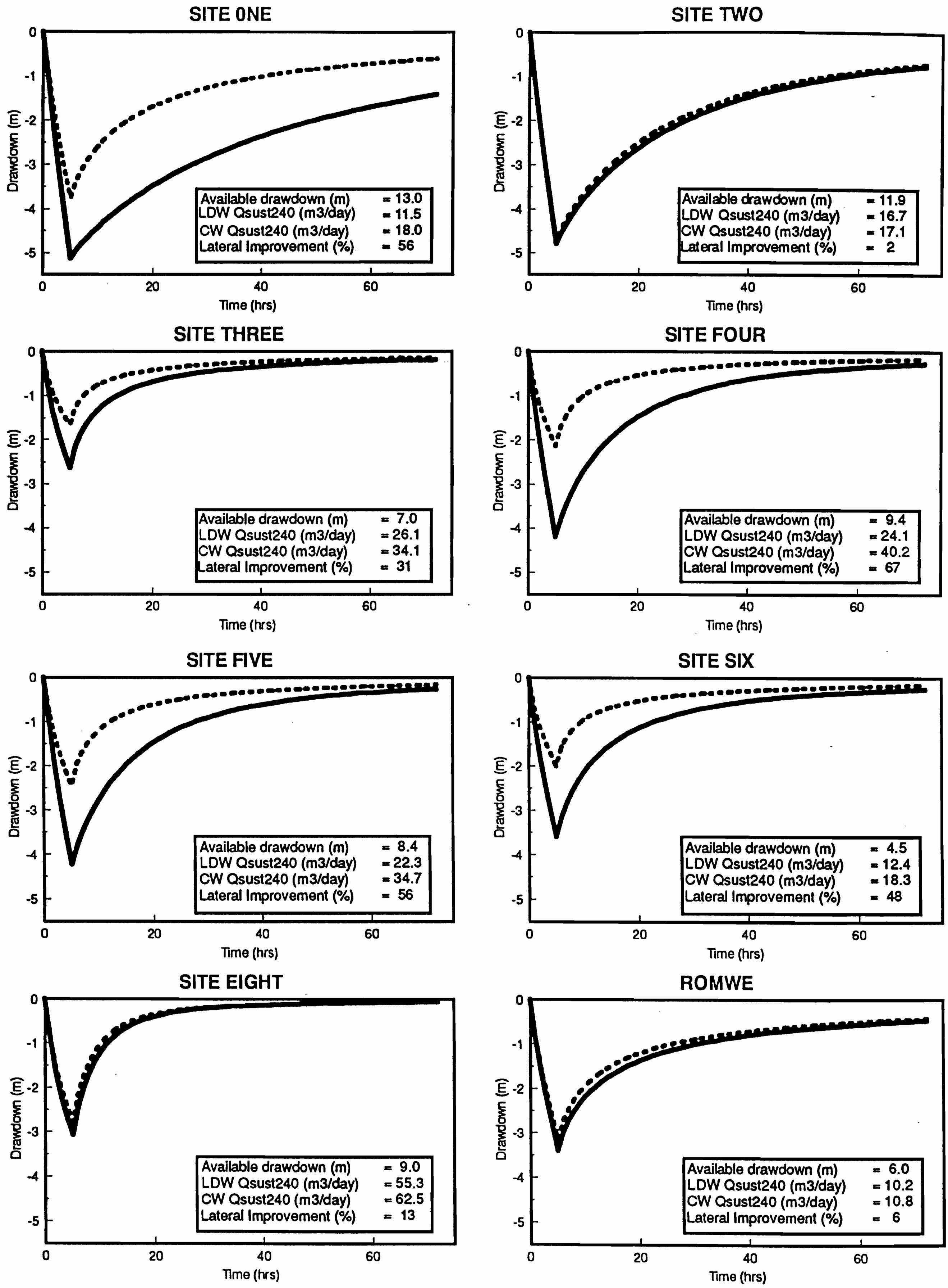


Figure 7 *Well recovery (——) before and (------) after lateral drilling (Simulated well response to a standard test of 1l/s for 5hrs)*

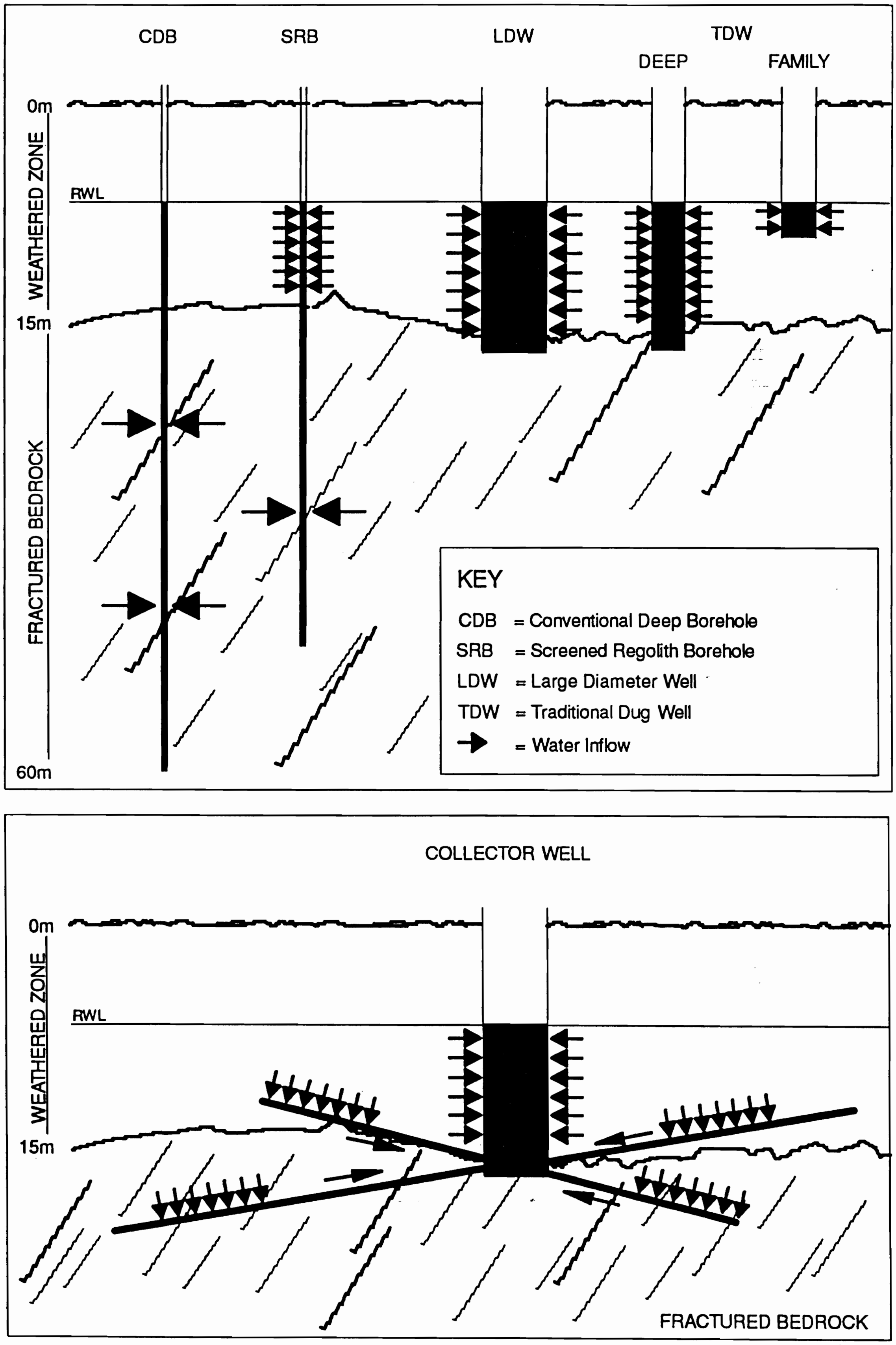


Figure 8 *Five well designs used for groundwater abstraction in basement aquifers*

Conventional Deep Boreholes (CDB)

Conventional deep boreholes (or tubewells) of 150-200 mm diameter are the most widely constructed type of groundwater abstraction point in southern Zimbabwe. Being mechanically drilled they are relatively easy to construct and, with modern air rigs, can be drilled in a relatively short time. Few in Zimbabwe are completed in the upper weathered zone and most penetrate the bedrock in search of fractures which yield water (Figure 8). A depth of 50-70 m is typical. Where interconnected fractures occur they allow deep conventional boreholes to draw on the higher storativity of the regolith. If major water bearing fissures are intercepted and produce locally high transmissivity, high yields can be achieved. However, the pattern of fracturing in crystalline bedrock is highly variable and not easy to predict. Despite use of geophysical siting techniques, many boreholes do not intercept fracture systems sufficient to satisfy either the volume of water or longevity of supply required, and poor drilling success rates reflect this difficulty. For the purposes of this comparison, tests were conducted on existing conventional deep boreholes at each site where these existed.

Screened Regolith Boreholes (SRB)

Generally, the weathered zone of conventional deep boreholes is cased rather than screened. This reduces costs and eases construction but denies access to water from the upper aquifer. Where the upper aquifer is productive, screening is possible. For the purposes of this comparison, exploratory boreholes used to site collector wells were screened in the regolith and deepened into the bedrock to create a screened regolith borehole and allow the aggregate transmissivity of regolith and bedrock to be determined.

5.5 FACTORS THAT INFLUENCE CHOICE OF WELL DESIGN

A number of factors influence choice of well design and should be considered during a groundwater development programme:

Geology and rainfall

Two principal physical factors influencing choice of well design are geology and rainfall. These determine the relative positions of the base of the weathered zone and the water table (Chilton and Foster, 1995). Geology and rainfall may also influence groundwater quality. Where the regolith is very thin or absent or the water tables are deep, dug well construction may be virtually impossible and boreholes may be the only option. If the regolith is thick and water table shallow, dug wells are likely to be viable.

Community preference and sense of ownership

Ensuring local involvement in designing, implementing and managing water projects brings the greatest chance of success (Carter, 1989; Underhill, 1990). Sense of ownership and responsibility for upkeep of a water point is more likely if the well is dug by the community rather than drilled by an external agency.

Pump capacity and ease of repair

Rural farmers owning traditional wells generally use a bucket and windlass to abstract water. Communal wells however are often fitted with a pump. The nature of the rural environment prohibits use of high technology pumps. A source of power is rarely available or within people's means and the necessary tools or skills are not available to repair such equipment. Simple hand-powered single action reciprocating pumps (eg. Zimbabwean bushpump) are thus most often used. These pumps are typically able to supply 5-10 m^3/day. A borehole will only allow one such pump to be fitted: the borehole may thus be under utilised if the potential yield is greater than the pump capacity. A large diameter well, in contrast, will allow several pumps to be fitted. This has the added advantage of less wear and tear per unit and when one pump breaks water may still be abstracted by another. Community-based maintenance of the pumps is the ultimate goal. Irrespective of well design, this requires training of local people and provision of tools, but is made easier on a dug well than on a borehole due to the shallower depth and corresponding lighter pumping unit to be extracted.

Well performance and cost-effectiveness

Ultimately, the type of well chosen must provide the volume of water required, be sustainable, and be cost-effective. It was with the aim of better understanding this aspect of well selection for use with small-scale irrigation that the following comparison of well designs was undertaken.

5.6 WELL COMPARISON METHODOLOGY

Table 2 indicates the well types either existing or constructed that were tested at each site.

Table 2 *Geology, annual rainfall (mm) and depth of well (m) either constructed or existing at each site. (Length of laterals (m) are shown where drilled)*

Site	1	2	3	4	5	6	7	8
Geology	gneiss	gneiss	gneiss	granite	gneiss	gneiss	basalt	basalt
Rainfall	780	790	780	780	820	785	580	580
LDW	15.8	15	15	15	13	9.5	8.76	18
CW	15.8 (1x15, 4x30)	15 (4x30)	15 (8,9,25 27,28)	15 (1x18, 3x30)	13 (14,16 28,30)	9.5 (2,4,8, 23,30)	8.76 (none)	18 (9,19, 27,27)
TDW	-	-	-	12.75	-	-	-	-
SEB	15*	15	-	15	15	15	-	-
SRB	40	30	-	-	33	-	18	30
CDB	48	-	43	-	39	-	-	-

LDW=large diameter well CW=collector well
TDW=traditional dug well SEB=shallow exploratory borehole
SRB=screened regolith borehole CDB=conventional deep borehole

Pumping test procedure

Pumping tests listed in Table 3 were conducted on the large diameter well at all sites prior to lateral drilling and at seven sites on the collector well after lateral drilling. Additional tests were also completed on the best shallow exploratory borehole drilled during well siting, on the same borehole deepened to 40 m and screened in the regolith, and on the nearest conventional deep borehole and traditional dug well where present. Test results were analysed to obtain values for transmissivity and storativity at each site for both the shallow and deep aquifers. Values of available drawdown were used to model the abstraction that could be sustained by each well type at each site for a period of one dry season.

Table 3 *Pumping-tests performed at each site*

Well type	Pumping rate (litres/sec)	Pumping time (mins)	Site
LDW + CW low discharge	0.65	120	1 + 2
LDW + CW high discharge	4.5	120	1 + 2
	2.65	240	3 + 4
LDW + CW medium discharge	1	300	5 + 6 + 8 (no CW at 7)
SEB	0.4	60	1,2,4,5,6,7
SRB	0.6	240	1,2,5,8
CDB	0.6	60	1,3,4,5

Pumping test analysis

Analysis was performed using program BGSPT (Barker, 1989). The package consists of two parts: PTFIT which analyses pumping-test data; and PTSIM which simulates well drawdown using specified well and aquifer parameters and which can be used to estimate sustainable yield of the well. PTFIT accepts ranges of aquifer parameters as input and optimises the fit of the pumping-test data to the built-in conceptual model of the aquifer by varying the parameters within these ranges. The conceptual model is that of a fully penetrating well in a confined homogeneous aquifer of infinite extent. Flow within the aquifer is assumed horizontal and within the aquitard, vertical. The water-table in the aquitard was assumed to be horizontal. The well is defined by the radius of the casing Rc and the screened section of the well Rw. During this project, the program was developed to allow the radii to be varied along with other parameters. This allowed increase in effective radius, Rw, of the large-diameter well due to laterals to be estimated.

Complexities of the basement aquifer

In a pumping test, drawdown during abstraction and subsequent recovery are monitored. By fitting this response to a mathematical model, properties of the aquifer in the vicinity of the well can be estimated. The model is based on a simplification of the aquifer. Crystalline basement rocks form complex aquifers. Regolith and bedrock aquifers are different in form. The first varies both vertically and laterally. Often its composition changes from being sandy on watersheds to clayey in valley bottoms. Derived from *in situ* weathering of parent rock, permeability tends to increase with depth as the proportion of secondary clay minerals reduces. The lowest part of the regolith may be the most permeable and productive part (Wright *et al.*, 1989; Chilton and Foster, 1995), and the collector well is targeted at this zone. Bedrock permeability in contrast depends on the connectivity of fractures. The boundary between the two aquifers is not usually sharp. The form of the aquifers also changes from site to site being dependent on lithology and geomorphological history. Even at one location lateral variation can have hydraulic significance where, for example, hard bands in the rock form barriers to groundwater flow.

This complex nature means that it is difficult to describe crystalline basement aquifers with a mathematical model. There may not be a single set of parameters that define the hydraulic system. To assume the aquifer to be confined in this study appeared justified at most sites, by observation that the depth of first water strike was below the final rest water-level. It is unlikely, however, that the weathered aquifer remained confined throughout all tests. To assume the wells to be fully penetrating was reasonable, as they were dug to the base of the weathered zone, as digging further into unweathered rock is slow and difficult. However, the aquifers do not extend infinitely and drawdown was not always small compared to saturated thickness. Rarely also were absolute rest water-level conditions possible prior to tests. The wells were dewatered to allow construction and the time required for full recovery would have affected progress overall and denied access to water by the local people. Compensation was made in the analysis where this was important. In some cases, fracturing of the aquifer in the vicinity of the well may have increased storage as the water-level did not decline as fast as expected. In other low yielding wells, a seepage face may have developed as drawdown was greater than expected.

Consequently a number of difficulties were encountered in the analysis of the data obtained from the pumping tests. In some cases, data could not be fitted to the model without allowing input parameter ranges to be set at unrealistic values. In particular the fitting of storativity was problematic and values were obtained that were higher than would be expected even for unconfined aquifers (eg. at site 6). Despite these difficulties, a level of confidence in the results was possible, based on the sum of errors of the modelled fit, consistency of aquifer properties determined by testing different wells at one site, predicted versus measured well behaviour for those wells that were monitored (eg. Figure 6), and the history and performance of all wells as reported by the communities. This degree of confidence was assigned a level ranging from 1 to 5, most confidence being represented by the higher values. The results presented below should be considered indicative rather than absolute, but are believed to be a true reflection of the relative performance of each well type tested and indicate the relative magnitude of the sustainable yield that might be expected from each.

5.7 AQUIFER PROPERTIES AT PROJECT SITES

Table 4 shows aquifer properties estimated at each site using pumping test results for the various wells. In the shallow aquifer, transmissivity values at all sites are consistent with previous work in the regolith in southern Zimbabwe (Wright, 1992) and elsewhere in Africa (Howard and Karundu, 1992; Chilton and Foster, 1995). Sites 3-6 have somewhat higher transmissivities than sites 1 and 2, and could therefore be the more favourable sites for the construction of a dug well or screened regolith borehole.

Table 4 *Aquifer properties of transmissivity (T) and storativity (S) determined at each site*

	SHALLOW AQUIFER					DEEP AQUIFER				
Site	Depth (m)	T (m^2/d)	S	Conf	Source of data	Depth (m)	T (m^2/d)	S	Conf	Source of data
Romwe	12	1.1	0.520	2	LDW	-	-	-	-	-
1	15	0.8	0.005	4	LDW	48	32.0	2e-6	4	CDB
						40	4.48	5e-3	4	SRB
2	15	1.4	0.008	4	LDW	30	2.4	8e-3	4	SRB
3	15	2.9	0.007	1	LDW	43	118.0	7e-3	4	CDB
4	15	2.9	0.010	3	SEB	25	0.9	1e-2	2	CDB
5	14	3.1	0.007	3	LDW	33	5.6	9e-3	3	SRB
						33	0.8	7e-3	2	CDB
6	10	2.5	0.077	4	LDW	-	-	-	-	-
7	9	30.2	0.565	3	LDW	18	206	2e-3	3	SRB
8	18	9.8	0.004	3	LDW	30	9.8	1e-6	2	SRB

Transmissivity in the deeper aquifers is highly variable, but the storativity is consistently smaller. Tests on the conventional deep boreholes, which are cased through the regolith, are therefore indicative of bedrock productivity. The bedrock can be highly transmissive where these boreholes intercept significant, interconnected fractures (sites 1 and 3), and very high yields may be obtained. Where fractures are not encountered, the bedrock has very low transmissivity (sites 2, 4 and 5) and poorly productive boreholes result. There is a noticeable difference at site 1 between bedrock transmissivity at the existing borehole and at the exploratory borehole, further indicating the high spatial variability of this property.

The screened regolith boreholes (Table 4) are open in both shallow and deep aquifers, and the test results provide an aggregate of the transmissivity provided by both. At some sites, yields from the screened regolith boreholes drilled by the project as part of site exploration were higher than those of existing conventional deep boreholes. This is important, as it suggests that: a) siting deep conventional boreholes by shallow exploratory drilling in the regolith to identfy the greatest depth of saturated weathering may be a reasonable approach for helping to overcome the spatial variability found in the deeper aquifer; and b) boreholes in this region would generally be better if screened in the regolith rather than cased. A similar conclusion that greater and more economical use could be made of the regolith aquifer where sufficient saturated thickness exists was made for Malawi (Chilton and Smith-Carington, 1984).

5.8 PREDICTED LEVELS OF SUSTAINABLE ABSTRACTION

To compare performance of the alternative well types at each site, measured aquifer properties and well dimensions were input to the PTSIM program. This program uses the same mathematical model as PTFIT described earlier. The model was made to simulate a cycle of daily abstraction, pumping at 1.5 m^3/hour (an arbitrary but typical rate) for five hours in the morning (06:00 to 11:00) and for five hours in the afternoon (13:00 to 18:00) and repeated for 240 days, the average length of a dry season. As drawdown is proportional to pumping rate in PTSIM, the maximum abstraction rate was evaluated as the simulated rate (15 m^3/day) multiplied by the ratio of maximum available drawdown to simulated drawdown. Available drawdown was taken to be the inlet depth of the pump in the case of wells and two-thirds the depth of deep boreholes, a level of drawdown considered to give optimum abstraction for a borehole (Bromley, pers.comm.). Table 5 shows the results.

Table 5 *Maximum sustainable yield of wells tested at each site for a simulated dry period of 240 days*

	LDW		CW			TDW		CDB cased in regolith		SRB screened regolith		DEB cased in regolith	
Site	Q	CL	Q	CL	%imp	Q	CL	Q	CL	Q	CL	Q	CL
Romwe	10.2	3	10.8	3	6	1.6	2	-	-	-	-	-	-
1	11.5	4	18.0	4	56	-	-	200	2	43	2	35	2
2	16.7	4	17.1	4	2	-	-	NA		26	2	8	2
3	26.1	3	34.1	3	31	-	-	769	2	-	-	-	-
4	24.1	3	40.2	3	67	2.1	3	2	2	-	-	-	-
5	22.3	3	34.7	2	56	2.9	2	1.4	2	37	3	25	3
6	12.4	4	18.3	4	48	-	-	-	-	-	-	-	-
7	47.0	3	NA	NA	NA	-	-	-	-	407	2	347	2
8	55.3	4	62.5	4	13	-	-	-	-	31	2	<2	2

DEB = deep exploratory borehole (comparable to conventional deep borehole but sited by exploratory drilling)

At no site did a traditional well satisfy the target of 15 m^3 per day. This is due in part to the smaller diameter and shallow depth typical of this well type but may also be because the shallow well is dug into the less permeable, clay-rich part of the regolith weathering sequence. It must also be due in part to the method of siting employed. A communal farmer must site his well on his own land, ideally in a position convenient to house or garden. He may employ a diviner but he will still operate under these restrictions. In contrast, project wells were sited to serve the community with few restrictions on area and with the considerable benefit of exploratory drilling to locate preferred aquifer properties prior to digging. It is likely that a well of traditional diameter sited in this way would be better.

At six of nine sites, the large diameter well is shown to supply the required volume of water. This ratio improves to eight of nine sites with lateral drilling. Aquifer heterogeneity caused the success of lateral drilling to vary from site to site. At Romwe and Gokota improvement was minimal but at other sites it was significant, giving an average improvement on basement rock of 38 per cent. This improvement can be thought of in two ways. Radials can increase maximum sustainable yield for the period of a dry season, or radials can increase the period for which a particular abstraction rate can be sustained. At site 1 for example, the large-diameter well would sustain pumping at 11.5 m^3/day for 240 days. The collector well would last for 300 days. This has important implications for villagers trying to water their vegetables throughout a period of low recharge or an extended dry season, and care must be taken when placing a value on this additional water. Any increase in yield made possible by lateral drilling cannot simply be divided by the additional cost of this operation.

On basement rock, the yields of large diameter wells, collector wells and screened regolith boreholes sited by exploratory drilling, although lower than yields of conventional deep boreholes at some sites, are shown to be far more consistent and quite adequate for small-scale vegetable production. Sites 7 and 8, however, highlight the role that geology can play in well type selection. Unlike weathered basement, the shallow weathered zone of basalt is not marked. Instead, groundwater flow is concentrated in zones of horizontal sheet jointing, and these zones, both shallow and deep, can be highly transmissive (Table 4). Both large diameter wells and exploratory boreholes gave high yields but well digging was made particularly difficult by the compact layers of rock. Consequently, although either well type would suffice, a screened regolith borehole is preferable in basalt due to the far greater ease of construction.

Table 6 *Comparison of costs of providing 15 m^3 of water per day using different well designs*

Scheme type	Interest Rate (%)		Profit (%)	Cost (Z$)	ACC (Z$/$m^3$)
	Construction	Amortisation			
1 collector well & 2 handpumps	13	13	0	77107	2.57
2 conventional boreholes & 2 handpumps	13	13	0	98040	3.27
1 conventional borehole & motorpump	13	13	0	90857	3.03

Pumping capacity remains an important consideration. High yielding boreholes at sites 7 and 8 (and similarly at sites 1 and 3) unfortunately hold only one handpump and actual abstraction is far less than potential. In cases such as these, it may be cost effective to use a design of pump that allows two units to be mounted on the single borehole casing (eg. Vergnet foot pump as used in West Africa) or to drill a second borehole at the site of the first with the intention of intercepting the same productive network of fissures.

5.9 ECONOMIC VIABILITY OF EACH WELL DESIGN

A framework to analyse the capital costs of collector wells and boreholes has been developed. The example shown at Annex 3 is for a hypothetical programme to develop 25 schemes per year for 10 years. The wells would be implemented by an inter-disciplinary team using one set of drilling equipment and five sets of digging equipment simultaneously digging five wells per year. Costs shown assume steel well lining imported from South Africa. The example is for a non-commercial approach whereby Government itself undertakes construction, making no profit and writing off equipment and the schemes at the social discount rate of 13 per cent. This is the yardstick set by Government through the Agricultural Finance Corporation (AFC) for appraising projects aimed at benefiting the small-holder farming sector. It has the effect of reducing both the capital cost of the well and annual capital charge but involves a significant subsidy by Government. Table 6 summarises the results.

Costs for the collector well assume that labour for digging is provided free by the community. Experience has shown that not only does this save time and money (compared with employing wage labour) but it also enhances the community's sense of scheme ownership. Abstraction from the collector well is by two or more handpumps. Two boreholes holding single handpumps would be needed to yield the 15 m^3 of water per day required for domestic use and irrigation of 0.5 hectare. A single high yielding borehole ($>$0.6 l/s) with motorpump is an option but this type of scheme will have higher running costs and difficulties of repair that may prove to be beyond the means of poor rural communities.

It should be noted that drilling success rate is a critical factor when determining the true cost of borehole schemes. DWD statistics for the whole country and based on blowing yield measured at the time of drilling indicate a success rate of only 35 per cent for boreholes considered to yield greater than 0.6 l/s (Wright *et al*, 1989). Figures for southern Zimbabwe are similarly low. In three local programmes of borehole drilling undertaken by contractors on behalf of ODA (Bikita), the Red Cross, and a private sugarcane farmer, success rates of 54, 63 and 25 per cent and real costs of Z$57000, Z$53000 and Z$64000 per successful borehole were recorded respectively. Table 7 shows siting success rates measured by 5 hour pumping tests in a recent World Bank Drought Relief Programme in the seven districts of Masvingo Province.

Economic evaluation of well performance thus indicates that siting success rate is critical to the economic viability of boreholes in groundwater resource development in this region. Similarly, exploratory drilling is critical to the performance of collector wells, large diameter wells and screened regolith boreholes. When real costs of success are considered, the average capital cost per unit of water for boreholes and collector wells is shown to be very similar and those for large diameter wells and screened regolith boreholes where appropriate will be proportionately less due to reduced drilling and material costs.

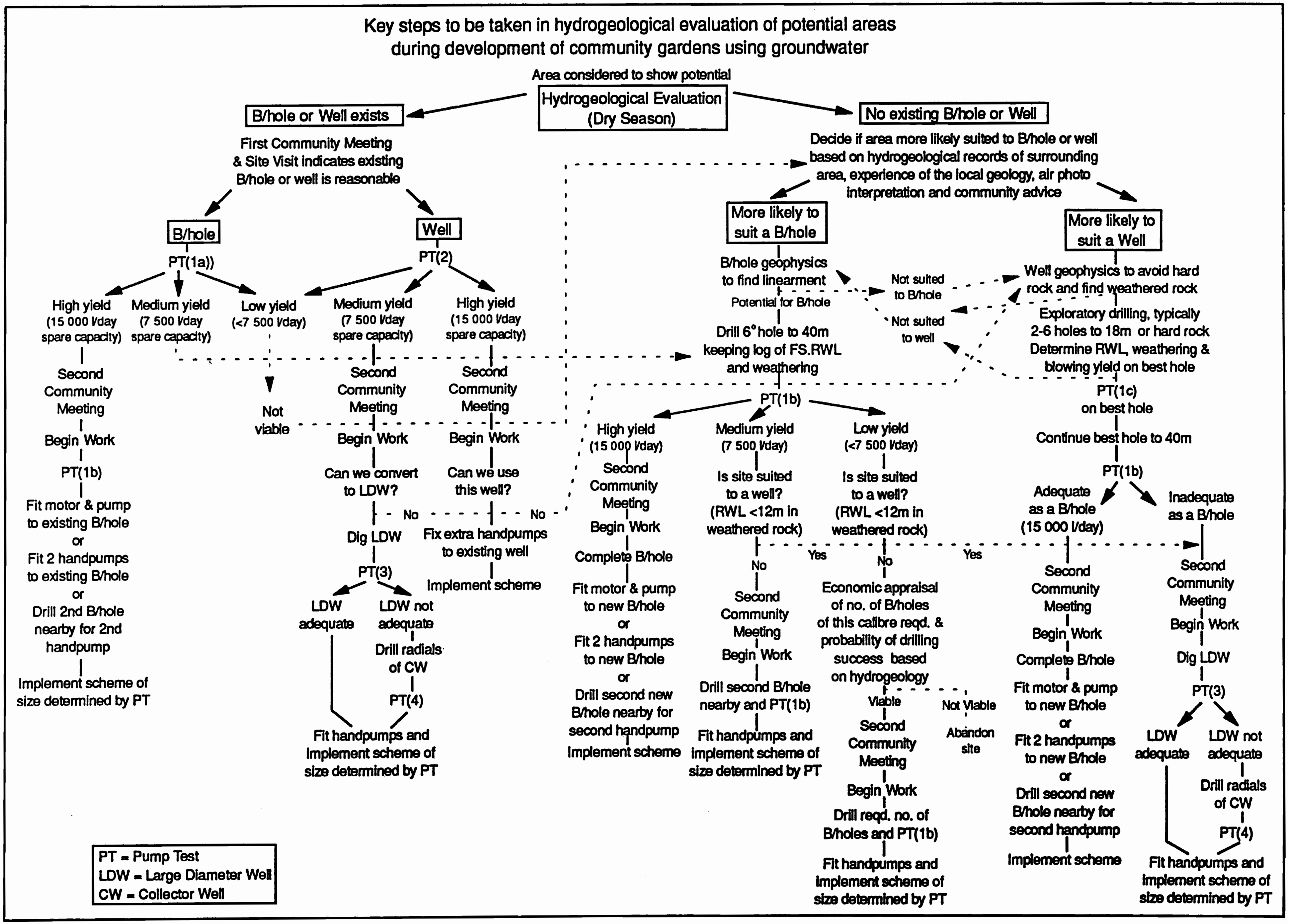


Figure 9 *Hydrogeological evaluation of potential areas during development of community gardens using groundwater*

Table 7 *Borehole siting success rates in Masvingo Province (min depth 45 m, average depth 64 m, max depth 121 m)*

District	Number of Boreholes	Percentage of Boreholes			
		Dry	0-0.3 l/s	0.3-0.6 l/s	>0.6 l/s
Chivi	12	26	33	33	8
Zaka	11	8	46	46	0
Chiredzi	12	33	25	33	9
Bikita	12	25	50	8	17
Gutu	40	14	33	13	40
Masvingo	50	0	34	28	38
Mwenezi	12	17	25	33	25

5.10 HYDROGEOLOGICAL DECISION SUPPORT

Both technical and economic evaluation thus indicate an important role for four well types in future development, namely: collector wells, large diameter wells, screened regolith boreholes and conventional deep boreholes. The challenge lies in quick and cost effective identification of the appropriate well type and location within a given area. Figure 9 presents a hydrogeological decision tree developed during the pilot project to assist with well type selection and siting. In a separate report (Thompson and Lovell,1995), practical examples using data from the pilot project are provided to illustrate how rapid exploratory drilling, simple pump testing of exploratory holes and existing water points, and limited geophysical surveys, can be used in conjunction with Figure 9 to determine appropriate well type and location within a given area.

While not yet answering all questions, Figure 9 provides a basis on which to build in the next phase of work. Certain aspects remain to be tested, for example: a) the potential of geophysics to reduce the number of exploratory holes needed to identify greatest depth of weathering; b) the viability of siting deep boreholes by prior exploratory drilling in the regolith, c) the viability of screened regolith boreholes, and d) the viability of drilling second boreholes next to existing water points presently underutilised due to limited pumping capacity. Monitoring both well and aquifer performance in all cases will be vital.

6 Social and Economic Viability of Collector Wells and Community Gardens

6.1 ASSESSMENT OF THE GARDENS

6.1.1 Garden performance to date

Monthly data collection on garden performance has been ongoing since completion of the first scheme at Romwe in 1991. As each new scheme has come into operation, garden committee secretaries elected by each community have kept routine data on inputs to and outputs from their gardens and have recorded information on cropping patterns, irrigation and water use, crop protection, fertilisation, crop yields and market prices. Monthly visits by project staff to collect these data have allowed observation of progress and the discussion with members and extension staff of issues arising as the schemes develop. Regular analysis of all data has provided detailed information on both the financial performance of each garden on a season by season basis and better understanding of the social dynamics of each community garden.

Table 8 presents a summary of gross margins recorded at all schemes since 1991. The figures were calculated using "garden gate" prices and include the imputed value of vegetables taken by members for home consumption. Some variability in economic performance is indicated from scheme to scheme and a few marked fluctuations in the performance of individual schemes have been observed from year to year, but generally returns recorded at all schemes are high and are increasing. The returns are, in fact, far higher than returns given by other land use options in this dry area. With an overall average gross margin per hectare per year of Z$55,700 per scheme, the figures indicate the excellent returns possible from small, intensively cultivated pieces of land when a reliable source of water can be made available.

Table 8 Indicators of garden performance recorded to date

Site	Gross Margin Z$/ha					Gross Margin Z$/member					Gross Margin Z$/labour day				
	1991	1992	1993	1994	1995	1991	1992	1993	1994	1995	1991	1992	1993	1994	1995
Romwe	658	45870	26298	18903	3946	14	249	204	378	12	0.67	2.85	6.12	5.77	0.67
Muzondidya			15628	27673	38804			62	100	140			3.51	4.52	5.30
Gokota				35348	85416				316	256				3.42	5.76
Dekeza				47459	62423				989	503				5.90	9.39
Nemauka				2221	66910				9	309				0.42	11.84
Mawadze				11183	52264				233	455				4.18	16.92
Matedze					162270					500					24.78
Average			20963	23798	67433			133	338	310			4.82	4.04	10.67

Of particular note are high figures recorded at Romwe during the drought of 1991/92, when all surface water sources failed in the region and all vegetables grown sold for high prices, and returns recorded at Gokota, Dekeza and Matedze during first seasons of operation which indicate that within many communities there exists the necessary qualities of leadership, experience of gardening and institutional structures to make community projects successful quickly if a primary constraint (in this case water shortage) can be removed.

In most cases, lower figures shown in Table 8 can be linked directly to the absence or temporary failure of good leadership at a scheme, and the corresponding increase in the number of problems that this causes particularly in those tasks undertaken as a group, namely pump repair, pest and disease control, and the establishment of nursery beds. An excellent account of these problems, and of the social dynamics so important within community-focussed projects, is provided by Mazhangara *et al* (1995) in the accompanying report on recent garden performance during the winter of 1995. Lower than anticipated returns from the Romwe Garden in the 1992/93 summer season and the 1993 winter season were a result of a plague of mice and a period of exceptionally low temperatures respectively.

6.1.2 Number of people involved in the gardens

The project baseline survey (Brown and Dube, 1994) predicted that the total populations which could be expected to join the collector well schemes would vary from approximately 50 members at Dekeza to 130 at Muzondidya and Gokota. The baseline survey also suggested that the performance of gardens with large and small memberships should be compared in terms of their output and the extent to which non-members would benefit. The social and economic circumstances of members and non-members in terms of their access to land, labour, capital, local leaders and agricultural extension were also to be compared to determine whether particular groups were favoured or excluded.

From the information gathered in the return-to-household survey (Waughray *et al* 1995), it is possible to estimate the total number of households directly involved with the pilot project schemes. Table 9 presents the estimated population of members' households directly involved with the pilot project at each site.

Table 9 *The estimated population of members' households directly involved with the pilot project.*

Site		Estimated population of members' Households	Confidence interval (95%)
No.	Name		
1	Muzondidya	1226	164
2	Gokota	840	169
3	Dekeza	373	133
4	Nemauka	765	142
5	Mawadze	458	65
6	Matedze	799	190

The estimated population of those households directly involved in the six pilot project schemes is 4 461 people *(se 206.04, ci at 99%: 409.49)*. In other words, it is 99% certain that the population of members' households served by the six schemes lies between 4 052 and 4 870 people.

6.1.3 Income generated from the gardens

The data on incomes generated from the collector well gardens that the return survey revealed for the 1994/95 season are presented in Table 10. Figure 10 presents these data graphically, showing the mean amount earned per month for each site. Overall, the mean income generated from the collector well gardens per member in 1994 can be estimated as Z$ 255.20 pa (se99.3; ci 248). This can be favourably compared to the average gross margin per member (the farm gate value of all vegetables grown in the garden) for 1994 of Z$338 (table 8). In general it can be said that between a third and a half of vegetables produced on the collector well gardens are consumed, and the remainder are sold.

Table 10 *Mean income per scheme for the collector well gardens (1994)*

	Muzondidya	Gokota	Dekeza	Nemauka	Mawadze	Matedze
Amount earned (Z$)	67	96	664	68	430	206
Period of selling (month)	2.8	3.7	7.5	2.4	5.2	6

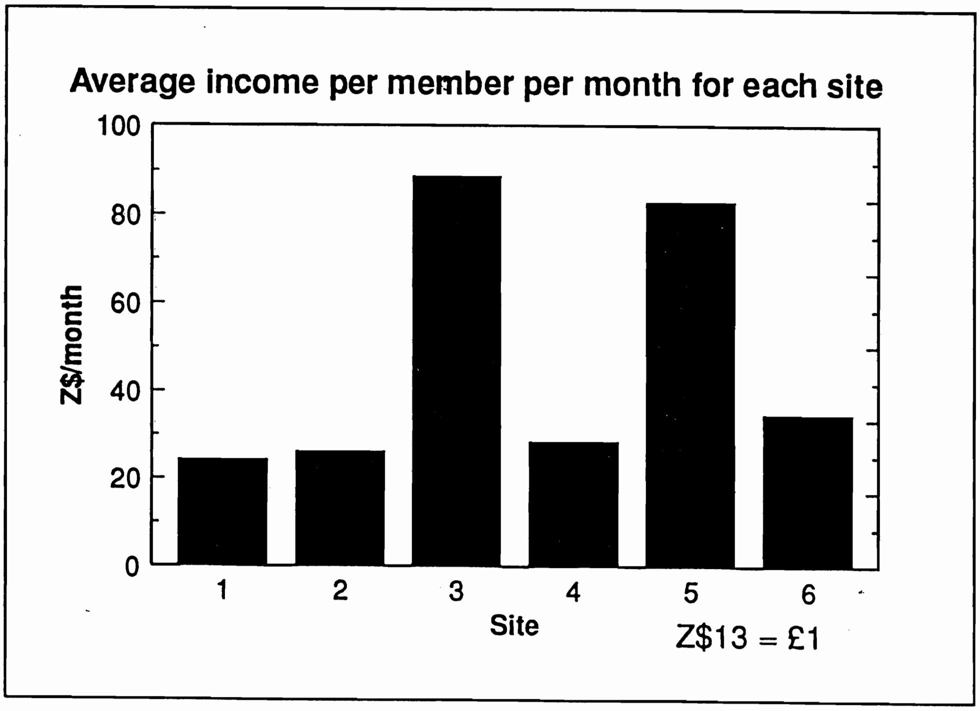


Figure 10 *Income per month per member from the collector well gardens (1994)*

Estimated income details for each site are:

At site 1, members earned on average (ie a net cash surplus on top of vegetables consumed and inputs purchased) Z$ 67.20 *(se7.7; ci20.79)* over a maximum period of 2.8 months selling. Customers mostly came to the garden on an informal basis.

At site 2, members earned on average Z$ 96.00 *(se32; ci86.4)* over a maximum period of 3.7 months selling. Customers mostly came to the garden on an informal basis.

At site 3, members earned on average Z$ 664.00 *(se242; ci653)* over a maximum period of 7.5 months selling. At this site members were active in finding markets for their produce, walking with dishes of vegetables for sale up to a 8km radius. "Block" purchases of vegetables (securing an assured Z$30 /day) also occured with agents coming from Chiredzi and Jerera. A nearby school and small township also supply a ready market for the site's vegetables. A second crop (tomatoes) was grown in this season. It can be assumed that the members of site 3 have both sought and responded to the market potential for vegetables in the location. With effective marketing strategies and exploitation of location, site 3 may offer an example of the financial potential of the collector well gardens.

At site 4, members earned on average Z$68.00 *(se 14.9; ci 40.4)*, over a maximum period of 2.4 months of selling. Customers mostly came to the garden on an informal basis.

At site 5, members earned on average Z$430.00 *(se 97; ci 261)* over a maximum period of 5.2 months selling. Again, all members sampled were supplying agents with block purchases and were harvesting two crops / season.

At site 6, members earned on average Z$ 206.60 (se59; ci 159) over a maximum 6 months. 60% of members sampled were supplying agents with block purchases and were harvesting two crops / season.

From an analysis of both the data and site specific information on income levels generated by the schemes, it seems that the size of garden membership (the smaller the better) and the length of time attached to both working in the garden and actively marketing its produce (the longer the better) can significantly improve net returns to effort (Waughray *et al* 1995). However, the schemes are only two seasons old and there may be many other important variables which may emerge that can be shown to significantly influence income levels generated by the garden. For example, leadership, marketing strategies, pest control, other extension advice, effectiveness of collective action, and locational aspects, may all be critical factors. As a better record is built up over several seasons about good and bad years in the gardens, more sophisticated analyses can be carried out to ascertain the most significant variables that influence high income levels from the garden per member. Disseminating this kind of information should substantially improve the performance of ongoing and future schemes, as and when they are implemented.

6.2 ASSESSMENT OF THE WELLS

The baseline survey identified water as the principal problem reported by respondents at all sites. At Mawadze the priority was for a cleaner and more reliable source of domestic water and closer gardens. At the other sites there was a need to grow more vegetables both for home consumption and for sale since current production was constrained by shortages of by shortages of water, most acute at Matedze. Secondary needs were for more reliable sources of domestic water at Muzondidya and cleaner water at Dekeza and Nemauka

6.2.1 Improved water supply

Information gathered in the return to household survey has allowed estimates of the number of people who are obtaining their domestic water requirements from the collector wells to be calculated. Figure 11 presents these estimates for each site. In total, an estimated 489 households, or 3 882 people, obtain their domestic water requirements from the collector wells. This figure can be split between an estimated 238 member households and an estimated 251 non-member households.

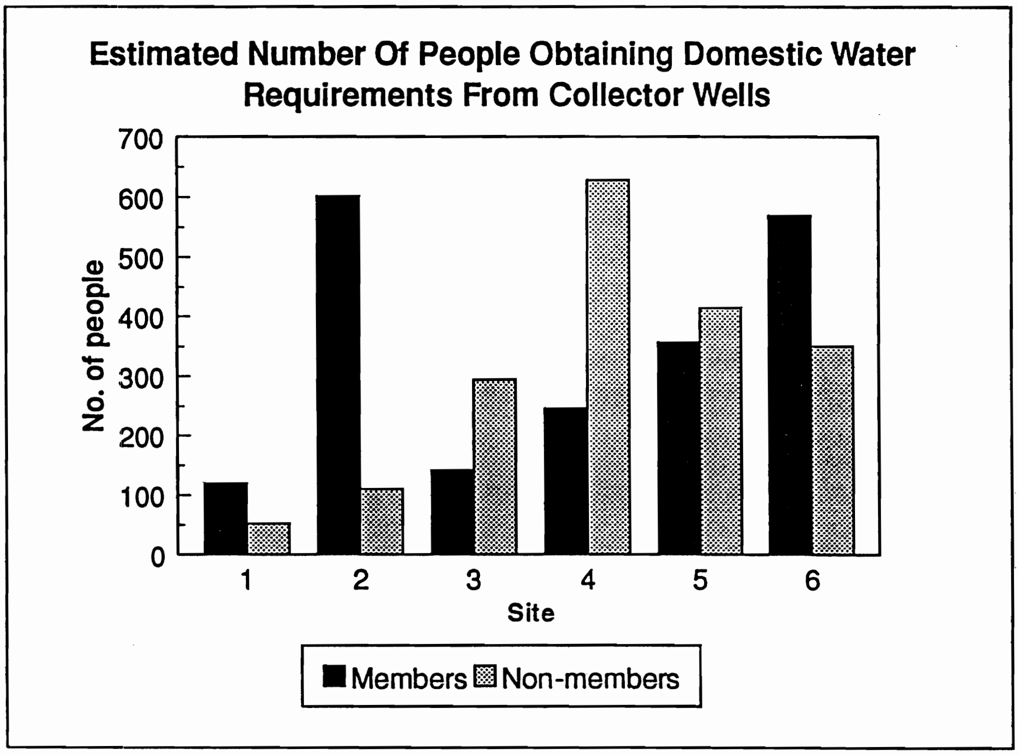


Figure 11 *Estimated number of people obtaining their domestic water requirements from the collector wells*

From the return survey sample 50% of members said they obtained their domestic water from the collector well. 49% of members said they obtained their domestic water from a borehole, hand dug well, river or another water source. Of the 50% who use the collector well , 22% said it saved them on average 56 mins/day. The average distance travelled to the collector well by members to collect domestic water was said to be 1055m *(min 100 max 3000, sd 293.2)*. The average distance travelled by members to a borehole, hand dug well, river or other water source to collect domestic water was said to be 463m *(min 0 max 1500, sd 151.4)*.

From the return survey sample 39% of non-members said they obtained their domestic water from the collector well, and 61% said they obtained their domestic water from a borehole, hand-dug well, river or another source. Of the 39%, who use the collector well, 12% said it saved them on average 42 mins/day. The average distance travelled to the collector well by non-members to collect domestic water was said to be 1515m (min 100 max 3500, sd 862.2). The average distance travelled to a borehole, hand-dug well, river or another water source by non-members was said to be 603m *(min 0 max 3500, sd 298.9)*

A further 22% of respondents, on average, said they also use the collector well for domestic water when their nearest other water source fails. This figure varies significantly between sites (54% at Muzondidya down to 3% at Matedze). Further information on the seasonal "surges" in collector well use is provided by Waughray *et al* (1995). The fact that in times of water scarcity the collector wells experience "surges" of use by non-members who would otherwise not use them, is testament to the reliability of these wells as a source of water. The value people attach to the collector wells for their reliability can be seen in the greater distances women choose to walk to the source in the knowlege that it will be working. Respondents in the return survey stated that one of the key benefits of the collector wells is their reliability. Furthermore, a high economic value for the wells, including their reliability, was elicited using direct valuation techniques (Waughray *et al* 1995).

It is apparent however that during periods of water scarcity, and as livestock numbers recover, garden committees at the pilot project sites are becoming increasingly concerned about the open access nature of these wells as a source of water for all. It has already been known for disincentive flat rate charges to be set to deter people from using the wells for domestic water, and for people who come from far away to be turned away. As pressure on the wells increases the need for definition of property rights to use this water resource will grow. Careful research will be needed to see how, if at all, user rights can be defined for the well water if these problems are not to escalate during water scarce periods.

Socio-economic surveys undertaken during the pilot project have also allowed general patterns of domestic water consumption to be monitored. The mean amount of domestic water utilised per day for the sample of members households is 110 litres/day *(range 50-300, sd 17.4)*. With an average size of 8.62 people per household (sd 0.71), this equals approximately 13 litres per person per day. The mean amount of domestic water utilised per day for the sample of non-members households is 97 litres/ day *(range 40-300, sd 16.8)*. With an average size of 7.28 people per household (sd 0.69), this also works out at approximately 13 litres per person per day. A graphical representation of mean daily domestic water consumption per person at each site is given in Figure 12.

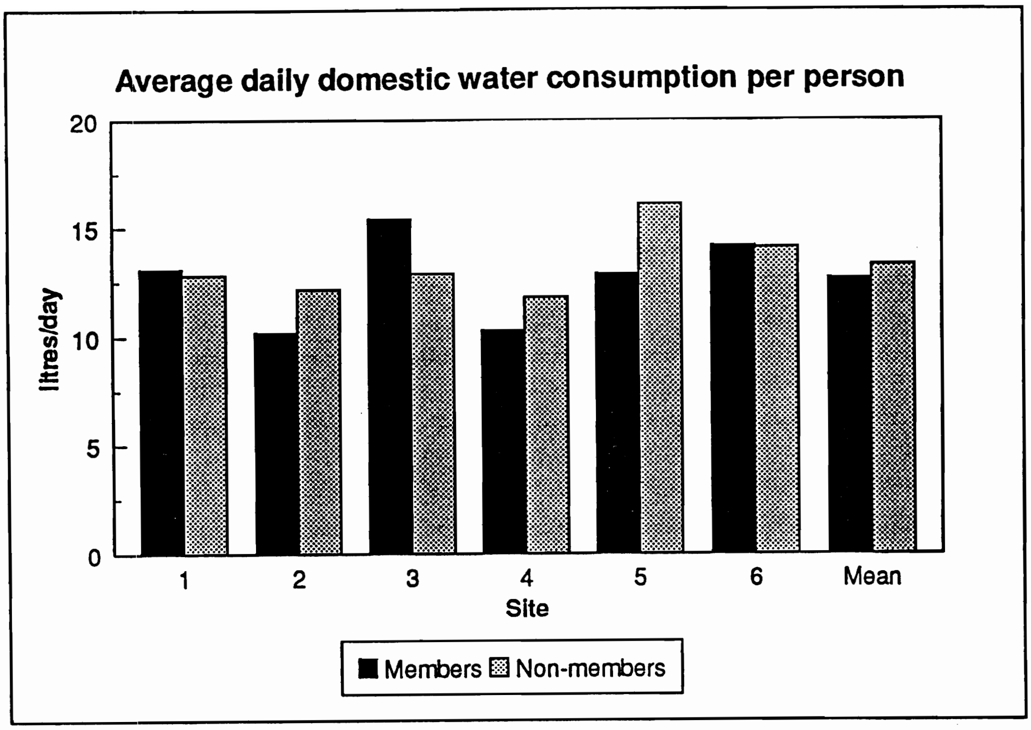


Figure 12 *Average daily domestic water consumption per person per site (return survey)*

Domestic water consumed per household at each site before and after the collector well pilot project ranges from 12-17 litres per person per day before to 10-14 litres per person per day after for members and 11-16 litres per person per day for non-members. The difference between members and non-members is not significant. However, what is important is that there has not been a significant *increase* in domestic water utilisation per household as a result of the collector wells. Analysis of the data (Waughray *et al* 1995) suggests that instead of giving the same number of people more water, the schemes are (i) supplying cleaner and more reliable water; and (ii) serving more people than anticipated, particularly during periods of water scarcity.

6.2.2 Meeting the particular water needs of each site

The baseline survey noted that it was important to identify site specific impacts of the collector wells on different community needs for improved water supply. Routine monitoring and return to households surveys have identified the specific changes in water supply at each site.

At Mawadze (where the greatest need was for clean and reliable water sources): Members said that the first-best benefit of the scheme is in fact the opportunity to grow fresh vegetables to eat and confirmed the second-best benefit of the scheme is the provision of a more reliable water supply. Non-members said the first-best benefit of the scheme is a reliable water supply. However, 36% of non-members at Mawadze still identify water shortages as a problem in the area.

At Matedze (where the greatest need was for water to grow vegetables): Members confirmed that the first-best benefit of the scheme is the opportunity to grow fresh vegetables to eat, the second-best being the opportunity to grow fresh vegetables to sell. Non-members said the first and second best benefits are a more reliable and cleaner source of water respectively; the third best being the opportunity to buy fresh vegetables.

At Muzondidya and Gokota (where secondary needs were for more reliable sources of domestic water): Members at Muzondidya said that growing vegetables is the first-best benefit and the second best is the provision of more reliable domestic water. Non-members said that the opportunity to buy fresh vegetables is the first-best benefit, provision of clean water the second best and access to more reliable water the third best. At Gokota members said that growing vegetables is the first-best benefit and provision of clean water is second best. Non-members said that the opportunity to buy fresh vegetables is the first-best benefit and the second and third-best benefits are reliable and cleaner water supplies respectively.

At Dekeza and Nemauka (where secondary needs were for cleaner water): At Dekeza members said that the first-best benefit is vegetables to eat, the second best is vegetables to sell and the third best is reliable domestic water. Non-members said that the opportunity to buy fresh vegetables is the first-best benefit and more reliable, nearer and cleaner water are the second, third and fourth best benefits respectively. At Nemauka members said that, after growing vegetables, provision of closer domestic water is the second-best benefit. Non-members said that the first-best benefit is the opportunity to buy fresh vegetables, the second best is the opportunity to meet and talk and the third best is the provision of cleaner water.

Overall it seems that the range of benefits the schemes supply have adequately met the competing demands for a range of community issues at each site

6.3 ASSESSMENT OF THE BROADER IMPACTS ON STAKEHOLDER WELFARE AND INSTITUTIONS

The wide range of impacts the pilot project has had on the welfare of the communities and on local institutions has been assessed through analysis of data elicited in the baseline, case study and return-to-household surveys undertaken during the project. Full presentations of results of the baseline, case study and return to household surveys can be found in Brown and Dube (1994), Murata, Semple and Dube (1994) and Waughray *et al* (1995) respectively. The following paragraphs summarise the main findings of these surveys.

6.3.1 Frequency of vegetable consumption

In essence it seems that the collector well gardens have:

- reduced the period of scarcity of fresh vegetables that communities in the area face by up to four or five months

- lowered the number of people who suffer a period of fresh vegetable scarcity by about 25%, and

- decreased the time during scarce periods that people miss out on eating fresh vegetables by about four days in every week.

Figure 13 illustrates these results graphically.

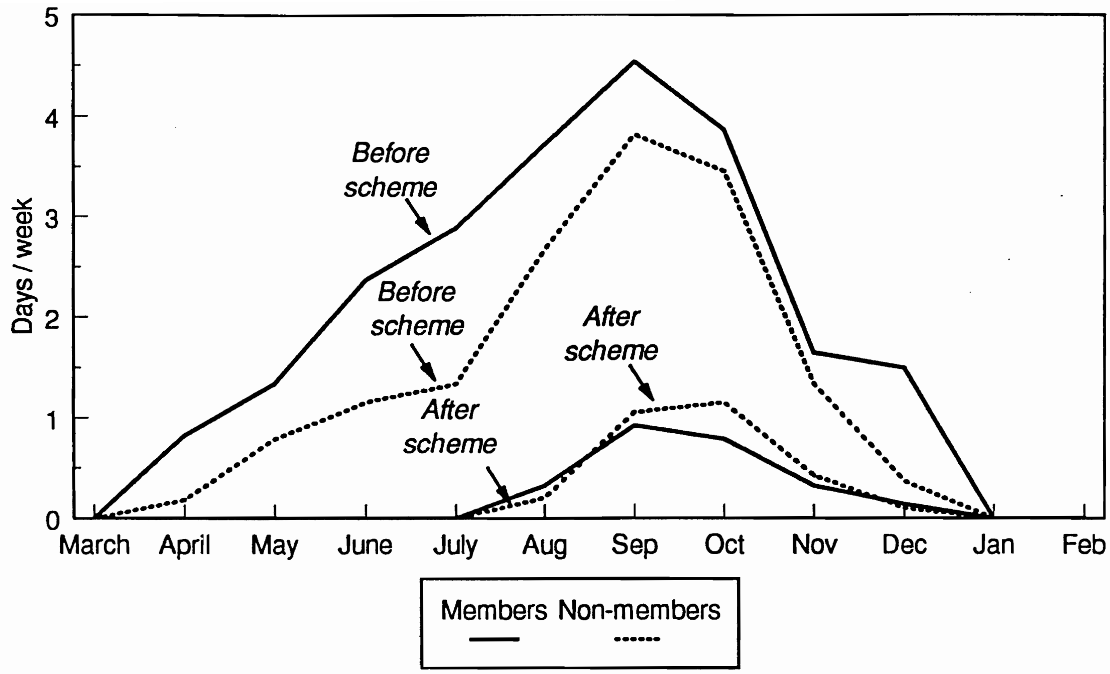


Figure 13 *Fresh vegetable "non-consumption" before and after scheme implementation*

Building on the baseline survey, the return survey asked respondents in more detail about the periods of scarcity for fresh vegetables they faced *before* the scheme was implemented. 72% of members surveyed identified a period of scarcity for fresh vegetables lasting ten months at its widest (April - January) and four months at its peak (September - December). During this period fresh vegetable consumption was said to be, on average, 1.85 days/ week. At peak scarcity fresh vegetable consumption dropped to less than one day per week. For non-members, 91% identified a period of scarcity before the collector well scheme. The period of fresh vegetable scarcity was spread at its widest for ten months (April - January), peaking for four months (September - December). During this period fresh vegetable consumption was said to be, on average, 2.4 days/ week. At peak scarcity fresh vegetable consumption dropped to just over one day per week. These observations support the information obtained in the baseline survey, but provide more detail about the length and severity of fresh vegetable scarcity during the dry season.

The return survey then asked respondents in detail about the periods of scarcity for fresh vegetables they face *now* that the collector well gardens have been implemented. When asked about periods of scarcity for fresh vegetables now, a smaller number, 47%, of members identified a period lasting five months at its widest (August- December), and three months at its peak (September - November). During this period fresh vegetable consumption is said to be, on average, 5.8 days/ week. At peak scarcity now, fresh vegetable consumption is thought to drop to about 5 days a week. For non-members, 68% still identified a period of scarcity now. At its widest the period is spread for five months (September - November), and at its peak it is said to lasts for three months (September - November). During this period fresh vegetable consumption is said to be, on average, 5 days/ week. At peak scarcity now, fresh vegetable consumption is thought to drop to about 4.5 days per week.

6.3.2 Changes in expenditure on fresh vegetables

Average grocery bills per month are generally higher for members than for non-members, reflecting perhaps the improved levels of disposable income the schemes have generated for members. Changes within the grocery bill for amount spent on fresh vegetables each month are of interest. In general these have declined for members but have risen substantially for non-members (Figure 14). This may be a reflection of there being more fresh vegetables in the region that non-members choose to purchase, or that non-members are choosing to divert disposable income away from other items of expenditure in order to buy more vegetables. Either way, it is a good indication that the collector well schemes have boosted the market for vegetable trading in the region, and are meeting a demand by non-member communities for fresh vegetables during the dry months. Although reported for the Romwe Garden previously, there is no indication of non-members working in the newer gardens for payment in vegetables. More emphasis appears to be placed on the cash/bartering transactions.

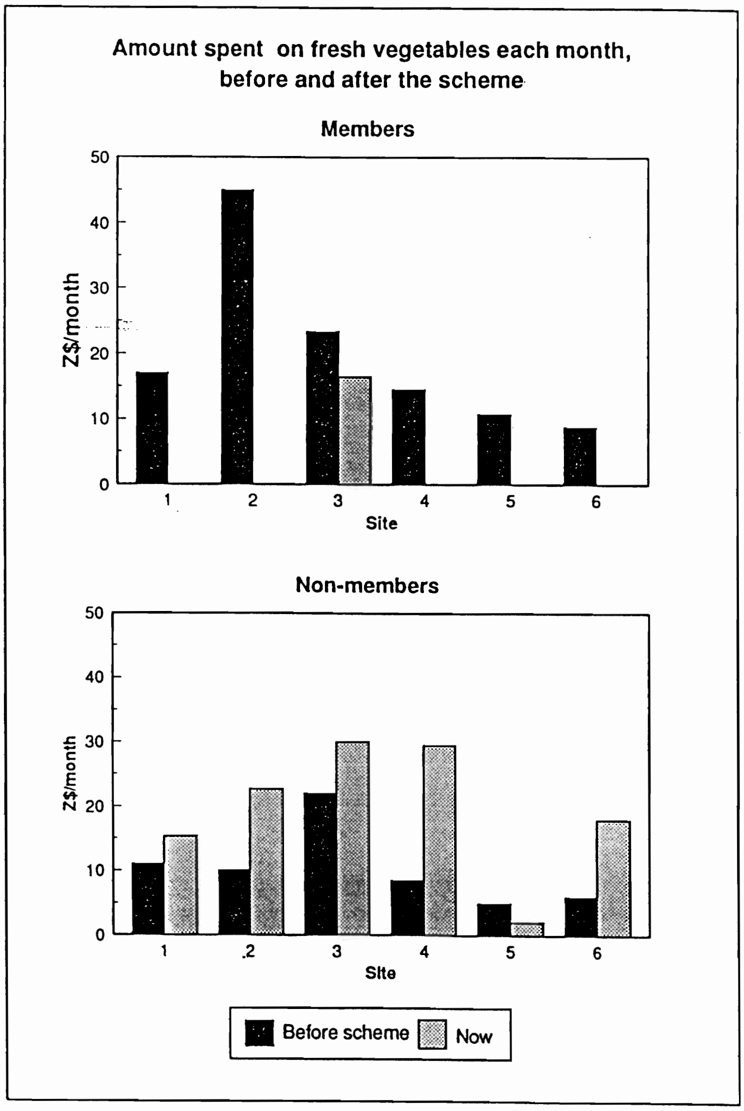


Figure 14 *Amount spent on fresh vegetables*

6.3.3 Changes in wealth

The baseline survey identified differences in wealth between and within sites as revealed by indicators such as ownership of livestock, implements and modern housing, areas of rainfed crops and gross incomes earned from them. On all of these criteria, except housing, Mawadze appeared to be the wealthiest and also, together with Nemauka, had the most equal distribution of incomes from rainfed cropping and land.

Estimating from the baseline sample about who, from a surveyed community in an appropriate hydrogeological location, would join a collector well and community garden scheme, 10% are likely to be "wealthy" *(se 0.034; ci 6.7%)*, 42% are likely to be "averagely" well off *(se 0.057; ci 11.4%)* and 49% are likely to be "less wealthy" *(se 0.058; ci 11.6%)*. Although the project schemes have been operating for a very short time, the return survey found indications of improvement in wealth for scheme members. This is apparent at all sites regardless of the initial wealth status of the members. The estimated number of households who have improved in wealth since joining a pilot project scheme is shown in Table 11 below. Further improvements in wealth in the future may be likely as garden members improve their crop husbandry and marketing strategies. However, although an improvement in observable wealth is encouraging, it is more desirable to test for actual changes in income levels as mentioned above.

Table 11 *Estimate of the number of households at each site who improved in wealth since joining a pilot project scheme*

Site No.	Name	Estimated No. Of Households	Confidence intervals
1	Muzondidya	36	(se 15.8, ci 34.1)
2	Gokota	69	(se 16.7, ci 36.7)
3	Dekeza	36	(se 7.1, ci 15.6)
4	Nemauka	49	(se 12.4, ci 27.8)
5	Mawadze	31	(se 7.0, ci 15.3)
6	Matedze	40	(se 13.7, ci 30.1)

From these sets of comparative data it can be estimated that with an average membership of 85 members per scheme *(se 19.76; ci 38.82)*, 51 households are likely to improve in wealth by observation *(se 0.060 ci 10)*.

6.3.4 Availability of labour and selection of members

The baseline survey noted that the criteria for selection of garden members would need to be referred to since different methods were favoured at different sites, ranging from payment of a joining fee to selection of members by village leaders. It also suggested that the availability of labour depended on the numbers of male family members who are absent (varying from 57% at Gokota to 35% at Muzondidya) and the extent to which hired labour was used. The main labour peaks were found to arise from the demands of rainfed cropping.

The return survey found that a number of different approaches had been chosen by communities or community leaders when selecting garden members. These included payment of a joining fee and provision of labour during scheme implementation as an alternative to a joining fee. Although there were disadvantages and advantages in each system in terms of equity and garden performance, it is still too early to say which method or methods were most appropriate.

In general, 67% of all members across the six sites joined the schemes through a mixture of contributing labour for the well and garden construction and paying a reduced joining fee. 32% paid a joining fee alone. The mean payment to join a scheme was Z$22, and the number of people still wanting to join a scheme ranges from 10-22 people per site, the mean number being 16 per scheme.

The method of supplying labour to join a scheme has an advantage in that it promotes a sense of ownership. However it has to be recognised that availability of labour is a dynamic variable. Labour availability is greatest during the winter and at its most scarce during the summer as people are busy preparing their rainfed fields. Supporting the baseline survey these findings suggest that the timing of project construction within the farming calandar is critical for obtaining male labour and thus encouraging membership in this manner. There is also a danger by this approach that households with less spare male labour will miss out on becoming members. If these households are poor, then they will not have funds either to pay a cash joining fee or to hire labour.

At Mawadze and at Muzondidya, it is interesting to note that most people who joined the scheme did not have another garden; and most people that declined to join did. This may have been due to the fact that they did not have labour available to manage two gardens, that they were put off by the joining fee, or that they were quite satisfied with their existing gardens. At Matedze (site 6), the vast majority (92%) of people who were not able to join said that this was due to lack of room in the garden. Great demand for vegetables exists at Matedze as indicated by the fact that non-members increased spending on fresh vegetables from Z$6 to Z$18 per month since garden inception.

It is clear that the issue of joining and expanding membership of the schemes to ensure a fair chance for all households in the community is a complex one. Perhaps there is potential in investigating the possibility of allocating spaces in the garden in an auction system, with some kind of equity constraint. Or, of the construction of a mortgage system for the poorest or those with no male labour available to allow the members to pay back a joining fee over time with the aim of eventually buying the plot from the committee. However, this issue will need careful thought and inputs from both communities and project staff as existing schemes develop and new schemes begin.

6.3.5 Experience of community-focused schemes

The baseline survey identified variations both between and within communities on the extent to which people had participated in or had knowledge of previous community development schemes and the lessons which have been learnt from them. Mawadze had the greatest such experience, encompassing both community gardening and a host of other schemes.

Experience from the project, and information gained in the return survey, shows that implementing community-based development initiatives is not easy at all. This is primarily because decision making is slow and often disrupted by leadership and ownership disputes.

Whether these disputes can be overcome depends on whether the potential benefits of the development are sufficient to ensure that the community maintain interest in the development during a dispute and to ensure that the community has sufficient incentive to overcome a dispute. Although it is still too soon to be sure, there is some indication that previous community development experience is a key factor in determining the success of subsequent community developments. This experience can be considered as adding to the "social capital" of the community, enabling future participative schemes to be more easily implemented. The performance of the Mawadze scheme supports this argument. However, a recent leadership dispute at Mawadze has demonstrated that even schemes with plenty of community development experience can still have serious leadership disputes.

6.3.6 Importance of local leaders

The baseline survey found that in general traditional leaders (kraalheads and headmen) were regarded as slightly less important in project communities than representatives of the more modern institutions such as councillors, VIDCO Chairmen or agricultural extension workers. However this trend did vary from site to site. Experience during the pilot project has confirmed that the agricultural extension worker is often seen as the most important person within the community when it comes to implementation of this type of scheme. As an outside person largely independent of local community structures but living within the community, Agricultural Extension Workers are the best persons and are ideally placed to play the critical facilitatory role during disputes and leadership problems that can and do arise as kraalheads, VIDCO Chairmen, councillors or other individuals sometimes try to increase their own power by taking a leading role with respect to the new community project.

In the return survey 60% of respondents said that the most important person in the community was the agricultural extension worker (29% said the kraalhead and 11% said both). However, 77% of respondents suggested that in order to notify project staff about a community's desire for a *future* collector well and garden scheme, the community's request should be passsed to the local councillor via the traditional kraalhead or headman. Only 23% suggested that the agricultural extension worker should play the middleman. The reasons given for this apparent contradiction were that the agricultural extension worker may take too long, or that he might end up implementing the wrong sort of scheme. This kind of feedback should not be seen entirely as a criticism of the agricultural extension worker. Instead, it may suggest that the collector well and garden schemes are perceived by the community to be not just about irrigation and gardening, but also to do with the provision of a wider range of social benefits, such as a reliable water supply and a focal point for meeting and chatting. Alternatively this anomaly may simply be due to respondent bias. The relative importance of community leaders may have been chosen on the basis of the question being perceived to relate to agricultural or institutional issues. Thus, leadership issues at every site will be different and cannot be generalised. All leaders at any site must therefore be identified and worked with.

6.3.7 Gender Issues

The baseline survey found that women supplied most of the labour for all existing gardens as well as management where these were privately owned. However women tended to be less involved in the management of existing community gardens (at Dekeza and Mawadze) where men and the agricultural extension workers assumed the major roles. The baseline survey determined that the net effects of the new project schemes on women would depend on the balance between extra work, which the schemes would demand, the distribution of the benefits, and any opportunity cost in terms of other activities which would have to be compromised such as rainfed cropping or off-farm activities.

The return survey found that 80% of the sample said that the main decision maker and most labour for the new community garden came from women or wives of the head of household, with the help of children. At Dekeza, site 3, where there was a low percentage of households headed by women, 62% of the garden plots were said to have a female decision maker. At Mawadze, site 5, where the available labour force, and female labour in particular were lowest, 40% of the collector well garden plots had a female decision maker and the rest were managed through joint decisions.

Nevertheless, availability of labour is still seen as a constraint at all schemes. Watering, pumping and queuing all take time. As yet, the time spent working in the garden during winter is not considered to compromise any other tasks. However, it is possible that, as the gardens become more successful, the decreasing opportunity cost of gardening during the summer months as compared to working in rainfed fields will be seen as justification for the growing of more vegetables over longer periods. Evidence for this can be seen at Dekeza and Mawadze, where women are already extending their working season in the gardens.

Evidence from the rapid increase in revolving funds would also suggest that the gardens are benefiting women and children and that women are controlling the saving and investment of cash generated from schemes. From a relatively small sample of collector well scheme members (n=30) it is clear from the return survey that there are at least 15 revolving funds operating within the 6 schemes. Membership of these funds ranges from 3 to 40; amounts invested per month from Z$5 to Z$120. Table 12 shows the 15 revolving funds identified, the number of members they involve and the total amount saved each month as a result.

Table 12 Revolving Funds Operating in the Collector Well Gardens

No. of members in fund	Amount saved/month/member (Z$)	Total saved/month/fund (Z$)
40	5	200
33	20	660
32	30	960
25	10	250
24	20	480
20	10	200
20	10	200
10	20	200
10	20	200
10	40	400
8	50	400
7	20	140
6	30	180
6	25	150
3	120	360

Total no. funds: 15
Total no. members involved: 254
Total saved each month: Z$ 4 980

At least 49% of all members of the gardens were found to be involved in these funds, with the total amount being saved each month being at least Z$4 980. From the sample surveyed, only one fund was said to have existed before the collector well gardens and that has now expanded from 10 to 33 members. The main items of expenditure during members' "turns" to use the funds are said to be school fees, kitchen utensils / pots/ pans, savings for emergencies and safe keeping, and the purchase of materials for other income generating activites such as knitting and mat making. As the community garden schemes progress it will be interesting to note both the development of the revolving funds themselves and the subsequent increase or otherwise in the range of income generating activities for women based on the capital purchases derived from these funds. Furthermore, the increase in community-based and women-focused savings groups that has resulted from the collector well gardens adds more weight to the suggestion from communities that the experience of collective action and involvement in the collector well garden aids the implementation of further community-focused projects and sustainable income generating initiatives.

6.3.8 Priorities for extension advice and assistance

The baseline survey suggested that the priorities for extension advice for the community gardens should include pest and disease control, pump repair and maintenance, the need to raise money to purchase inputs, and water saving irrigation methods.

The return survey suported some of the baseline observations. Pest control, for example, *is* seen as a problem at all schemes. Also, methods of irrigation that reduce the time taken to complete the irrigation are seen as more important than saving water itself, although for the present systems of irrigation, water-efficient irrigation would equate to time-efficient irrigation. Advice and training in methods of open book-keeping are needed as there have been problems on some sites. Although strategies that take better account of market demand are evolving naturally, advice would be useful. It seems that advice on raising funds to provide inputs is not required as money is generally used from the garden 'joining fees' initially and thereafter from the sale of vegetables.

The baseline survey noted that the three most frequently recalled extension messages all related to rainfed cropping. Very little advice seemed to have been absorbed by communities on the subject of vegetable cultivation and no mention was made of irrigation. However, in the return survey, respondents said that they *had* now received advice from the agricultural extension worker to help with the community garden, mostly on irrigation amounts and schedules for vegetables, growing vegetables in time to sell and on planting arrangements in the garden. Non-members also said they had received more advice on vegetable growing with less emphasis however on growing vegetables in time to sell. But, similar to the baseline survey, the most commonly cited pieces of extension advice both sets of respondents recalled were still to do with rainfed farming - contour ridges, winter ploughing and drainage ditches. In general, non-members of the garden schemes suggested that they got more advice from their family than from the agricultural extension worker, as compared to members.

6.4 ANTICIPATED BENEFITS AND COSTS OF REPLICATION OF SCHEMES ON A WIDER SCALE

The social and economic analyses undertaken during the pilot project have identified the wide portfolio of benefits that the collector well and garden schemes can provide to communities. Some of these have been mentioned above. As a part of the pilot project, a draft large scale development proposal to implement one hundred community gardens over a period of four years has been prepared. Details of this proposal, entitled NGADI (Nutrition Gardens And Groundwater Development In Zimbabwe) are held by the National Coordination Unit of Zimbabwe and ODA. This section aims to present an outline of some of the potential economic benefits and costs of this proposal, and of replication of the pilot project on a wider scale in general.

6.4.1 Number of people the schemes could reach

Based on the experiences of the pilot project it can be estimated that 41% of a sample population in a hydrogeologically appropriate area would join a collector well and garden scheme. Based upon population estimates for the pilot project area, it can be estimated that between 67 533 and 81 167 people would be in households that would have a member in one of the proposed one hundred community gardens, and would thus have direct access to fresh vegetables. Again, based on the data obtained in the pilot project, a suite of one hundred collector wells could be expected to supply the domestic water requirements for 8150 households, or 64700 people, including both members and non-members of the gardens. Experience with the pilot project would suggest that this number would rise during periods of water scarcity.

The nutritional and health improvements to the population as a result of the improved supply of fresh vegetables and clean, reliable water sources as well as the economic benefits in terms of improved labour productivity and decreased pressure on health sector resources have yet to be quantified. Aggregated over the potential user community for each scheme, and discounted over a twenty year period, the economic benenfit of this "health" value may be expected to be quite significant (PlanAfric, 1994).

6.4.2 Income generation opportunities

Similarly, with an estimated 8 600 members across 100 schemes, obtaining an estimated average income from the gardens of Z$255 per annum, it can be expected that rural incomes would receive a significant boost. Coupled with the evidence of the blossoming of savings clubs and revolving funds among the women which seems to accompany the development of these gardens, the income generating and savings potential of replicating the project on a larger scale is significant.

6.4.3 Environmental benefits

As well as direct environmental benefits such as improved and more reliable water supplies and more fresh vegetables in the diets of the communties, there are a range of less direct but equally significant environmental benefits that large scale replication of the pilot project could promote. A decrease in pressure on households to cultivate increasingly marginal lands in order to make ends meet, and a reduction in the need to cut down bushes for building private vegetable garden fences could significantly reduce rates of soil erosion and land degradation.

Furthermore, by building on the communities' experiences of successful collective action and the benefits of their community gardens, the project can promote a participatory approach and help to develop and implement an integrated environmental management plan at each site and for each small catchment considered. Such community-focused activities can improve natural resource management in the long term whilst simultaneously generating and diversifying incomes for individual households. The ability to meet competing demands and supply such a wide portfolio of benefits means the proposed project can play an important role in tangible sustainable development strategies for semi-arid areas such as Zimbabwe.

6.4.4 Towards a total economic valuation of a collector well scheme

Attempts have been made to quantify some of the wide range of non-market benefits that the pilot project schemes have supplied. For example, the return survey undertook a valuation exercise to quantify the environmental benefits of a reliable and clean water supply and of a safe, secure and well watered plot on which to cultivate vegetables, two of the benefits that people have identified as the most important.

The mean willingness to pay (WTP) for maintenance of a collector well for both members and non-members was Z$6.25 per month. 75% of respondents would pay Z$5 or less per month. Cross tabulations of bids by wealth and distance confirmed the stability of the figure elicited. People better off were WTP more (although the very poorest attached a higher value to the collector well than others) and respondents 500m or further away from the collector well were WTP more than those living nearby to ensure the functioning of the water source. Aggregated over a mean population of a collector well catchment, and assuming a 20 year project life with 13% discount rate, the aggregate net present value of welfare benefit that the collector well brings to the community as a water source is Z$129 501 or £9 960 per well (Z$13 = £1).

Mean WTP to join a collector well garden was Z$168.70 (sd93.9) as a one off payment. 60% of the sample were WTP between Z$150 and Z$300. Cross tabulations of bids by wealth and distance confirmed the stability of the figure elicited. People better off were WTP more, and the distance that respondents lived away from the collector well garden did not affect the perceived welfare benefits the garden supplies. Aggregated over a mean population of a collector well catchment, and assuming a 20 year project life with a 13% discount rate, the aggregate net present value of welfare benefit that a collector well garden provides is Z$114 738 or £8 826 per scheme (Z$13 = £1).

Further research using multivariate models to analyse the relationships that describe the determinants of the willingness-to-pay bids is currently being conducted. Nevertheless the values already obtained can be added to the financial value of a collector well scheme, in an attempt to calculate a total economic value for a scheme. A total economic value of the collector well scheme would include use values (both direct and indirect) and non-use values. A direct use value of the scheme could be taken to be the gross margins of vegetables grown over the time horizon of a project (Z$ 217 481); indirect use-values could be taken as the economic values of the clean and reliable water supplied (Z$ 129 501); improved health and labour productivity, and the environmental benefits of the scheme such as reduced pressure on marginal lands (both unquantified as yet). Non use values could be taken as the option or existence values people place on the garden's presence (Z$ 114 738). However, in order to undertake this exercise in a comprehensive manner, and to properly compare the total economic value of a scheme to its anticipated cost, a full calculation of its range of benefits should be undertaken using shadow prices for labour and gross margins.

6.4.5 Anticipated Costs

In a general sense the economic costs of extending the pilot project can be said to depend on:

- The opportunity cost of capital - what the cost is of diverting money away from other needy areas to invest in the project. This will depend on the ability of the project to fulfill the stated objectives or priorities of the donor, the current portfolio of project options the donor has to choose from, and the amount of money available.

- Prices for project inputs - locally purchased materials or labour inputs are subject to price distortions depending on the structure of the domestic economy the project is implemented in. Shadow prices should be used to calculate the true economic cost of the project's inputs, and to allow meaningful comparisons between regions and over time.

- Whether the project is part of a multi-purpose development policy the donor is pursuing eg. to improve water supplies and improve food security in Zimbabwe. If this is the case, the project's cost should be calculated as part of the wider overall economic costs and benefits of the policy.

- Acknowledgement of the importance of evaluating the total economic value of the project. The total welfare change the project brings to the region may well be underepresented by an evaluation based solely upon financial and market-based economic indicators. The analysis outlined above attempts to show how "social" and "environmental" welfare changes the project supplies can be captured and quantified. These changes may also however include hidden institutional and transitional costs in altering the status quo of communities and extension services.

A framework illustrating the capital costs for a hypothetical programme to complete 250 collector well schemes is set out as an annex to this report.

It should also be noted that due to the variability of the physical environment in which individual schemes are likely to be placed, and the resource-poor nature of the communities in more arid locations, marginal costs of implementing individual schemes may fluctuate by as much as three times about the average. Furthermore, the erratic nature of locational factors that affect individual scheme costs will be exacerbated by the range of social and environmental factors that can also influence the level of benefits that accrue from schemes. Disorganised communities, random feuds, unforseen environmental stresses such as pests or drought, can all easily affect scheme performance and hence lower the level of quantifiable benefits. However, that should not mean that no schemes will be implemented in "difficult" areas. The resulting trade-off for both the implementing and donor agencies is whether the net benefits of the project are calculated on a scheme by scheme basis (whereby difficult sites calculated using a net economic cost for implementation would not get a scheme), or on a project wide basis (whereby across one hundred schemes net benefits are calculated to outweigh net costs even though some schemes do not initially indicate an individual net benefit to investment). This is a critical problem to overcome, as the very poorest comunities which the project would be keenest to target, are likely to be situated at sites where the cost-benefit margins for implementation are closest, and would thus be extremely sensitive to unforseen problems. The Institute of Hydrology is currently working on a decision support system for siting schemes that is able to take account of these difficulties.

7 Agro-economic performance of community gardens

7.1 GARDEN IRRIGATION VERSUS LARGE IRRIGATION SCHEMES

With the exception of the Nile Delta, large scale irrigation was unknown in Africa until this century (Underhill, 1990). In contrast, small-scale irrigation has been practised since time immemorial, in many varied forms according to local circumstances. The use of groundwater from hand-dug wells has been particularly common in semi-arid areas of Africa for irrigating small vegetable plots, especially by women for whom it is a traditional activity.

Carter (1989) lists some of the problems that have beset large formal irrigation schemes in Africa. These include:

- very high capital costs of large scale land and water development;
- inadequate financial resources for operation and maintenance;
- lack of trained manpower and lack of irrigation experience among farmers on the schemes;
- conflicts between the aims of government irrigation agencies and the aims of farmers;
- overwatering leading to waterlogging and salinity
- low crop yields and poor returns both to the national economy and to the farmers;
- difficulties of operating and maintaining mechanised crop production on smallholder schemes;
- a range of environmental and health problems.

Underhill (1990) lists some of the comparative advantages of informal small-scale irrigation when compared to large irrigation schemes. These include:

- implementation of informal irrigation can be considered as part of a development process rather than a one-off development action;
- informal irrigation is based on self-reliance, schemes are farmer or community owned and managed;
- informal irrigation rarely involves migration or resettlement, where possible water resources are developed where rural people live;
- relatively little infrastructure and low external inputs are required;
- informal irrigation is highly adaptable and fits well into traditional farming systems that include rainfed crop production and livestock production;
- as one of several agricultural activities, informal irrigation enables farmers to spread risk across a range of activities.

7.2 COMMUNITY VERSUS PRIVATE GARDENS

In organisational terms, there are a number of different types of garden that can be found in semi-arid areas of Africa. These include: *private gardens* whereby one farmer or one household fence and manage their garden using water from their own well, from a river or a public water point; *community* or *allotment-type gardens* whereby a number of farmers or households have plots within a fenced area and water is obtained from a public water point; and *collective gardens* whereby a garden is operated by the community and the produce is shared. The type of gardening practised depends on a number of factors that include: availability of water resources, social and institutional factors and the advice given to communities by extension services.

Availability of water is a major constraint on gardening in areas of crystalline basement to the extent that few farmers are able to implement groundwater-based private gardens either because there is insufficient groundwater beneath their land or because the cost of accessing groundwater is prohibitively high. Although there are some collective gardens, most rural communities in Zimbabwe, when given the choice, prefer some type of community garden.

Assuming that sufficient water resources are available, the main advantages of private gardens versus community or collective gardens are all related to the relative ease with which they can be set up and managed. Decision making is made by a single household and leadership disputes, which are inevitable with community gardens, are less common. However if water resources are scarce, private gardens tend to promote inequality between the relatively richer garden owners and relatively poorer non-garden owners.

Apart from improving equity at the village level, community or allotment gardens have the advantage over private gardens that they can reduce competition for water resources between private farmers. Community gardens also have the important advantage that they can provide communities with confidence and organisational experience that can be used to tackle other resource management problems at the village level. Many of these, such as reducing overgrazing of communal grazing areas or reducing run-off from hill slopes, can only be tackled effectively by community action.

7.3 COMPARISON OF THE AGRO-ECONOMIC PERFORMANCE OF DIFFERENT SCALES OF IRRIGATION

Table 13 provides indicative values of agro-economic performance of community gardens using groundwater compared to other types of irrigation system operating in southern Zimbabwe. It can be seen that the relatively large schemes listed that use water from rivers or reservoirs cost between Z$35,000 and Z$100,000 per hectare to develop. These figures are lower than Agritex's current estimates for the development of water and irrigation infrastructure for small and medium sized schemes which range from $100,000 to Z$160,000 per hectare of land. Although the aims and objectives of large, medium, small or garden irrigation schemes are often very different, it can be seen that the cost of developing groundwater gardens per unit area is broadly similar to that for developing larger schemes that use surface water.

Table 13 shows that for people fortunate enough to live near to a wetland or river, development of a dambo garden or a river-bank garden is a low-cost venture that can be extremely profitable. However, legislation is currently in place that prohibits vegetable gardens on dambos or river banks for environmental reasons. Although it is not rigorously enforced, this legislation constrains the number of dambo and riverbank gardens.

Table 13 *Indicative values of agro-economic performance of various scales of irrigation system operating in southern Zimbabwe*

Name	Natural region (rain)	Size (ha)	Type of scheme	Number of members	Average area per family (ha)	Gross Margin (Z$/ha)		Annual total ($/ha)	Gross margin per unit of water ($/ha/m)	Typical cost per hectare (Z$/ha)	Approx cost per scheme (Z$)	IRR (%)
						Summer (crop)	Winter (crop)					
ADA Chisumbanje[1]	V (450 mm)	2400	River water pumped to canals & syphons	118	3.60	1370 cotton	707 wheat	2077	n.a.	3500[2]	84,000000	5
AGRITEX Towona[1]	V (408 mm)	151		245	1.20	1336 maize	1530 tomato	2866	2186	35000[2]	5,285000	8
AGRITEX Mabodza[1]	IV (660 mm)	12	Gravity fed from dam to canals & syphons	92	0.13	777 maize	3562 tomato	4339	2355	100000[2]	1,200000	3
AGRITEX Chirogwe[3]	V 500 mm)	5		105	0.05	7877 rape & tomato		7877	n.a.	60000[3]	300000	13
DAMBO GARDEN Mushimbo[1]	III (708 mm)	12	Buckets of water from shallow dug wells	14	0.89	1557 mealies	1022 veg	2579	3384	5000[4]	60000	52
DAMBO GARDEN Mbiru[5]	III (743 mm)	4		57	0.07	3125 mealies	2637 veg	5762	3359		20000	115
COMMUNITY Romwe[5]	IV-V (560 mm)	0.5	Collector well & two handpumps, water by buckets to community garden	46	0.01	2388	17520	19908	52197	96000[5]	83500	12
Muzondidya[5]				134	0.005	15628	2576	18204	38211			11
Gokota[5]				112	0.005	-	25444	25444	40999			15
Dekeza Sch[5]				49	0.01	-	13748	*	*			
Mawadze[5]				50	0.01	-	1690	*	*			

Source:
1) Meinzen-Dicl et al (1993) Agroeconomic performance of a small holder irrigation in Zimbabwe, UZ/IFPRI/Agritex Workshop, Zimbabwe, Aug-46.
2) FAO (1994) National Action Programme on Water and Sustainable Agricultural Development, Zimbabwe.
3) Agritex (pers. comm). Figures based on first two years of operation, 1991-93.
4) Estimate based on cost of fencing alone.
5) Lovell *et al.* (1994) Small scale irrigation using collector wells Pilot Project-Zimbabwe: 4th Progress Report, Institute of Hydrology, UK.
6) Financial analysis: IRR calculated for a common project life of 40 years (assuming proper maintenance and sustainable use of natural resources) and a social discount rate of 13 percent.
*) Not yet completed one full year.

Figures 15 and 16 show average size of a farmers irrigated land holding plotted against total annual production per hectare and gross margin per unit of water respectively. These figures use data from Table 13. It can be seen clearly that the value of production per unit area and the value of production per unit of water increases substantially as plot size decreases. The main reason for this is that smaller plots of land tend to be intensively cultivated (Meinzen-Dick *et al*, 1993). Higher value crops are grown on smaller plots, crop husbandry and irrigation practices tend to be more precise and, in some cases, a third crop is grown every year.

Gross margins shown in Table 13 must be considered as being indicative because the assumptions used to calculate the values for schemes, other than those in the project, are not known and a number of questions remain unanswered in the respective reports (e.g. was hired labour used ?, what output prices were used ?, how did these vary between the schemes ?, was the value of produce consumed at home included in the gross margin and, if so, how was it valued ?). Typically half the produce grown on community gardens is consumed at home. The value of this produce is included in the gross margins of project schemes shown in Table 13 and it was valued at the selling price.

Table 14 presents data from the Romwe Garden on the production of rape and cabbage during the severe drought of 1991/92 when rainfall was very low and there was no rainfed cropping in the region. Taking account of uncertainties in the estimates of yield and water use efficiency, it is clear that the water use efficiencies realised on the Romwe Garden are similar, or even better, than water use efficiencies achieved when these crops are flood irrigated at the Chiredzi Research Station. More details of the Romwe Garden 1991/92 crop season can be found in Lovell *et al* (1993a).

Table 14 *Estimated production from Romwe garden during 1991/92 summer season*

Crop	Home consumption (kg fresh leaves)	Sold (kg fresh leaves)	Total (kg fresh leaves)	Average Yield (kg/ha)	Water use efficiency (kg/m^3)
Rape	3,408	5,310	8,718	78,967	11.12
Cabbage	2,918	3,166	6,084	55,209	7.91
Total	6,326	8,476	14,802	-	-

7.4 DESIGN AND MANAGEMENT OF COMMUNITY GARDENS

7.4.1 Layout of community gardens

All project community gardens have been divided into beds with each garden member having a certain number of beds. It is rare for households to have more than one garden member on a scheme or for the number of beds to be anything but evenly distributed between all garden members. The Mawadze garden being an exception where 30 members have five 8 m beds, 10 members have five 6 m beds and 10 members have five 8 m beds as well as five 6 m beds. The normal layout of plots or allotments for an individual garden member is in a strip running across the garden rather than as a square block. This enables blocks of land to be planted up with one type of vegetable thereby facilitating chemical pest control.

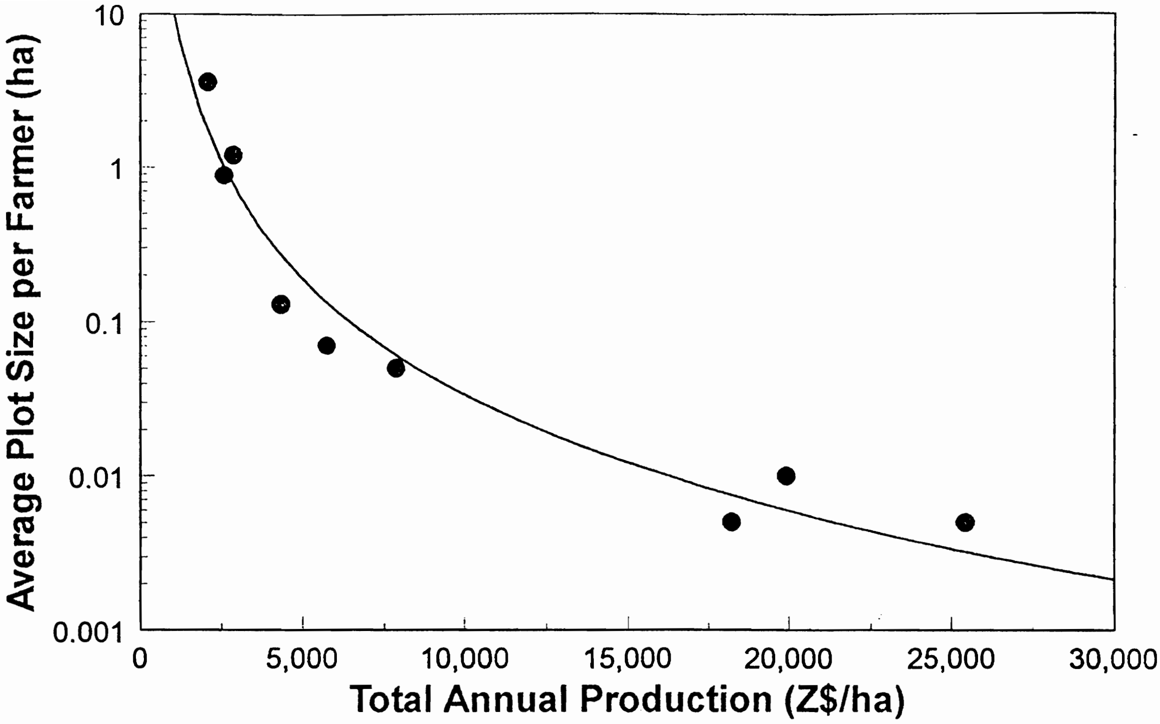


Figure 15 *Relationship between size of irrigated land holding and productivity*

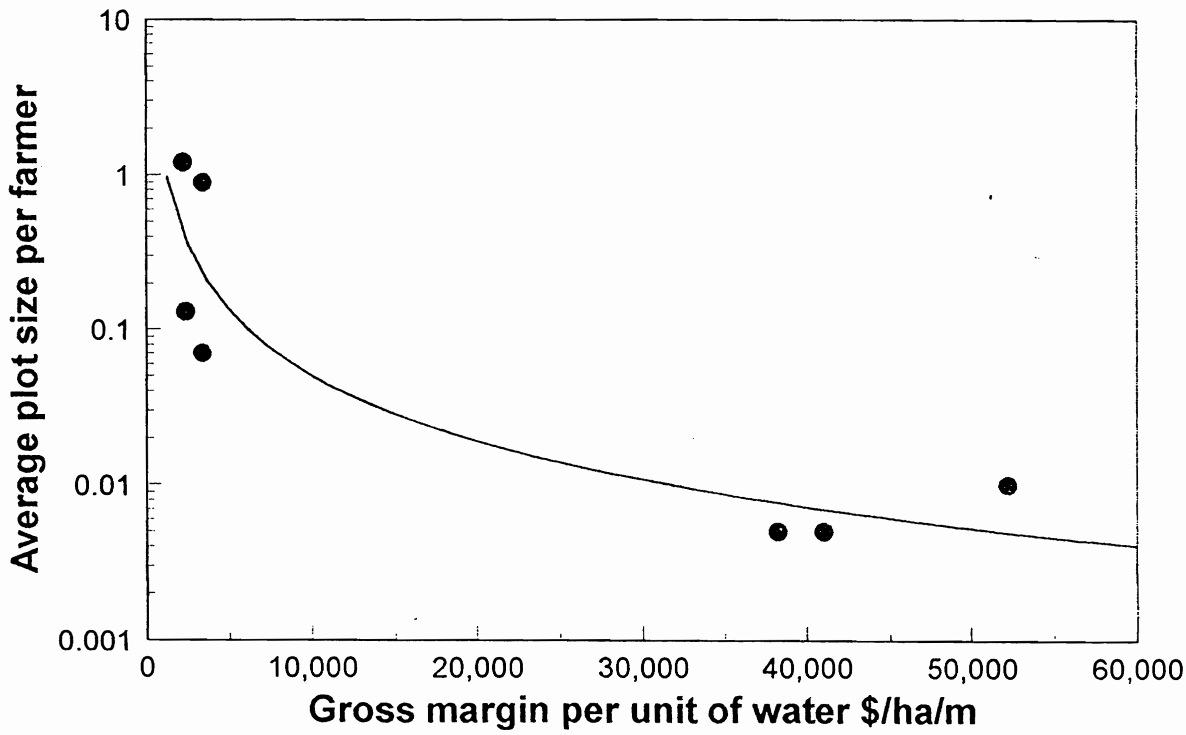


Figure 16 *Relationship between size of irrigated land holding and water use efficiency*

Water is generally carried in 20 l buckets from the water tank at the well to the individual plots. Some attempt has been made on the gardens to design the layout of the strips so that the amount of walking is roughly the same for all members. However, as the wells and tanks are not located in the centre of the garden, some strips are much easier to irrigate than others.

Table 15 summarises information from all the gardens on number of beds, size of bed and the layout of holdings within the garden. Path widths between beds are usually less than 0.5 m, although they do vary within a garden and between gardens.

7.4.2 Management of community gardens

Although there are subtle variations, management of all the project gardens is part cooperative and part individual. In general, an elected committee decides on such matters as the crops to be grown, the area to be grown under each crop, the timing of planting and transplanting, irrigation schedules, chemical pest control to be used and the timing of application of pesticides. Committees are also responsible for purchasing seeds and chemicals and establishing nurseries. Individual members tend their own beds, harvest vegetables for home consumption and retain the proceeds from vegetable sales less any payments required by the garden committee.

Table 15 *Layout of ODA-funded Gardens*

Garden	No. of members	No. of beds per member	Size of beds (m)
Romwe	48	7	6 x 1
Muzondidya	124	3	4 x 1
Gokota	130	4	4 x 1
Dekeza	56	16	3.5 x 1
Nemauka	74	3	12 x 1
Mawadze	30	5	8 x 1
	10	5	6 x 1
	10	10	8 x 1 and 6 x 1
Matedze	87	7	3 x 1

The current management procedures result in gardens that have a regimented appearance. The advantages of this approach are:

- savings can be made by buying and using seeds and chemicals cooperatively;
- irrigation rota are simple to organise;
- chemical pest control is easier and more effective.

The disadvantages of this approach are:

- individual choice is not catered for and self-reliance is not encouraged;
- non-chemical pest control is difficult;
- a relatively large quantity of vegetables comes onto the local market at the same time.

It should be noted that all the gardens are still quite new and it is quite probable that management procedures that are currently being adopted may not still be in use in a few years time. There are already indications that several gardens, most notably Mawadze, are trying new cropping strategies as a means of maximising income from the garden. These strategies include individual members selecting different cropping patterns. The key factor is probably the importance that garden members attach to income generation as opposed to growing vegetables for home consumption. If income generation is the highest priority, there is an incentive for members to adopt their own cropping strategies.

Pest control is a major problem on vegetable gardens in semi-arid areas, particularly during summer months. Many vegetables are very sensitive to pest attack and severe attacks often result in complete crop failure. This is one of the reasons that garden members choose vegetables such as covo or rape that are relatively hardy with regard to pests and diseases. Chemical sprays are used frequently if garden members can obtain chemicals and if they have access to a sprayer. It is clear that the need for good pest control is well understood by garden members, but advice is often required regarding appropriate choice of pesticide and correct application rate. For example, during the 1992/93 summer season spraying of tomatoes and rape against aphids was carried out fortnightly over the period 16 December to 10 February on the Romwe Garden. There was some dissatisfaction among members who felt that spraying would and should have been done more frequently but for the preoccupation of the garden chairman with other activities. The garden chairman supplied and charged for the sprayer and labour. At the end of the season the members purchased their own sprayer using income from vegetable sales.

In contrast to chemical sprays, gardeners use hardly any inorganic fertiliser unless this can be obtained cheaply or as part of a drought-relief handout. Inorganic fertiliser represents an increase in cost of production and additional investment that may be lost in the case of crop failure. Gardeners, therefore, prefer to use organic fertilisers when available.

7.4.3 Current irrigation procedures

The predominant irrigation method on all the gardens is flood or surface irrigation whereby water is carried to beds in 20 l buckets. Water is then tipped onto the soil surface. Irrigation schedules are usually rigid with a fixed number of buckets of water being applied to each bed each week regardless of the crop growth stage. For example, in a survey of irrigation practices in Chivi Communal Area, Lovell *et al* (1992) identified that the standard irrigation schedule, for a 3 x 1 m bed, was to apply eight buckets of water in the first week after planting (equivalent to 53.3 mm) and six buckets per week thereafter (equivalent to 40 mm/week) for the duration of the crop. Although nice and simple, this schedule results in over-irrigation at the beginning of the season and under-irrigation when the crop reaches full canopy (Murata *et al*, 1995).

Mulches are being used on some gardens during some seasons but, as yet, there is no indication of adoption of the improved irrigation practices described in the next section.

On the better organised gardens (eg. Gokota and Dekeza) irrigation rota are used whereby garden members are divided into groups that irrigate their plots on specific days. This procedure has the obvious benefit that queuing time at the wells is minimised. Cooperative effort such as some women pumping while others carry water can also reduce the effort required to carry out the irrigation. In contrast, at less well organised gardens (eg. Romwe) irrigation takes on a "free-for-all" approach as members rush to collect and apply as many buckets of water as possible from a central tank following collective pumping to this storage facility.

7.5 IMPROVED IRRIGATION TECHNIQUES

One of the aims of the pilot project was to promote and facilitate the uptake of the improved irrigation techniques that were developed and evaluated at the Lowveld Research Stations before this project started and, to a lesser extent, at the same time as this project has been carried out. These irrigation techniques are aimed at improving crop yields, crop quality and irrigation efficiency and reducing labour requirements for carrying irrigation water.

The results of trials carried out at the Lowveld Research Stations are presented and discussed in four reports (Batchelor *et al*, 1990; Lovell *et al*, 1990; Lovell *et al*, 1992; Murata *et al*, 1995). Water balance experiments showed that there is enormous scope for improving irrigation efficiency on irrigated gardens by reducing losses of irrigation water to non-productive soil evaporation. For example, measurements during a flood-irrigated maize crop showed that 54% of irrigation water and rainfall was lost as evaporation from the wet soil surface.

Different approaches to reducing soil evaporation were evaluated, these included low-head drip irrigation, subsurface irrigation using clay or slotted bamboo pipes, pitcher irrigation and improved flood irrigation using mulches. Table 16 compares the advantages and disadvantages of these methods.

Of the methods evaluated to date, subsurface irrigation using clay pipes and improved flood irrigation using mulches have shown the most benefits. They have the major advantages of being low cost and easy to use as well as being more efficient than traditional flood irrigation.

Figure 17 is a schematic diagram showing subsurface irrigation using clay pipes. Table 17 summarises the yield and water use effectiveness (WUE) results of recent trials at the Chiredzi Research Station that have compared flood irrigation with subsurface pipe irrigation. A full discussion of these results can be found in Murata *et al* (1995).

Table 16 *Advantages and disadvantages of simple micro-irrigation methods in low-cost vegetable production*

Irrigation method	Advantages	Disadvantages
Flood irrigation	Traditional, well-known method. Easy to perform. Good crop establishment. Minimum additional inputs required.	Not efficient in water use. No inherent control against over-irrigation. Labour intensive.
Low-head drip irrigation	Improved water use efficiency. Good uniformity of wetting. Reduced drudgery and effort of carrying water.	Cost and availability of materials. Degree of management skill required. Water filtration required. No inherent control against over-irrigation.
Subsurface pipe irrigation	Improved water use efficiency. Pipes can be made locally. Robust method. Low labour requirement. Some inherent control against over-irrigation. Good uniformity of wetting. Low-cost, simple method, easy to learn. Once installed pipes can be used over several seasons.	Initial labour and skill requirement for manufacture and installation. Crop establishment can be poor if initial irrigation only via pipes.
Pitcher irrigation	Improved water use efficiency. Inherent control against over-irrigation. Can be positioned next to individual plants or in centre of small plots. Good on undulating land.	Initial skill and labour requirement for manufacture and installation. Less robust than clay pipes. More labour intensive, pots have to be filled individually. Porosity of pots decreases with time. Difficult to cope with high water requirements.
Improved flood irrigation (mulch)	Improved water use efficiency. Low skill requirements and easy to carry out. Good crop establishment. Protects fruit from damp soil. Prevents soil capping and reduces soil erosion.	Potential for increase in pests and diseases. Mulches are not always readily available.

7.6 EXTENSION OF IMPROVED IRRIGATION TECHNIQUES

7.6.1 LVRS open day for Agritex staff

An open day for Agritex staff involved in the project was held on 25 July 1994 at the Chiredzi Research Station. There were thirteen participants including the DAEO's of Zaka and Chiredzi Districts. The day involved demonstrations and discussions on the principles of vegetable production, improved irrigation techniques, manufacture of clay pipes and pest control.

The following observations regarding the activities of the day were made:

- there was great interest in the nursery practices, especially propagation of the fruit trees for the gardens;

- principles of vegetable production also generated a lot of interest and lively discussions on plant spacings and varieties ensued. It became clear that in practice the choice of crops available to the farmers depends primarily on the limited seed availability on the local market.

- the participants were impressed with the potential of the alternative irrigation methods but would not commit themselves to say which method they thought had the greatest potential in their area. However, they expressed a willingness to demonstrate these alternative methods of irrigation in the collector well gardens. Furthermore they suggested that arrangements should be made to bring some garden members to the research station to learn how to make pipes. All agreed that pipe making was an easy task which people could learn in a day. Some tried it themselves and found it easy.

- pest control was thoroughly discussed and questions about alternative methods of control were asked. LVRS staff did not have sufficient information and are to refer to work carried out at the Plant Protection Research Institute.

Table 17 *Percentage improvement in yield and wue for subsurface treatments as compared to equivalent flood treatments*

Expt.	Crop	Average Improvement		Best Improvement	
		Yield %	WUE %	Yield %	WUE %
91/4	Maize	64.4	64.2	94.3	95.6
92/1	Tomato	5.5	8.2	5.6	8.9
92/2	Rape	8.6	27.5	17.1	45.0
93/1	Okra	5.0	-1.1	17.8	8.6
93/3	Tomato	-0.9	4.8	9.7	10.9
93/4	Rape	8.6	14.0	22.2	43.7
Mean	-	15.2	19.6	27.8	35.5

7.6.2 LVRS open day for project farmers

As a follow-up to the open day for extension workers, an open day was planned for members of project schemes. This open day should have taken place on 16 November 1995 but unfortunately it had to be cancelled as a result of organisational problems. It is now planned that this open day will take place in early 1996.

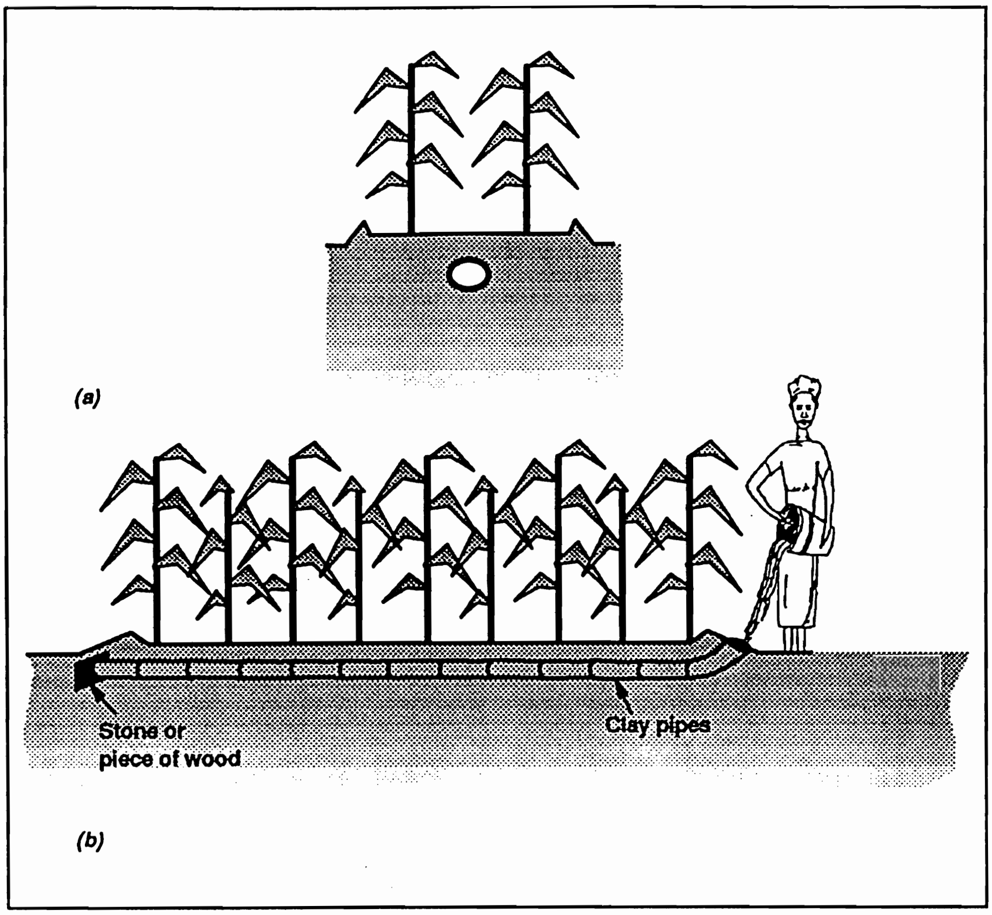


Figure 17 Schematic diagram of subsurface irrigation using homemade clay pipes

7.6.3 ITDG experiences with improved irrigation techniques

Although funding constraints and changes in project personnel led to less work being done on participatory extension of the improved irrigation techniques than had been hoped, it is encouraging that there is evidence of uptake of improved irrigation techniques by some gardens in the region. Groups of women were brought to LVRS as part of the Intermediate Technology Development Group's Chivi Food Security Project. Murwira (1995) states: "Work on clay pipes was seen to be appropriate for women in Chivi as they already use clay in their pottery work. A total of sixty-two women started the work in 1992 and today we have over 300 women practising the technology. The amount of time spent watering has been drastically reduced from about 20 hours to 5 hours per week.

The following information was taken from Murwira (1995):

> "Traditionally, women in Chivi District have joined with others in their village to form gardening groups. A suitable area is fenced off and, within this garden, each group members tends several beds. Vegetables are grown to supplement family food supply, and any surplus produce is sold for cash. Women are always very busy,

because of the competing demands of both running the home, and looking after children, as well as working on the family farm. The gardening group enables the women to assist each other, by sharing their ideas on, and knowledge of, fencing, cultivating, weeding and watering techniques.

Water is a continuous problem. Gardens are often on the slopes above a river but, in the dry season, this may well be dry, and wells have to be dug in the river-bed to obtain water. Whatever the season, they have to carry the water to the gardens. This is time consuming and requires many journeys, as only a small amount of water can be carried each trip.

ITDG's Chivi food-security project organised a trip for gardening group representatives to visit a government agricultural research station at Chiredzi. Here, the women saw a trial using porous clay pipes laid at root level as a way of irrigating small vegetable beds. Each pipe is about a foot long, and a run of them is laid along the length of a bed. The pipes are laid at rooting depth, loosely butting up to each other. One end of the pipe is plugged with a ball of clay. The other end has an angled pipe, so that the end of the final pipe protrudes through the soil surface. Water can be poured into this open end. The water seeps out slowly through the cracks between the pipe sections, and through the porous walls of the pipes. This is a particularly efficient way to deliver water, as it arrives directly at root depth, and evaporation losses are greatly reduced.

The women were particularly interested in this idea, as it addressed a pressing problem. In addition, the women were already skilled potters, making clay pots for cooking and storage, so they felt capable of making their own pipes.

The women's experiments with this system in their own gardens have proved the idea works well and reduces the amount of watering required. This in turn means that they need to spend less time tending their gardens."

8 Institutional viability of collector well gardens

8.1 PROJECT OBJECTIVE

One of the aims of the pilot project has been to assess the institutional viability of collector wells and community gardens in semi-arid areas. It was recognised during project planning that the institutional arrangements for implementing and managing communty wells and gardens would inevitably be more complex than for private wells and gardens. Experience during the pilot project has confirmed that institutional problems can have a serious impact on scheme performance. However, experience has also shown that many institutional problems, particularly at a local level, can be avoided or greatly reduced if certain key steps are followed during the planning and implementation of schemes (Section 4.2). It is becoming clear also that communities are able to solve a lot of their own institutional problems once their schemes are in operation, as long as the benefits of the schemes have become apparent to the communities and provide sufficient incentive to overcome temporary setbacks.

The institutions and local leaders who people regard as influential have been found to vary between different locations and, in some cases, within the same community. At each scheme these institutions and local leaders need to be identified. In southern Zimbabwe, both traditional and more modern, politically appointed leaders are present in most communities. Temporary leadership problems and disputes are thus almost inevitable, and experience in the pilot project has shown both the need for an inter-disciplinary team approach for succesful scheme implementation, and the value of trained facilitators and agricultural extension workers in helping to resolve difficulties when a scheme is experiencing these social "teething" problems.

This section of the final report considers institutional factors identified during the pilot project that remain important to the viability of replicating collector well gardens on a wider scale, and includes identified training needs that should be addressed in any future programme.

8.2 INSTITUTIONAL VIABILITY AT A NATIONAL LEVEL

The pilot project has been implemented by staff of the Zimbabwe Departments of Agricultural Technical and Extension Services (Agritex), Research and Specialist Services (R&SS), and Water Development (DWD), in collaboration with staff of the British Institute of Hydrology, British Geological Survey and ODA. One anticipated output of the project was a core of trained staff in Government capable of running collector well gardens (PDS BDDSA, 1992). Training of Zimbabwean counterpart staff during the pilot project has included:

Name	Institution	Position	Training	Duration
Mr E Mafunga	DWD	Driller	Collector well siting & construction Pump maintenance Equipment maintenance	30 months
Mr G Kakungwa	DWD	Technical Hand 3	Collector well construction techniques	2 months
Mr Chikuni	DWD	Driller	Collector well siting	2 schemes
Mr G Mtetwa	R&SS	Agricultural Technician	Well monitoring	18 months
Ms M Murata	R&SS	Agronomist	Community development Participatory methods	24 months
Mr T Dube	R&SS	Agricultural Assistant	Community development Participatory methods	36 months
Mr Mazhangara	R&SS	Agricultural Economist	Conventional & Envir-onmental economics	18 months
Mr Makunde	Agritex	Extension Worker	Participatory methods	Silveira House
Mr Magonde	Agritex	Extension Worker	Participatory methods	Silveira House
Mr Takaindisa	Agritex	Extension Supervisor	Participatory methods	Silveira House
9 Extension Staff	Agritex	2 DAEO's 7 AEW's	Irrigation methods	Field Day LVRS
40 Villagers	Project schemes	Committee members	Aspects of Leadership	Workshop
Mr T Chiunye	Casual	Site Foreman	Well construction techniques	24 months
Mr P Musanhu	Casual	Site Foreman	Well construction techniques	24 months

It is pleasing to note that field staff of Agritex are now fully responsible for working with the communities at each site to develop and run the gardens, and are highly revered by these communities (Section 6.3). Trained staff of R&SS are also now fully responsible for monitoring garden and well performance and collection of socio-economic data to assess impact of the schemes upon the communities.

There remains however a critical need to create an inter-disciplinary core of trained staff in Government capable of implementing collector well gardens on a wider scale. This has not been possible in the pilot project and, indeed, was not an objective. The development of only six sites did not afford the opportunity for Government to allocate sufficient high calibre staff to a small project given current resource constraints.

If further work is contemplated, the following inter-disciplinary team of trained staff should be created in order to undertake and be responsible for the sequence of steps now known to be important to successful development of community gardens using groundwater:

Project Manager	Government or Private Sector	Overall coordination and responsibility
Social Development Officer(s)	NAT.AFF or MoH	Community development by participatory approach
Agricultural Extension Officer	Agritex	Garden management and environmental village plan
Pump Test Engineer	DWD or DDF	Well siting and selection
Driller	DWD or DDF	Exploratory & radial drilling
Assistant Driller	DWD or DDF	Exploratory & radial drilling
Mechanic	DWD or DDF	Vehicle & equipment maintenance
Geophysist (on call)	DWD or DDF	Borehole siting where appropriate
Site Foremen	Contract	Well construction
Monitoring Officer	R&SS	Well and garden performance

At a national level, overall planning, coordination and financial responsibility will require the placing of a representative and accountable Government institution at the centre of future development. At Provincial level, a Government body must provide coordination with other activities in the province and bring appropriate inter-disciplinary skills and experience to bear during scheme implementation. The future project must also be structured to take account of the need to build capacity at Local Authority level to plan and manage their own district development programmes and to take a fuller part in all aspects in future.

8.3 INSTITUTIONAL VIABILITY AT VILLAGE LEVEL

There is a critical need to ensure that any new investment in water and garden facilities is sustained into the future and does not fail through either neglect or lack of resources to maintain the facilities. Pilot project results indicate that the key to sustainability from a social perspective lies in fostering community sense of ownership of the facilities and in developing community self-reliance through programmes of village level training.

Local communities are much more likely to look after and pay for the upkeep of their water points and gardens if they know that they belong to them and not to another agency such as DDF, DWD, an NGO or the RDC. This has been proved during the project. It is the basis of the informal contract between community and project staff used during scheme implementation (Annex 2) and has been highlighted by the popularity and success of the community training programme provided in pump maintenance and repair (Section 4.2). An important corollary of this finding is that the community is involved at all stages of the resource development, from its inception, through planning and construction, to subsequent maintenance and management.

A key element in this approach is to recognise the special role of women in all aspects of water and gardening. It is the women, predominantly, who collect the water and thereby use the water points the most. It is the women, predominantly, who are responsible for providing relish and thereby use the gardens the most. It is vital therefore to make a special point of including women in all aspects of the management and maintenance of the schemes, and to minimise wherever possible their workload by thoughtful scheme design.

Developing institutional capacity at village level to implement sustainable water points and community gardens, and involving local communities in all aspects of the ownership, management and maintenance of these resources, must inevitably involve equipping these same communities and local extension staff with the necessary information and education. Information and education is needed to assist local communities to fully benefit from the development of the water points and gardens and to make sensible and rational choices on such matters as garden management, leadership and treasury, pump maintenance and repair, integrated control of pests and diseases, methods of irrigation, and crop marketing strategies. This will call for a coordinated and sustained effort, and again a recognition of the particular need to target women in all these actions.

8.4 IDENTIFIED TRAINING NEEDS

Clearly, there should be a strong element of 'training the trainers' in any future project, and training at Provincial, District and Village levels should be key project activities throughout. We suggest that the various components of training be brought together in a detailed Training Plan prepared at the time of project inception by pilot project staff in consultation with the appropriate institutions. This will help to ensure that staff requirements and training needs identified in the pilot project are considered, that the modules are complementary and relate to the strategic aims of the new project, and that effective use is made of other complementary training programmes, some of which have been used during the present work (for example, Training for Transformation by Silveira House, the ITDG Chivi project, the Bikita IRWSS project, the Lowveld Environmental Awareness Programme (LEAP), and the AZTREC programme).

In general, training should follow a hands-on, learning-by-doing approach. However, the Training Plan will need to stress the following:

- the lead roles to be played by local authorities and line ministries at district level, and the need therefore to build on existing activities and capacities;
- the increased role of local communities through the project planning system and emphasis on community management of resources;
- the implications of this for extension staff, whose role should be facilitatory rather than directive;
- the implications of this for the Training Plan design, which must be flexible and responsive to community needs and initiatives rather than formalised or 'top-down' in nature;
- the new approach to well siting and selection which will have to be considered;

It is suggested that the Training Plan should comprise of at least 6 Programmes:

- Institutional Development
- Technical Training
- Social Training
- Production of District and Community Training Materials
- Skills Development at District Level

- Village Level Training

Principal components of these programmes should include:

- The formation, training and effective coordination, management and operation of an inter-disciplinary project Team;
- Enhanced coordination and capacity of Government at each level to implement community gardens using groundwater;
- Participatory approaches to community development and project initiation building on key steps identified in the pilot project;
- Horizontal radial drilling;
- Well siting by exploratory drilling, and well selection by pumping test analysis and hydrogeological decision tree (as opposed to conventional geophysical siting of predetermined well designs);
- Technical aspects of effective garden management;
- The development of village environmental plans;
- Initiation of community-based catchment resource management

The substantial training and education programmes identified are seen to enhance institutional capacity at all levels to participate and shape future development of community gardens using groundwater and thereby realise maximum benefits from the pilot project.

The approach outlined will require an important degree of liaison and coordination between the key providers of manpower at all levels. An important point to make about this level of training is that it needs to be undertaken with a full understanding of the objectives and strategy of the proposed development. The increasing emphasis on community involvement and empowerment requires a very different approach to community level training than implied in the phrase "mobilisation". The people are not to be mobilised to fulfil top down directives or meet pre-established planned programmes. Rather, they are to be equipped to make sound decisions and to be able to plan, implement and manage their own resources at local level.

Ward Community Coordinators (WCC), Village Community Workers (VCW) and Agricultural Extension Workers (AEW) will be expected to transmit a great deal of the approach to people at ward and village level. Accordingly, appropriate training modules must be included to achieve this.

9 Environmental appraisal of collector well gardens

9.1 POTENTIAL OF THE GROUNDWATER RESOURCE

Extent of groundwater resource

Crystalline basement aquifers, which are present over much of Africa, provide a limited but extensive resource which has the potential for greater use. A review of the extent and availability of these groundwater resources in Zimbabwe and other countries of southern and eastern Africa can be found in Anon (1989). Over the last decade, interest in shallow water in the crystalline basement regolith has gained considerable momentum with the recognition that the regolith may provide a more sustainable and less costly source of rural water supplies than the underlying bedrock fractures which have traditionally been exploited (Howard *et al*, 1994). Despite increasing interest, many basic questions relating to the development and sustainability of shallow basement aquifers have only been answered in part.

In principle a sustainable level of abstraction from an aquifer is one that does not exceed the recharge to groundwater. The exception to this is if the abstraction is very small compared to the storage of the aquifer, in which case the impact of the abstraction will be negligible, at least in the short term. Failure to match abstraction to recharge will result in a non-sustainable well yield and will permanently reduce groundwater levels with consequent effects throughout the whole ecosystem. Even abstractions that are equal to or less than recharge can have a deleterious impact; groundwater levels will not rise as much in response to seasonal rains and the flow of ephemeral rivers fed by groundwater during parts of the year will be reduced in volume or become extinct. Such rivers may be important sources of water for settlements and will certainly have an ecosystem dependent upon them.

Groundwater recharge in south-east Zimbabwe

Houston (1988) estimated recharge for the Masvingo province of Zimbabwe using three independent methods; baseflow analysis, environmental tracer (chloride) and soil moisture budgets (based on a monthly recharge-runoff model). Data from 22 raingauges and 3 class 'A' evaporation pans were available for an area of 22000 km^2 roughly centred on Masvingo. Flow data were available from the Chiredzi, Mzero, Musokwesi and Lundi rivers for periods ranging from 8 to 17 years. Houston estimated recharge throughout the Masvingo province to be 2-5% of rainfall, a range which was shown by all three methods. Houston further suggested that recharge was very dependent on annual average rainfall with low rainfall areas likely to have a recharge of 2% of annual rainfall. Based on an area receiving 500 mm annual average rainfall and a recharge rate of 2%, Houston calculated that an area of 65 ha was required to sustain a hand pump delivering 6500 m^3/annum.

Meigh (1988) made a first attempt at estimating recharge for the Lowveld region using two independent techniques based on a soil moisture budget model and two empirical models. The soil moisture model was a simplification of the Houston (1988) model but using meteorological data from the Lowveld Research Station and the airport at Buffalo Range. The empirical approach involved relationships developed for a number of catchments between annual average rainfall and runoff and base flow index (BFI) and soil type (Bullock, 1988). A second empirical approach used relationships for annual average rainfall and runoff and annual average rainfall and BFI developed by Meigh (1987). These methods gave recharge estimates of 0.5-6%, a range that encompasses that of Houston (1988).

Groundwater recharge in other African basement areas

Wright (1992) reported estimates of recharge calculated by a number of methods for areas of Zimbabwe that generally have a higher rainfall than south-east Zimbabwe. Recharge calculations using base flow analysis demonstrated the importance of dambos and relief on base flow and hence on recharge. These relationships are also discussed by Farquharson and Bullock (1992). With rainfall in excess of 800 mm, groundwater recharge was estimated by Wright (1992) to be typically in the range 10-20% of mean annual rainfall which he considers to be substantially in excess of the demand of rural populations (1-3 mm). Estimates of recharge using chloride balance, again for an area with rainfall higher than normally experienced in south-east Zimbabwe, was 9-14% of mean annual rainfall.

Howard and Karundu (1992) estimated recharge for basement aquifers in south-west Uganda. Annual rainfall in this area is normally in the range 750 - 1000 mm. Using daily water balance techniques, mean recharge was estimated at 30 mm (3-4% mean annual rainfall) over an eight year period. However, median recharge for the same period was estimated at 17 mm (2% mean annual rainfall) and this value was considered to be more representative of annual recharge in the area. Howard *et al* (1994) used water balance calculations and information from aerial photographs and LANDSAT images to assess the influence of land use change on groundwater recharge in south-west Uganda. Recharge estimates for the period 1954 to 1961 were found to be just over half those for the period 1988-91. The difference was attributed to large-scale deforestation during the intervening 30 years which has increased recharge by causing significant reductions in rates of actual evaporation.

9.2 EFFECTS OF LAND MANAGEMENT ON GROUNDWATER RECHARGE

Wright (1992) explains that "*the basement aquifers of this region (S.E. Zimbabwe) are distinctive in that their occurrence and characteristics are largely a consequence of the interaction of weathering processes related to recharge and groundwater throughflow. A close relationship exists therefore between groundwater occurrence and relief, surface water hydrology, soil and vegetation cover. Recharge is sensitive to certain land use changes, notably those associated with desertification. Improvements in the understanding of these relationships will be fundamental to the management and planning of groundwater resources in crystalline basement terrain.*"

The investigation of the relationships between hydrological phenomena and land use has normally been carried out within small experimental drainage basins or catchments. Results from such catchment studies, carried out in eastern and southern Africa, have been reviewed by Whitlow (1983) and Bullock (1994). These catchment studies have proved invaluable particularly in providing information on the impacts of afforestation and deforestation in sparsely populated upland areas. However, the critical water and soil resource problems throughout much of Africa occur in catchments that are heavily populated by subsistence farmers and their livestock (Pereira, 1961). With few exceptions, there is a paucity of data from such catchments (Whitlow, 1983).

In response to growing populations, an increasing area of land is being taken over for crop production throughout Africa (Whitlow, 1983). Declining productivity of existing croplands has also promoted extension of cultivation often on to more marginal terrain better suited to other less intensive forms of land use. Extension of cropland is often at the expense of grazing lands, thus placing even greater pressures on the remaining grazing land (Whitlow and Campbell, 1989). The net result is reduction in vegetation cover, land degradation and changes to the water balance. The mechanisms by which land degradation can influence different components of the water balance have been discussed by Whitlow (1983). Wallace (1994) provides an alternative framework for discussing the interactions between hydrological processes and land degradation.

In 1992 work started on a project in the Romwe Catchment in south-east Zimbabwe that is studying the influence of land use and land management on groundwater recharge (Butterworth *et al*, 1995). This project is currently being expanded to become a long-term assessment of the physical and socio-economic benefits of taking an integrated approach to community management of resources in semi-arid areas.

9.3 GROUNDWATER DEVELOPMENT AND DRY SEASON RIVER FLOWS

Investigation of the factors which determine dry season river flow reveals a dominant rainfall control, reflecting the relationship between groundwater base flow and rainfall (Farquharson and Bullock, 1992). Ephemeral rivers, such as many of the sand rivers of southern Africa, occur when the water tables in local aquifers rise to the surface as a result of seasonal rains. It is clear therefore that abstraction of water from the aquifers may affect both the duration and flow rate of rivers during dry seasons. In south-east Zimbabwe, dry season river flows are used for irrigation and domestic consumption. It should be noted also that these low flows are very important to the ecology and biodiversity of the region.

Well abstraction levels in an area should not exceed those that will be detrimental to regional ground water levels. It is possible that widespread use of wells for increased domestic consumption and garden irrigation may reduce water tables in the dry season to levels that can not be recovered in the wet season by anything less than exceptionally high rainfall. Thus the local population and ecosystems that rely on the sand rivers will find that their water supply is more unreliable. The users of ground water will benefit at the expense of the river users with perhaps little net water resource benefit to the population of the whole water catchment. However, this scenario is considered unlikely given that abstraction levels are very low when compared to natural groundwater flow away from an area.

The quantification of the effects of groundwater abstraction on river flows is complicated being a combination of aquifer recharge, aquifer properties (transmissivity and storage coefficient) and location and pumping rate of the wells. This complexity requires that mathematical models of the aquifer-river system be constructed in order that these interactions are accounted for fully. Such approaches have been attempted. Oakes and Wilkinson (1972), for example, developed a model of a hypothetical aquifer-stream system and investigated the effects on stream flows for a range of abstraction regimes assuming different aquifer properties. A similar approach but based on a calibrated model of a specific catchment was undertaken by Clausen *el al*, (1993). Both studies showed similar results, in particular, that in the simplest case of a constant abstraction once equilibrium is reached, the river base flow is reduced by an amount equal to the pumping rate. The time to reach equilibrium depends on aquifer properties, a small aquifer with a high conductivity and a well close to the stream will reach equilibrium quickly, whereas the other extreme set of values for these factors will result in equilibrium taking several years to be achieved. Thus under intermittent abstraction regimes the effect on the rivers is less easy to characterize simply. Oakes and Wilkinson (1972) showed that the effects of continuous abstraction could be diminished by the sequential operation of two groups of wells at different distances from the river, the nearer group being pumped in winter and the farther in summer.

Results presented in Section 5 give an indication of the potential of collector wells. It is clear that collector wells are not a universal solution when it comes to developing limited groundwater resources in semi-arid areas. In many circumstances screened regolith boreholes or large diameter wells sited by exploratory drilling are a more cost-effective option than collector wells. However, improved siting of these wells will enable more efficient and widespread development of groundwater from basement aquifers with certain characteristics.

Increased use of these wells coupled with an increase in community gardening will at some stage have a quantifiable influence on the regional hydrology of south-east Zimbabwe. It is anticipated that research being carried out in the Romwe Catchment and related modelling studies will provide information on the influence of widespread introduction of groundwater-based gardens in basement areas. It is anticipated also that research being carried out in the Romwe Catchment will provide information on approaches to catchment management that are sustainable in terms of utilisation of resources both within the catchment and in areas outside the catchment that are influenced by activities within the catchment (Butterworth *et al*, 1995; Macdonald *et al*, 1995).

9.4 EFFECTS OF COMMUNITY GARDENS ON GROUNDWATER QUALITY

9.4.1 Background

Environmental problems associated with the intensification of agriculture have been apparent in the northern hemisphere for some twenty years or so. The link between a combination of expanding cultivated areas and increased fertiliser use and nitrate concentrations in groundwater has been extensively researched in both Europe and North America. Expensive measures to control nitrate pollution from agricultural sources are being implemented. More recently, pesticides originating from intensive cultivation have been identified in groundwater used for potable supply in Europe and North America, also requiring expensive measures to meet drinking water standards. While much of the work in temperate zones relates to cultivation without irrigation, nevertheless the same principles can be expected to apply to irrigated agriculture in tropical regions.

Concern has been expressed about the potential impact on groundwater quality from the intensification of agriculture in tropical regions. This impact could be felt in relation to nutrients, salinity or pesticides. However, much less quality monitoring information exists from which the overall situation with respect to the impact of agriculture on groundwater quality in tropical regions can be appraised. A recent study by BGS under the ODA TDR programme indicated that, for the most vulnerable aquifers, intensive agriculture can produce serious deterioration in groundwater quality, resulting principally from the leaching of nitrogen fertilisers.

Pesticide use has also produced major benefits for agriculture in reducing pest and disease attacks and weed competition. As for fertilisers, the increase in usage is now more rapid in some developing countries than in the developed world. Awareness of the leaching of nitrate has led to concern about the possible leaching of pesticides. There is now evidence of significant pesticide occurrences in groundwater in agricultural areas of Europe and North America, but hardly any routine monitoring of pesticides is carried out in developing countries. This is because of the sophisticated and costly analytical procedures, the wide range of compounds in common use and the care required in sampling (Chilton *et al*, 1995).

9.4.2 Pollution vulnerability of the basement aquifer

The risk of an aquifer becoming polluted depends on the interaction between the natural vulnerability of the aquifer and the pollution load imposed on it as a result of human activity. The pollution loading can be controlled or the source of pollution removed. The vulnerability of the aquifer cannot be changed; it is determined by the intrinsic properties of the material of the aquifer and the strata above it. An assessment of pollution vulnerability thus requires knowledge of those characteristics which determine the likelihood of the aquifer being adversely affected by an imposed contaminant load. These characteristics are:

- the thickness and nature of the strata making up the unsaturated zone
- the physico-chemical attenuation capacity of these strata, resulting from chemical reactions, adsorption and biochemical degradation.

Aquifers and the material above them can thus be assessed on the basis of their overall lithology and permeability and the depth to groundwater, and many schemes have been developed for mapping aquifer vulnerability. Taking extreme cases, a fractured coral limestone aquifer with very thin soil cover on a low-lying island with water table just below the ground surface would be highly vulnerable. A deep sandstone or limestone aquifer overlain by a significant thickness of confining clays would, in contrast, be relatively well protected from pollution.

Turning to the Basement regolith aquifers of southern Zimbabwe, although the water table is relatively shallow, within 5-10 m of the ground surface, both soils and aquifer material have low permeability. The almost ubiquitous rise in water level after striking water is an indication of the semi-confined nature of the regolith aquifer. Permeability is low, recharge is low, and unsaturated zone travel times are likely to be long, allowing adequate time for pollutant attenuation. The regolith aquifer is considered to have relatively low vulnerability to pollution from agricultural activities. Exceptions could occur, however, where local recharge reaches the water table more rapidly through fractures, quartz veins or stone lines. Further, the basaltic aquifers may be significantly more vulnerable to pollution because of the thinner soils, different weathering patterns and greater potential for more rapid transport of pollutants to the water table through the jointed and fractured lavas.

9.4.3 Fertiliser and Pesticide Usage in Community Gardens

Although nitrogen fertiliser usage is now increasing in some of the most rapidly developing countries at rates greater than in temperate countries (Chilton *et al*, 1995), the use of such fertilisers in the communal lands in Zimbabwe remains low. This was confirmed by an informal survey of gardens in Chivi Communal Area in 1991 (Lovell *et al*, 1992). Many garden members could not afford to purchase chemical fertilisers, which were in any case not always available in rural stores. Most gardeners applied animal manure if available, preferring goat manure to cattle manure and considering poultry manure to be even better. This is not surprising as, based on comparative figures for the UK, poultry manure should have significantly higher nutrient content. Application rates of one or two 20 litre buckets of manure to each bed per crop (Lovell *et al*, 1992) could be equivalent to a nitrogen application of some 250 kg N/ha. While this appears high, it is unlikely to be applied to all or even many of the beds in each garden. During the recent drought, for example, in the absence of cattle many garden members at Romwe used composted leaves as a substitute.

From the same survey it was clear that some cooperative gardens bought fertilisers, which were either used collectively or distributed amongst members. Thus, it was estimated (Lovell *et al*, 1992) that some 340 kg N/ha was applied to tomatoes and some 300 kg N/ha to cabbages. These seem somewhat high in relation to applications to similar crops elsewhere. Huang *et al* (1994) record applications of 250 kg N/ha to tomatoes in Florida and 170 kg N/ha to cabbages in Texas. Application rates are similar in the UK for cabbages, an average of 180 kg N/ha, but perhaps half of that quoted above for tomatoes. Although these applications are made at present only to a relatively small proportion of the garden, they are nevertheless close to the well and the estimates therefore require further refinement.

Pesticide usage in community gardens is also likely to be limited both by local availability and by cost. Nevertheless, a range of compounds are in regular use, dominantly insecticides. A preliminary estimate of their susceptibility to leaching can be made from consideration of the physiochemical properties of the pesticides (Table 18). Together with evidence from other regions of their occurrence in groundwater, this can be used to select target compounds for monitoring, although there are few published studies for any of these compounds.

The mobility, solubility and degradation classes used in Table 18 are arranged such that the low numbers indicate those which are most likely to be leached, and the high numbers those which are unlikely to penetrate beneath the soil. The compounds which are most likely to reach groundwater are those which are soluble, mobile and persistent. Thus, of the compounds listed in Table 18, lindane, dimethoate and diazinon have been observed elsewhere in existing monitoring programmes or have been shown by such means as lysimeter studies to be leached to groundwater. The last two were selected for monitoring by this approach in the BGS study in Barbados (Chilton *et al*, 1995), but neither was observed in subsequent sampling of groundwater. For the compounds listed and at the application rates given in Table 18, it seems unlikely that significant pesticide residues could infiltrate to the water table and thence to the collector wells. A potential cause for concern, however, might be the washing of knapsack sprayers close to the well, and extension advice should be used to guard against this.

9.4.4 Projected and Observed Groundwater Nitrate Concentrations

Estimates can be made of possible groundwater nitrate concentrations, if the volume of recharge and the leaching losses are known. In the absence of actual data for either of these, however, such estimates must be considered as indicative only. Thus, assuming a leaching loss of even 50 kg N/ha from the fertilised garden plots and a recharge of 50 mm/a from the irrigated land, nitrate concentrations in the recharge immediately beneath the garden could be of the order of 100 mg NO_3-N/l. However, this relatively high concentration applies only to a small percentage of the total recharge to the collector well. The proportion of recharge affected would be more significant where the well is within the garden boundary. Using a total annual groundwater abstraction of some 5500 m^3 (15 m^3 per day), and an overall recharge figure of some 25 mm/a, the area contributing recharge to the well is some 220,000 m^2, compared with the garden area of 5000 m^2. Nitrate concentrations in the balance of the recharge are likely to be negligible. It is unlikely that, with present inputs, nitrate concentrations exceeding the WHO guideline value of 11.3 mg $N0_3$-N/l will be observed in the collector wells. This might not apply, however, if further development success in the gardens resulted in greatly increased fertiliser inputs.

Table 18 *Susceptibility to leaching of pesticides used in community gardens in south-east Zimbabwe*

Active ingredient	Use	Type	Acute oral toxicity[1]	Mobility class[2]	Solubility	Soil half-life[3]	Average application (g/ha/a)	Detection in groundwater
Used in gardens								
Malathion	I	OP	III (1400)	5	4	1/2	50	
Carbaryl	I/G	C	II (850)	4	4	3	1000	
Amitraz	H	A	III (800)	6	6	1	300	
Dimethoate	I	OP	II (300)	2	2	1/2	100	Citrus unsaturated zone, Spain (Beltran *et al*, 1993)
Diazinon	I	OP	II (300)	5	5	3/4	70-120	San Joaquin valley, USA (Domasalski & Dubrovsky, 1992)
Lindane	I	OC	II (90)	6	6	4	-	Found at very low concentrations in many areas
Benomyl	F	C	V (>10000)	5	6	4	140-550	
Mancozeb	F	Zn-TC	IV (>5000)	5	6	1/3	1.4-1.9	
Potentially used							**Recommended**	
Tetradifon	I	OC	V (>10000)	8	6	?	20	
Dicofol	I	OC	III (600)	8	6	5	0.6-4.5	
Fenvalerate	I	P	II (450)	8	6	3	25-250	
Lambda-cyhalothrin	I	P	? (80)	9	6	3	-	
Tau-fluvalinate	I	P	II (>3000)	9	6	1	60-160	
Triazophos	I	OP	Ib (60)	5	5	?	320-600	

[1] WHO classification 1988-89 on LD50 (mg/kg) rates but adjusted to include dermal toxicity and other factors, from The Agrochemicals Handbook (1993).

[2] Based on K_{oc} and K_{ow} partition coefficients. (1 = most readily leached - 9 = unlikely to be leached (strongly sorbed), after Briggs (1981).

[3] From Pesticide Manual, 8th Edition 1987, Huang *et al* (1994) and Rao and Alley (1993)

Use	Type	Solubility class	Soil half-life classes
H = herbicide	A = amidine	1 = >100 g/l	5 = <10 d
I = insecticide	P = pyrethroid	2 = 10-100 g/l	4 = 10-30 d
F = fungicide	OP = organophosphorus	3 = 1-10 g/l	3 = 30-100 d
G = growth regulator	OC = organochlorine	4 = 0.1-1 g/l	2 = 100-300 d
	TC = dithiocarbamate	5 = 0.0	1 = >300 d
	C G= = carbamate	6 = <1-0.1 g/l	

Current nitrate concentrations for groundwater drawn from the collector wells are reported by Lovell *et al* (1994c) and shown in Table 19. At all of the six sites in the weathered regolith, nitrate concentrations are negligible (less than 1 mg NO_3-N/l), reflecting the low historical inputs from traditional dryland farming. At the two basalt sites, however, observed nitrate concentrations were twice the WHO guideline value, probably reflecting the greater vulnerability of the fractured basalt aquifer to pollution from the surface. This may arise from nearby pit latrines or from direct ingress around the well; it may be more difficult to seal effectively wells in a fractured formation than in the weathered regolith.

It is recommended that a simple routine of groundwater quality monitoring be established to confirm the sustainability of this type of garden development. Annual samples of groundwater should be taken from each collector well for major ion analysis. In due course, when facilities are available within Zimbabwe, groundwater samples could be collected for pesticide analysis.

9.5 COLLECTIVE COMMUNITY ACTION

It is becoming more accepted that the crucial issues of resource conservation and sustainable development can only be addressed if people enjoy a secure livelihood. Current development patterns and inequities increasingly force rural poor to subsist in marginal areas that have low productivity and that are ecologically fragile. Good and appropriate management of resources in these areas is crucial, if poverty and environmental degradation are to be avoided. Although no panacea, collective community action can play an important role in avoiding or reversing environmental degradation and in promoting sustainable development.

As discussed earlier, the availability and distribution of groundwater resources in basement areas is such that setting up private gardens for all members of a community is not possible. However, as has been demonstrated by this project, there are sufficient resources available for the implementation of community gardens. What has yet to be determined is whether the experience gained by communities from implementing and managing their community garden can be channelled into other community-focused projects (eg. community forestry or community feedlots) aimed at reducing environmental degradation and promoting sustainable development.

9.6 COMMUNITY PARTICIPATION

There are many advantages in using participatory approaches to the implementation of improved resource management practices. However, before employing a participatory approach it is important to understand that there are many levels of participation. The following is taken from the 1993-94 annual report of the International Institute for Environmental Development (IIED):

"One of the biggest recent changes in agricultural development has been the increasing adoption of the word "participatory" to describe the interactions between external professionals and local people. Although everyone says they are doing it, participation means different things to different people.

Many analyses have shown "participation" to be one of the critical components of success in irrigation, livestock, water and agriculture projects, and as a result, the terms "people's participation" and "popular participation" are now part of the normal language of many development agencies. Participation has become a fashion.

Table 19 Baseline water quality analyses for each collector well

	Date	pH	EC mS/cm	Na	K	Ca	Mg	HCO_3	SO_4	Cl	NO_3-N	Si	P-Tot	B	Fe_{Tot}	F	SAR meq/l	RSC meq/l	Faecal e.coli/ 105ml
Guidelines:				400					400		10.0				1.0	2			<2.5
Human Cons		8.50	0.70	900	2.0	400	60	600	900	500	10.0		2.0	2.00	20.0	15	15.00	<2.5	
Irrigation																			
LVRS C.Well	3/6/89	8.08	0.99	79	0.7	73	59	651	26	33	4.8	27.5	<0.5	0.14	0.02	0.9	1.66	2.1	-
	1/7/93	8.08	0.99	91	<0.5	88	85	599	25	152	8.4	31.3	<0.5	0.14	<0.02	0.9	1.65	-1.7	-
TSD C.Well	25/4/91	7.73	0.35	32	<0.5	26	19	253	9	42	1.1	37.7	<0.5	0.03	<0.02	0.3	1.14	1.2	-
	1/7/93	7.74	0.35	31	<0.5	25	18	202	4	19	3.7	38.0	<0.5	0.03	<0.02	0.3	1.13	0.5	-
Muzondidya	16/3/93	8.14	0.37	21	1.4	45	21	273	1	11	<0.4	26.8	<0.5	0.03	0.06	0.3	0.66	0.5	1.0
Gokota	1/4/93	8.19	0.29	23	1.6	32	12	203	2	9	<0.4	35.7	<0.5	0.03	<0.02	0.2	0.86	0.7	0.0
Dekeza	2/8/93	7.41	0.35	15	<0.5	22	18	175	1	13	<0.4	38.2	<0.5	0.03	0.37	0.6	0.56	0.3	5.0
Nemauka	17/6/93	8.06	0.44	54	2.3	37	13	301	1	16	0.9	30.4	<0.5	0.03	0.10	0.9	1.96	2.1	3.0
Mawadze	10/12/93	8.47	0.69	114	<0.5	27	12	320	1	61	<0.3	29.4	<0.5	0.03	<0.02	0.6	4.59	2.9	25.0
Matedze	2/5/94	8.34	0.42	18	0.8	25	29	211	25	10	<0.3	34.5	<0.5	0.03	,0.02	0.3	0.56	-0.2	50.0
Machoka	6/5/94	8.56	1.11	66	<0.5	9	106	455	8	89	23.1	36.9	<0.5	0.10	<0.02	0.4	1.33	-1.8	-
Masekesa	5/5/94	8.61	1.22	57	0.7	48	113	585	4	58	25.8	37.7	<0.5	0.07	<0.02	0.9	1.01	-2.2	-

All units are mg/l unless otherwise shown

SAR = sodium adsorption ration = $Na^{+}/((CA^{2+} + Mg^{2+})/2)^{0.5}$
RSC = residual sodium carbonate = $(CO_3^{2} + HCO_3) - (Ca^{2+} + Mg^{2+})$

This has created many paradoxes. For example, "participation" has been used to justify the extension of state control as well as the building of local capacity and self-reliance; it has been used to justify decisions imposed by external agencies as well as to describe the process of devolving real power and decision-making away from such agencies. But empirical analyses make it clear that only some types of participation lead to sustainable development."

Table 20 presents the seven types of participation identified by the IIED. These range from passive participation to self-mobilisation, where people take initiatives of their own without external prompting. It has to be said that the successful implementation of improved resource management practices will not be possible in southern Zimbabwe without the "functional" or "interactive" participation of local people and institutions.

Table 20 Different types of institutional and community participation

Typology	Characteristics of Each Type
1. Passive participation	People participate by being told what is going to happen or has already happened. It is an unilateral announcement by an administration or project management without any listening to peoples responses
2. Participation in information giving	People participate by answering questions posed by extractive researchers using questionnaire surveys or similar approaches. People do not have the opportunity to influence proceedings
3. Participation by consultation	People participate by being consulted, and external agents listen to views. This process does not concede any share in decision-making, and professionals are under no obligation to take on board people's views.
4. Participation for material incentives	People participate by providing resources, for example labour in return for food, cash or other material incentives. It is very common to see this called participation, yet people have no stake in prolonging activities when the incentives end.
5. Functional participation	People participate by forming groups to meet predetermined objectives related to the project. These institutions tend to be dependent on external initiators and facilitators but may become self-reliant.
6. Interactive participation	People participate in joint analysis, which tends to action plans and formation of new local institutions or the strengthening of existing ones. These groups take control over local decisions and so people have a stake in maintaining structures and practices.
7. Self-mobilisation	People participate by taking initiatives independent of external institutions. They develop contracts with external institutions for the resources and technical advice they need but retain control over how resources are used.

9.7 INTEGRATED CATCHMENT MANAGEMENT

Many institutions and international agencies are showing considerable interest in integrated catchment management (ICM) as a practical means of reducing environmental degradation and promoting sustainable agricultural development. The key features of an ICM programme are:

- ICM programmes comprise an overall strategy that clearly defines the management objectives, a range of delivery mechanisms that enable these objectives to be achieved and a monitoring schedule that evaluates programme performance

- Decision-making and action take place at the basin-wide, regional and local levels. Wherever possible, local communities should be involved both in decision making and in resulting activities

- Mechanisms and policies are established that enable long-term support to programmes of environmental recovery. This may not be attractive to bureaucrats and politicians who want a quick fix or another glittering initiative, it is nevertheless a fundamental requirement

Experience indicates that the aims of ICM programmes in semi-arid areas should be to:

- in the short term, prevent further environmental degradation and, in the longer term, restore degraded resources

- promote sustainable agricultural, industrial and urban development

- ensure appropriate resource use planning and management

- ensure a long-term viable economic future for basin or catchment dependents

- safeguard self-maintaining populations of native species

- preserve cultural heritage

- maintain the tourism potential and develop linkages between tourism and conservation

Experience also indicates that ICM programmes should recognise:

- that solutions must focus on underlying causes not merely their symptoms

- that issues must be approached in an integrated way

- in general, development of sound resource management will take place at the sub-regional or village level

There are many different combinations of interventions or measures that can be adopted for any given location. The successful identification and adoption of a package of measures at a given location will depend, to a great extent, on the participation of local institutions and communities. Hence it is important that local institutions and communities are directly involved in selecting the improved resource management practices that are most appropriate for any given area. The central institutions should concentrate on providing:

- a policy and regulatory framework that provides incentives to encourage preferred management practices and legislation to discourage inappropriate practices

- a coordinated framework that identifies and encourages local institutions and communities to take action

- a programme of education and information exchange

- a programme of research that involve the participation of local institutions (including extension services) and that is carried out outside research stations

- a programme of monitoring and review of progress of activities in the field and at different bureaucratic levels

It is planned that the Romwe Catchment and several catchments representing different physical settings in the NGADI project will be the location of long-term evaluation of the hydrological, agricultural and socio-economic effects of initiating and implementing an ICM programme. The collector well garden in the Romwe Catchment has already given this community a first experience of successful collective community action, and further activities are being planned with their interactive participation.

9.8 CLIMATE CHANGE AND COMMUNITY GARDENS

In southern Zimbabwe, drought is recurrent and high interannual variation in the amount and distribution of rainfall occurs. Furthermore, there is evidence of cycles of rainfall above and below average that appear to occur in phases of about 11 years or so (Butterworth *et al*, 1995). Obviously, such changes in climate can have important impacts on both surface and groundwater resources, and upon the effectiveness and sustainability of water resource development projects.

Given our current state of knowledge, it is impossible to quantify the possible influences on regional climate of widespread introduction of groundwater-based community gardening in semi-arid areas. However, as more scientific information becomes available, it may be necessary to consider the influence on regional climate of land use and irrigation when developing natural resource management strategies. In particular, the recycling of moisture by vegetation across continents is now considered to be an important process (Savenije, 1994). This is the process by which evaporation falls as rainfall, re-evaporates and falls as rainfall many times as an air mass moves across or circulates within a continent. Current theory suggests that irrigation during the dry season implies a loss of recycling capacity, as water evaporated during the dry season does not enhance rainfall for lack of rainfall-bringing mechanisms. In the context of irrigated gardening, this would mean that if the total irrigated area became significantly large, irrigation during the wet season would have a higher environmental benefit than irrigation during the dry season.

10 Conclusions

10.1 SCHEME IMPLEMENTATION

- Poverty and the physical environment are linked. If people are living in areas of poor soils above difficult aquifers they are likely to be poor and short of water. The corollary of this is that if poverty and shortage of water are used as the main criteria to select sites, prospective sites will include a high number that are technically difficult and some that are even impossible to develop. If, on the other hand, only physical and hydrogeological criteria are considered, prospective sites will include some where the communities are relatively well off.

- The resources needed to develop schemes in difficult areas will be higher but the communities and environment that benefit are likely to be the most needy. Whether these costs can be met depends largely on the aims and objectives of the donor. This project has highlighted the need to identify selection criteria during the design and costing stage of a project. Any project that uses cost per well as the main criteria for site selection will either overrun on costs, implement less cost-effective well designs or end up assisting less needy rural communities.

- Close liaison with district councils is vital in identifying ongoing and proposed water development projects and thereby avoiding duplication or conflicts of interest.

- Although there can be no substitute for genuine community interest and commitment, undertaking schemes on a ward-by-ward basis enables communities to see what is possible, be encouraged by progress at first schemes, and register their interest in the prospective project. Undertaking schemes on a ward-by-ward basis also allows communities to learn from each other more effectively and improves logistics of scheme construction.

- Experience has shown that monetary payment for work done should be avoided, whether this be payment by project staff or by other community members. In the former case, payment promotes neither sense of ownership nor good progress. In the latter case, payment causes difficulties because of the problems poor communities have in finding cash. Automatic membership of the project for those who do work is to be preferred.

- Successful siting and implementation of community gardens using groundwater draws on both social and physical criteria. Decision making is an inter-disciplinary process throughout that can best be achieved by a cross-discipline team of staff dedicated to the operation.

- Problems arise if the steps important to successful development of community gardens using groundwater are undertaken either by separate organisations, in the wrong order, or without supervision by a single authority. Success if wells are constructed by a drilling contractor for an NGO on behalf of a community, for example, will depend entirely on the close collaboration between all parties at all stages and regular cross-checks to ensure that all steps are taken and in the correct order.

- Both men and women from each community should be given training in pump maintenance and repair. A set of tools should be supplied with the pumps and be kept by a reliable scheme member. The well should also be registered with DDF in order to benefit from the third tier of their pump maintenance system that provides assistance in cases of emergency.

10.2 TECHNICAL AND ECONOMIC VIABILITY OF COLLECTOR WELLS

- Rainfall and geology are two principal physical factors influencing choice of well design. In southern Zimbabwe (average annual rainfall 400-800 mm) collector wells have been found to be particularly well suited in areas of younger undifferentiated gneiss and younger intrusive granite, but less well suited in areas of Karoo basalt. Collector wells could not be sited in areas of older gneiss complex because either depth of saturated regolith was insufficient or depth to watertable exceeded 15 m. Collector wells were also not sited on Beitbridge paragneiss in this project due to the high incidence of saline groundwater encountered. However, this geology underlies some of the neediest communal lands in the region, and it is recommended that the potential to use collector well laterals to skim fresh water from the upper layers of these aquifers should be tested in a small, independent R&D project.

- Other African countries having similar or even more favourable, climatic and hydrogeological conditions to those of southern Zimbabwe, and countries where collector wells should be particularly well suited include Malawi, Uganda, Tanzania and parts of Ethiopia.

- Basement complex aquifers in southern Zimbabwe have been found to be highly discontinuous and variable over distances of only a few meters. Consequently, when searching for water sufficient to support domestic use and community gardening in this region, it is important to identify a prospective area (4-10 km^2) rather than specific location. In southern Zimbabwe, this can usefully correspond with a Vidco (village development committee) comprising of several kraals or villages.

- It is important to acknowledge the vital role of exploratory drilling in locating optimum sites for water points in this region. Present geophysical methods do not have sufficient resolution to locate optimum well sites in terrain of such high spatial variability.

- At all project sites, a consistently adequate supply of water for domestic use and small-scale vegetable production has been obtained from the shallow regolith aquifer, both by large diameter wells (17.6 m^3/day, on average) and collector wells (25.9 m^3/day, on average).

- The increase in sustainable yield obtained by lateral drilling is variable but on average is significant at 38 per cent improvement on basement aquifers.

- Some screened regolith boreholes drilled by the project gave higher yields than yields of existing conventional deep boreholes. This is important, as it suggests that: a) siting deep boreholes by shallow exploratory drilling in the regolith to identify the greatest depth of saturated weathering may be a reasonable approach for helping to overcome the spatial variability found in the deeper aquifer, and b) boreholes in this region would generally be better if screened in the regolith rather than cased.

- The challenge for future groundwater resource development in the communal lands of southern Zimbabwe is suggested to lie in quick and cost effective identification of the appropriate well design and location within a given area. Practical examples taking data from the pilot project illustrate that rapid exploratory drilling, simple pumping tests of exploratory holes and existing water points, and limited geophysical surveys, can be used in conjunction with a hydrogeological decision tree (Figure 9) to determine the most appropriate well type and location within a given area.

- Social factors should also be considered during selection of well design. The sense of ownership that a community achieves from digging their own well increases the likelihood of their assuming responsibility for maintenance and management of the water point. The ability to attach several pumps to a well is also a major advantage compared to a borehole. It provides a safety net in the case of one pump breaking, and the relatively shallow depth reduces wear and tear on pump parts and the effort required both to lift water and lift the pumps during repair.

10.3 SOCIAL AND ECONOMIC VIABILITY OF COMMUNITY GARDENS

- Many social, environmental and economic factors influence well and garden performance. To date, project schemes are economically viable and water use efficient, with an average IRR of 19 per cent, average total gross margin per hectare per year of Z$24000, and an average gross margin per unit of water (Z$/ha/m) of $43800 per scheme (1994 figures).

- The schemes seem able to meet the range of competing needs for water supply and vegetables at the different sites.

- Leadership is the principal social factor influencing scheme performance but within most communities there appears to exist the necessary qualities of leadership, experience of gardening, and local institutional structures to make this type of community project successful. Where such qualities or structures are lacking or temporarily fail, trained facilitators can help enormously in resolving difficulties.

- Garden committees can experience a rapid change of personnel during first cropping seasons.

- Members of new gardens benefit from being able to visit established gardens and discuss issues of leadership, garden management, pump repair and crop husbandry.

- Despite social and institutional "teething" problems, production figures indicate that garden output stabilises at an acceptably high level relatively quickly. One senses however that greater things are still possible. Markets are not yet being fully exploited and members of some schemes report being constrained by present management structures that rely on decisions to be made by committees and certain key activities to be undertaken as a group. At some schemes, members are beginning to tend their own allotments more independently within the communal fence.

- Good and appropriate extension advice is important. It takes time for inexperienced gardeners to become aware of market opportunities and the value of different cropping patterns. Increased advice on marketing strategies, pest and disease control, irrigation methods and schedules, and the growing of vegetables during summer is needed.

- Women benefit particularly from the income generated by the schemes, managing and investing the money generated, and retaining authority over garden decisions and labour.

- The schemes can possess a wide and sometimes erratic range of benefits and, particularly, costs. More work is needed to formulate a decision support system to guide siting decisions that are based both on the certain and the uncertain social, environmental and economic costs and benefits a scheme may involve.

10.4 AGRO-ECONOMIC PERFORMANCE OF COMMUNITY GARDENS

- In contrast to large-scale irrigation schemes, small- or garden-scale irrigation schemes fit well into traditional farming systems.

- There are advantages and disadvantages of community gardens compared to private gardens. However, in crystalline basement areas, groundwater resources are often so limited that it is usually only possible to develop small numbers of wells in an area that have sufficient yields to meet domestic and stock water requirements and still have sufficient excess capacity for a garden to be set up. If these are used for private gardens instead of community gardens, inequity within rural communities is amplified. Although community gardens improve equity, they are more difficult to initiate and manage.

- Notwithstanding the very different objectives, the cost per hectare for developing collector well gardens is similar to that for developing larger irrigation schemes using dam water.

- Management of project gardens is currently being carried out partly on a cooperative basis and partly on an individual basis. This results in sole planting of large blocks. However, there are some indications that on some gardens some members intend to plant individually in order to maximise the income generating potential of their allotments.

- Although irrigation of the gardens is reasonably efficient, there is scope for improving efficiencies by gardeners adopting practices such as mulching, subsurface pipe and low-head drip irrigation. More participatory extension is required to help gardeners improve their irrigation practices as well as all other aspects of crop selection and management.

10.5 INSTITUTIONAL VIABILITY OF COLLECTOR WELL GARDENS

- There is a critical need to enhance institutional capacity in Zimbabwe to implement sustainable well points and community gardens in the future.

- The pivotal role of a national Government body in overall planning, coordination and financial responsibility requires the placing of a representative and accountable institution at the centre of this future development.

- At provincial level, a Government body must provide coordination with other activities in the province and bring appropriate inter-disciplinary team skills and experience to bear during scheme implementation.

- At district level, the pivotal role of local authorities in requesting and overseeing operations must be structured to take account of the need to build capacity at this level to plan and manage district development programmes and to take a fuller part in all their aspects in future.

- At village level, involving local communities in all aspects of the ownership, management and maintenance of their resources is critical and must inevitably involve equipping these same communities with the necessary information and education. Information and education is needed to assist local communities and extension staff to fully benefit from the development of the water points and gardens and to make sensible and rational choices on such matters as garden management, catchment management, leadership, book-keeping, pump maintenance, integrated control of pests and diseases, irrigation methods and schedules, and crop marketing strategies.

- The increasing emphasis on community involvement and empowerment requires a very different approach to community level training than implied in the phrase "mobilisation". The people are not to be mobilised to fulfil top down directives or meet pre-established planned programmes. Rather, they are to be equipped to make sound decisions and to be able to plan, implement and manage their own resources in their own way to suit their own needs and social structures. The required village level training programmes should be flexible and responsive to community needs and initiatives, rather than formalised or 'top down' in nature.

10.6 ENVIRONMENTAL APPRAISAL OF COLLECTOR WELL GARDENS

- Although variable in space and time, current use of groundwater in the communal lands of south-east Zimbabwe is only about 4% of average annual recharge, which is of the order 2-5% of annual rainfall. Increased use to develop community gardens thus appears viable if the available aquifers can be appropriately developed and managed.

- Land use and management have a significant influence on hydrological processes including groundwater recharge. Consideration should be given to land use and management in the vicinity of groundwater-based gardens to protect recharge and ensure physical sustainability of the schemes.

- It seems likely that increased use of groundwater for community gardens will have an influence on dry-season river flows, however, the importance of the influence is difficult to quantify given data currently available. Data and modelling work from catchment studies such as Romwe should provide insight and identify methods to minimise this effect.

- Average abstraction recorded per scheme is 3,200 m^3/year (8.76 m^3/day or 81 gallons/hour). This is very small when compared to abstraction rates of 10,000 gallons/hour often quoted by farmers irrigating commercial crops from high yielding boreholes in this region. Any environmental consequences of developing community gardens using groundwater should be considered in this context.

- Similarly, deforestation, overgrazing and the clearing of marginal land for rainfed cropping have had, and continue to have, major detrimental effects upon catchment hydrology and dry-season river flows in this region. In contrast, the development of community gardens using groundwater has little risk of negative consequences but may have far-reaching environmental benefits by helping to alleviate some of the pressures that presently cause these problems.

- Concern has been expressed about the potential impact on groundwater quality of the intensification of irrigated agriculture in tropical regions. The regolith aquifer of basement rocks is considered to be relatively vulnerable to pollution because of the shallow water table, but the weathered material forming the aquifer contains a significant clay fraction and has low permeability. As yet fertiliser and pesticide usage in community gardens in southern Zimbabwe is limited, and the potential threat to groundwater quality is low. This could change if agro-chemical usage increased with time, and a simple, annual programme of groundwater quality sampling is proposed.

- There remains a critical need to ensure that any new investment in water and garden facilities does not fail through failure to protect and monitor the groundwater resource. Community participation in the development of small-scale irrigation using groundwater provides the ideal springboard to other community projects, especially in health, agriculture and the environment. Future development of wells and gardens should proceed hand-in-hand with programmes of community-based catchment management and monitoring, building on the opportunity and incentive that the initial water development project provides.

11 Recommendations for future work

11.1 DEVELOPMENT OF GROUNDWATER-BASED GARDENS IN ZIMBABWE

The pilot project reported here has shown the enormous potential for widescale implementation of community gardens in crystalline basement areas and the wide range of social, economic and environmental benefits that can accrue from such gardens. As part of the pilot project, a proposal has been prepared for a much larger project that will build capacity within departments of the Government of Zimbabwe and implement a further one hundred community gardens over a period of four years. This larger project, which is called the NGADI (Nutrition Gardens And Groundwater Development In Zimbabwe) Project, will use and develop further the guidelines produced during the pilot project. It is strongly recommended that the NGADI Project be funded and started as soon as possible.

11.2 DEVELOPMENT OF GROUNDWATER-BASED GARDENS IN SOUTHERN AFRICA AND ELSEWHERE

Consideration should be given to evaluating the potential for developing basement aquifers for community gardening throughout the SADC region and in the other basement areas of Africa and Asia. In principle, pilot projects outside Zimbabwe need to be large enough to justify the purchase of horizontal-drilling rigs. Alternatively, agreements could be entered into with drilling contractors who would be willing to purchase and operate horizontal-drilling equipment in the SADC region and elsewhere on a commercial basis. To date, drilling contractors have not been willing to take the risk of purchasing horizontal-drilling equipment. However, the inception of the NGADI Project and the many donors wishing to fund collector wells in Zimbabwe may prompt a contractor to purchase horizontal-drilling equipment.

11.3 CONTINUED MONITORING OF EXISTING COLLECTOR WELL GARDENS

It is strongly recommended that funding be allocated for the continued monitoring of the schemes implemented by the pilot project. As the institutional structures that manage the schemes are still changing, it will be interesting and instructive to observe their development over the next few years. It is also clear that the management of gardens is changing rapidly as garden members gain confidence and experience and look for new marketing opportunities. Finally, the combined hydrological, hydrogeological, agricultural and socio-economic data sets for each scheme are already unique and of enormous potential value in future research studies of groundwater development in semi-arid areas. Extending the run of these data sets would increase their value further as well as being relatively inexpensive. Continued monitoring of the wells should also consider the following:

- the impacts of increasing livestock numbers (assuming livestock numbers continue to recover following the 1991/92 drought) on the environmental sustainability of land near to schemes and the socio-economic spread of benefits of well water;

- the value of the schemes during cycles of good and bad rainy seasons in terms of how much water the schemes supply and who benefits;

- the long-term sustainability of the schemes in terms of groundwater recharge and groundwater quality;

- the changes in income levels for scheme members and non-members over time to ascertain if there are significant differences;

- the marginal opportunity cost of working in the gardens as compared to the marginal benefit of working in rainfed fields, and the income elasticity of demand for vegetables and staples with a view to predicting gardening and rainfed cropping strategies;

- the land tenure systems that develop on gardens;

- the influence that the Economic Structural Adjustment Programme (ESAP) has on community gardens and, in particular, on marketing and purchasing strategies;

- the environmental benefits of groundwater-based gardens. Further monitoring will enable the total economic value of the schemes to be calculated and compared to other water supply or development projects.

11.4 IMPROVED MANAGEMENT OF GARDENS

It is recommended that a research project be carried out in parallel with the NGADI Project to look at ways and means of maximising the benefits that can be realised from groundwater-based community gardens. Although the pilot project schemes are performing acceptably well, the results of monitoring and research at LVRS would suggest that there is considerable scope for improving their subsequent management. Although agricultural extension workers provide schemes with some advice, they would benefit with improved guidelines on crop husbandry, integrated pest and disease control, improved irrigation methods, and cropping strategies aimed at taking more account of market demands in terms of crop quality and timing of production. These guidelines could be developed most effectively by carrying out trials on pilot project schemes with the participation of the scheme members.

11.5 GARDEN MEMBERSHIP

The pilot project has used, or rather allowed the different communities to use, different approaches to selecting the households or individuals that have plots on the community gardens. Communities have also been allowed to make their own decisions on the size of plot or holding within a garden. Size of plot determines the number of members a garden can have as well as being directly related to the returns that can be generated by a plot. Although there are definite advantages in giving communities a free hand to make decisions on garden membership, research is required on whether they should be given more guidance. The issues of garden membership and water rights are pivotal when considering the equitable distribution of benefits that a scheme can deliver. Research should be carried out on the feasibility, advantages and disadvantages of introducing water rights, permits or pricing of groundwater as a means of improving the equitable distribution of scheme benefits. This research should also consider land tenure and issues related to the expansion of the gardens whether this be size of the garden or the number of members or both.

11.6 OPTIMAL USE OF POOR QUALITY GROUNDWATER

Poor quality groundwater represents a valuable and under-utilised resource that is present in many semi-arid areas of Zimbabwe and elsewhere. It is recommended that further research be carried out on the potential of using collector wells as a means of exploiting the relatively poor quality groundwater sometimes found in the regolith aquifers. Sites in Zimbabwe have already been identified which would be appropriate for carrying out this work. Further research is also warranted on irrigation with poor quality groundwater via subsurface clay pipes and low-cost drip irrigation. Results from trials at the Chiredzi Research Station have demonstrated that these methods have the potential to improve yields, water use effectiveness and crop quality with good and poor quality irrigation water. On-farm trials of subsurface and low-cost drip irrigation using poor quality groundwater are now needed.

11.7 DECISION SUPPORT SYSTEM FOR DEVELOPING WATER RESOURCES IN SEMI-ARID AREAS

The pilot project reported here has produced a decision tree that can be used as a guideline for selecting the most appropriate design of well for a given location. It is recommended that this decision tree be developed further to include more social, environmental and economic decision support. The decision tree should also be expanded to enable rational decisions to be made regarding surface and groundwater resources when there is the option of developing surface water resources. As cost-effective siting of wells is a key component of NGADI, the continuing development of new geophysical techniques for siting wells should be kept under close review.

11.8 INTEGRATED CATCHMENT MANAGEMENT

Finally, one of the most exciting benefits of groundwater-based community gardens is that they can provide an initial step to other community-based activities that are aimed at improving resource management, reducing environmental degradation and promoting sustainable development. It is planned that a major component of the NGADI Project will be the development of environmental management plans for each scheme by the participating communities. It is strongly recommended that a similar approach be adopted by other projects that are developing groundwater-based gardens. It is also strongly recommended that funding be continued for the Romwe Catchment Study which is providing a field evaluation of the potential of integrated catchment management as a means of arresting environmental degradation in semi-arid areas of Zimbabwe.

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Annex 1: Site selection criteria adopted at the beginning of the project

Geographical

(a) Within a Communal Area of Natural Regions IV or V (ie. Chivi, Nyajena, Ndanga, Matsai, Sangwe, Matibi 2, Matibi 1, and possibly Maranda, Sengwe and Belingwe).

(b) In an area presently without reliable water sufficient to allow gardening, perhaps an area remote from dams, perrenial rivers or alluvial aquifers.

(c) On a basement complex rock or other problem aquifer where extraction of groundwater can be improved by use of the collector-well principle (perhaps wells exist but provide insufficient water to allow gardening at present).

Hydrogeological

(d) Where groundwater is found 12 metres or less below ground level, 15 metres if permeable material is found immediately beneath.

(e) The groundwater found is of a quality suitable for irrigation and domestic use.

(f) Wells can be dug by hand

Socioeconomic and agricultural

(g) The village group, found to be in need of vegetables, shows a strong interest in developing a community vegetable garden, and a willingness and ability to adopt new production techniques.

(h) The village group shows a willingness to allocate an area of land for use as a community garden and collector well site, the area henceforth to be available for the community and not overly influenced by any one single party.

(i) Perhaps a history of gardening exists in the area, but previous gardens were abandoned for legitimate reasons (eg. water at present insufficient to allow gardening).

(j) Though vegetables will be grown primarily for home consumption, access to a market should exist for surplus to be sold locally.

(k) A site chosen should ideally be one of several potential sites in an area, allowing other schemes to be developed following success of the first scheme.

(l) Many families (for example, more than 100) would benefit directly from the collector well garden if implemented.

Annex 2: Informal contract with community

Lowveld Research Stations
PO Box 97
Chiredzi

17 January 1994

To The Community:
Mushungwa & Chigarera VIDCOs
Ward 27, Zaka District

AGREEMENT FOR CONSTRUCTION, MAINTENANCE AND OWNERSHIP OF A COLLECTOR WELL AND COMMUNITY GARDEN IN YOUR AREA

Subsequent to our meeting of 6 December, in which your community expressed interest in contributing towards construction of a collector well and community garden in your home area, the following information is provided for your help and the following conditions outlined for your approval:

Ownership

- The collector well and community garden once completed will belong entirely to you the community.

- This project is designed to allow you the community to help yourselves by allowing you to contribute to construction and subsequently to manage your own well and community garden.

- The well and community garden will belong entirely to you and not at all to visiting project staff. These people will take part only during construction, helping you to create you own project. Thereafter, these people will visit only to see how things are going. Your help in providing information during these visits will be appreciated.

Construction

- During construction, project staff will provide:

  A resident foreman to supervise construction
  Materials for the well eg. steel lining, cement
  Digging tools eg. spades, picks, boots, hats
  Machinery and fuel eg. compressor, jack hammer, diesel
  Steel fence for a garden 75m x 75m square
  Cement for well headworks and garden fence posts
  Crushed stone filter for the well
  Two Zimbabwe 'B' type Bushpumps for the well
  Tools, rope, a manual and a gantry for pump repair

- The community should provide:

  Five strong men per day to dig the well. Working under direction of the foreman, it is probably best if each group of five men works for six days at a time before changing to the next group of five men. Digging will take approximately 6-7 weeks to complete depending on progress.

  Security for equipment left at the site. It is probably best if the community organises a night watchman system.

Labour to erect the garden fence. Working under direction of the foreman, many hands will make light work.

Collection of river sand, stones and rocks, and manufacture of bricks as required eg. for a small header tank. A local builder will be helpful.

Four men and four women to be trained in pump repair.

Management

- As mentioned above, all benefits from the well and garden once completed will belong entirely to you the community.
- As the sole owners of the project you will be responsible for all decisions regarding management.
- Most importantly, as the sole beneficiaries of the project, you will also be responsible for all upkeep, maintenance and repair that will be necessary for your project. This will include maintenance and repair of pumps on the well.
- Following construction and training as described above, outside staff can provide no further assistance or materials. The community should make arrangements to ensure that they can perform or pay for all necessary maintenance and repair of their project and any improvements that they might wish for in the future.

Suggestions to help start the project successfully

- Considering the above, the community should decide quite quickly who wishes to be involved and to contribute to a project as described.
- A community meeting to discuss the project might help, but efforts should be made to ensure that all interested people are informed of this meeting to allow them to attend.
- Once membership is decided, a small fee can be collected from each person (perhaps $10-$20). This money can be used by the community to form a first project fund to be used to buy seeds, sprays etc needed for the first cropping season.

Agreement

- If, upon reading this letter, you the community wish to contribute to the construction of a collector well and community garden in your home are as described above, you agree to provide the community contributions outlined, and you agree to be fully responsible for all management, upkeep, maintenance and repair of the project once completed, please select a representative of the community to sign below, printing also his/her name and position in the community.

Signature: ....

Name: ....

Position: ....

Date: ....

Annex 3: Capital costs for a hypothetical programme of 250 schemes

Capital costs for establishment of a collector well and comparisons with a borehole (non-commercial approach using S.African 2mm steel well lining)

This considers the case whereby Government itself undertakes the construction of the collector well. Therefore the 13% interest rate is used both for writing off the equipment used in building the well and for writing off the well itself. Also no profit margin is included. This has the effect of reducing both the capital cost of the well and the annual capital charge. It therefore involves a significant subsidy by Government.

Costs are for South African steel well lining, lorry-mounted drilling rig by Demco, and pick-up trucks rather than Landrovers where possible. Personnel costs remain for a full multidisciplinary team.

				Annual costs		Avg.cost
	Z$ inc.tax	Life years	R&M %	ACC	R&M	Z$ / well
1. Digging equipment						
Small compressor	97 300	10	2.5	17 932	2 433	4 073
De-watering equipment:						
Diaphragm pump	16 250	10	50	2 995	8 125	2 224
Air line	1 200	2	0	719	0	144
Hose (3" by 40m)	2 160	2	0	1 295	0	259
Jack hammer	10 000	10	5	1 843	500	469
Air line	1 200	2	0	719	0	144
Points (3 / well)	600					600
Manual winch	1 200	10	0	221	0	44
Cable	700	1	0	791	0	158
Kibble	600	10	0	111	0	22
Concrete mixer	27 500	10	1	5 068	275	214
Gantry	4 524	10	0	834	0	167
Oil drums (4)	200	2	0	120	0	24
Tent	3 000	5	5	853	150	201
Steel shed	3 575	10	0	659	0	132
Gum boots (6 pairs)	410	1	0	463	0	93
Goggles (2 pairs)	50	1	0	56	0	11
Hard hats (2)	50	1	0	56	0	11
Gloves (5 pairs)	95	1	0	107	0	21
Pick axes (3)	160	1	0	181	0	36
Shovels (3)	250	1	0	282	0	56
Wheelbarrow	400	2	0	240	0	48
Sub-total digging equipment						9 151
2. Drilling equipment						
Drilling rig & lorry	1300 000	10	5	239 587	65 000	12 183
Landrover (2)	460 000	10	5	84 777	23 000	4 311
Pick-up truck (3)	360 000	10	5	66 347	18 000	3 374
Trailer (2)	40 000	10	5	7 372	2 000	375
Bowser	20 000	10	5	3 686	1 000	187
Sub-total drilling equipment						20 431
3. Staff	Z$ / month					
Agric. Extension Officer	3 000					1 440
Community Devt. Worker	3 000					1 440
Driller	4 000					1 920
Pump Test Engineer	3 000					1 440
Scientist / monitoring	3 000					1 440
Mechanic	3 000					1 440
Assist. Driller / Crane op.	3 000					1 440
Foremen (5)	1 200					2 880
Sub-total staff						13 440

4. Other costs per well

	Z$ / litre	Litres	
Diesel fuel	2.02	3000	6060
	Z$		
Hand pump (2) & headworks	7000		7000
Brickwork	1000		1000
Crushed stone	1800		1800
	Z$ / metres	Metres	
Lining (SA Armco 2.0mm)	1215	15	18225
Sub-total other costs			34085
GRAND TOTAL (non-profit making)			77107

Assumptions

Discount factors (13%): No. years:

1	0.885
2	1.668
3	2.361
4	2.974
5	3.517
6	3.998
7	4.423
8	4.799
9	5.132
10	5.426

No. wells dug / team / year	5
No. wells drilled / year	25

Borehole costs by non-profit making driller (DDF) (55m hole)

1. Using handpump

	Z$	
Average total cost	25000	
Success rate (%)	51	ie. borehole which gives 0.3l/s
Real cost per success *	49020	

2. Using motorised pump

	Z$	
Borehole cost less handpump	22000	
Success rate (%)	36	ie. borehole which gives 0.6l/s
Real cost per success	62857	
Cost of motor pump	28000	
Total cost per borehole	90857	

Comparisons of yield and costs

Pumping rates (li / sec):	
Collector well (handpump)	0.3
Borehole (handpump)	0.3
Borehole (motor pump)	0.6
Pumping hours per day	7
Handpumps per collector well	2
Handpumps per borehole	1

Maximum yields (li / day):	Li / day	Cu m / year
Collector well	15120	5518.8
Borehole (handpump)	7560	2759.4
Borehole (motor pump)	15120	5518.8

Annual Capital Charge (Z$ per year):		
Collector well	14211	10 years at 13%
Borehole (handpump)	9034	10 years at 13%
Borehole (motor pump)	16745	10 years at 13%

Average Capital cost per cu m water:		
Collector well	2.57	
Borehole (handpump)	3.27	
Borehole (motor pump)	3.03	plus operating costs