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Tampere University of Technology
Department of Civil Engineering
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Cost Analysis in Rural Water Supply in Mbeya Region, Tanzania

Tampere, Finland 1990

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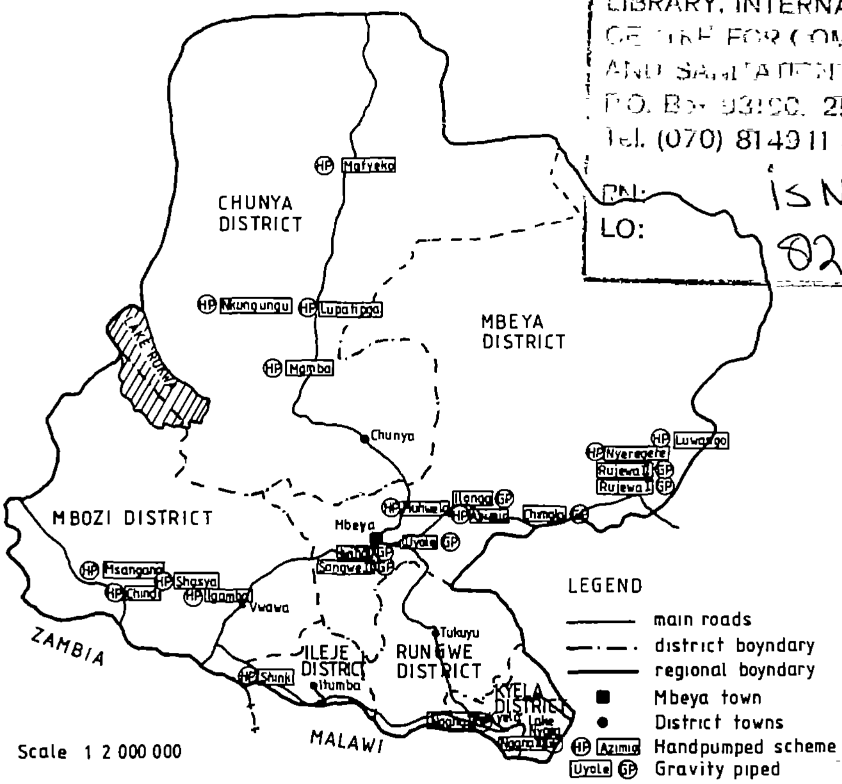

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COST ANALYSIS IN RURAL WATER SUPPLY IN MBEYA REGION, TANZANIA

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ABSTRACT

The study deals with cost analysis in rural water supply in Mbeya region, Tanzania, covering investment as well as operation and maintenance costs for different technologies.

All observations in the report are result of the analysis of piped gravity schemes covering 59 villages and 13 handpumped schemes.

Main factors influencing both capital and running costs identified in the Danish International Development Agency (DANIDA) -supported water project in Mbeya region in Tanzania have been studied. The study has been limited to piped gravity and handpumped supplies. Information regarding other types of technology is limited and therefore difficult to assess. A brief attempt was made to relate specific consumption to water supply scheme costs.

Available cost data from the donor agency working in the study area was compiled and analysed. Relevant literature, including physical project progress reports, regarding cost of rural water supplies was reviewed. A seasonal water-use study in selected water systems was carried out to estimate specific consumption.

The annual costs, including capital and running costs, per capita of providing improved water supply to rural population in Mbeya region based on DANIDA implementation set-up are about TZS 170 for gravity piped systems and TZS 100 for handpumped systems (1989 prices). This is based on direct scheme expenses excluding overheads, and zero rate of return.

In piped gravity supplies about 70 % of capital costs are due to pipes with accessories. In handpumped systems about 50 % of capital costs are caused by transport. On the other hand, labour and transport tend to be critical regarding operation and maintenance for the scheme types if centralized maintenance is practised.

Village scatteredness has been observed to influence the units cost. Also distances between villages have a large influence on construction cost.

Specific consumption figure of 25 l/cap/d adopted by the project since 1982, needs to be revised in light of recent water-use study reports.

Handpump technology is the cheapest in terms of capital costs. However, it exhibits higher running costs. Operation and maintenance (O&M) cost data is still limited to be conclusive. All costs refer to direct scheme expenditures excluding project overheads such as consultancy fee, equipment, etc. which can be as high as 60 % of the total scheme costs.

Improved O&M cost data collection procedure is needed. These costs need to be shown separately, year by year instead of being accumulated. For future sustainability of water supplies, only village level operation and maintenance (VLOM) should be promoted.

Water users are expected to meet O&M costs of their water supplies, a case of partial cost recovery assumed by the project. Annual follow-up of O&M water fund established in all handed over supplies is essential to access its adequacy in meeting scheme running costs.

Cost analysis study should be extended to other project regions of Iringa and Ruvuma to improve accuracy of the study findings.

When no value is given for the time spent on hauling water, handpumped systems constructed in Mbeya region in Tanzania with DANIDA funding support cost nearly 60 % of an equivalent standpipe gravity supply.

1 INTRODUCTION

The costs of supplying water and sanitation services in rural areas can vary considerably even within the same programme, depending on the technology selected, the environment, construction and maintenance regimes and several other factors. The available data on range of costs is usually limited, making generalization difficult.

The Danish International Development Agency (DANIDA) has supported implementation of improved water supply schemes in Mbeya region for the last decade, coinciding with the International Drinking Water Supply and Sanitation Decade (IDWSSD). Considerable experience has been gained during implementation regarding the cost of supplying water.

Actual scheme cost monitoring was introduced in early 1986 to follow the investment costs for different scheme types. The project has four-year cost record data on which the analysis for capital costs has been based. Expenditures prior to 1986 are project cost estimate figures.

Recording of operation and maintenance (O&M) costs for completed water schemes started in mid-1987. Costs of spare parts required for running of schemes are collected from the regional mobile maintenance units. The analysis of recurrent costs is based on centralized maintenance from the regional headquarters. Available data is very limited, as most of the schemes are new. In any case, O&M needs will increase with scheme age.

However, it is better to solve a problem with a crude approximation and to know the answer, plus or minus 10 %, than to demand an exact solution and not to know the answer at all (Park and Jackson 1984).

Particular scheme types have been noted to cause O&M problems especially with village level operation and maintenance (VLOM). Examples of such schemes include diesel powered pumped systems. Implementation and therefore cost analysis have been limited to VLOM technology options, namely gravity piped and handpumped supplies.

2 RURAL WATER SUPPLY DEVELOPMENT IN TANZANIA

2.1 Rural water supply situation in Tanzania

Tanzania has a total area of about 937 000 km^2 including inland waters. According to 1988 census the country had a total population of 22.5 million, out of which over 18.0 million lived in rural areas. Administratively Tanzania is subdivided into 20 regions with a total of 8 650 villages excluding regional capitals. Consequently water supply development issues are handled on regional basis.

Development of water supply in Tanzania dates back to 1946 when the Water Department and Irrigation Division was started. Prior to 1946, water development and provision of sanitation facilities to the rural population was not organized. In 1965 the Tanzanian Government started financing all investments and in 1970 it even covered the O&M costs.

The Arusha Declaration in 1967 demanded among other things, provision of essential services and basic needs distributed fairly well among rural population. The target was to provide all people with wholesome water of adequate quantities within reasonable reach, free of charge (MAJI 1989).

In pursuance of this directive, the Twenty year rural water supply programme (RWSP) (1971-1991) was launched in 1971. Regional water master plans (RWMP) were prepared to establish available potential water resources inventory considering also water quality aspects. Through assistance of various donor agencies (Table 1), 16 out of 20 regions have been covered by the year 1983. The coverage situation has not changed by 1990. The approximate current costs for preparation of each RWMP are also indicated in Table 1.

Table 1. External support for water master plan preparation in current prices (Katko 1987 modified by the author).

Donor	Regions and years	Costs USD x 10^3
Canada	Coast - Dar es Salaam	2740
Denmark	Iringa - Mbeya - Ruvuma	5170
Finland	Mtwara - Lindi	3180
FRG	Tanga	1670*
Japan	Kilimanjaro	n.a.
Netherlands	Shinyanga	1500
Norway	Kigoma - Rukwa	5300
Sweden	Kagera - Mara - Mwanza	3810
World Bank	Tabora	1270
	1970 1975 1980	
9 donors	16 regions 1971 - 83	26 600

* assistance agency staff estimate

n.a. = not available

Improvement in the rural water supply situation in Tanzania has in recent years grown into a major policy matter for the central government. Policy decisions regarding provision of piped water supplies giving easy access to domestic points and providing clean, potable and reliable water have been taken. The policy received full support with the United Nations International Drinking Water Supply and Sanitation Decade (IDWSSD) (1981-1990) aiming at providing safe water and adequate sanitation facilities. The government of Tanzania has now revised the target date to year 2000 (DANIDA 1988 a).

The objective of covering all villages is still quite distant although remarkable progress has been achieved. On national level, about 50 % of the rural villages are presently served, covering a total rural population of 8.5 million representing about 46 % of total population (MAJI 1989). The numbers, however, still give too optimistic picture, because it is reported that at least 40 % of all systems built are not functioning (DANIDA 1988 a). This leaves only a population of 5.1 million or 30 % of the total rural population, served with adequate water supply. However, Katko (1989) quotes only 40 % of constructed rural water supply schemes to be operative.

In Tanzania a large number of bilateral and multilateral donors have been active in the water and sanitation sector, some for as long as the last 18 years. Principal among them are DANIDA, Dutch Aid, FINNIDA, GTZ, Italy, JICA, NORAD, SIDA, UNDP, UNICEF and the World Bank. It has been estimated that the annual assistance to the sector ranged from USD 30 - 50 million (DANIDA 1988 a). While the World Bank assistance has largely concentrated in the urban areas, the bilateral donors have mostly been active in the rural areas. In case of rural water supplies, the assistance has been based on donor 'concentration approach'. The question is whether to review this approach as an attempt to enhance balanced development in the sector.

Arusha seminar in 1986 reviewed major problems particularly affecting water and sanitation sector in rural areas and made recommendations for improvements. This was followed by a workshop in Morogoro in 1988 on O&M aspects for rural water supplies.

MAJI (1989) has presented several policy papers on standardization, community participation, recovery of maintenance costs, ownership of schemes, etc. to the government for approval.

The evaluation of rural water supply situation in Tanzania carried out by special shallow well technical committee observed that the technological mix in use was approximated as shown in Table 2 at 1983 price level.

Table 2. Rural water supply technology mix in Tanzania in 1983 and 1988 prices (Msimbira 1984).

	Population served %	Per capita cost in 1983 TZS	Per capita cost in 1988 TZS
Surface gravity	28	330	1 320
Surface pumped	41	600	2 400
Boreholes	22	700	2 800
Shallow wells	9	160	640
Weighted average	100	506	2 020

The evaluation committee found out that the technology mix would require many years and unattainable resources to achieve the decade targets. MAJI (1989) later endorsed the observation. The mix was revised as indicated in Table 3. Even with the recommended technology mix, foreign exchange component would still be about 40 - 50 % of the total investment demanding stable economy including donor assistance (MAJI 1989).

Table 3. Recommended rural water supply technology mix in Tanzania in 1983 prices (Msimbira 1984).

	Population served	Capital unit cost (per capita)	Operation & maintenance per capita cost
	%	TZS	TZS
Surface gravity	15	330	7.5
Surface pumped	23	600	25.0
Boreholes	12	700	35.0
Shallow wells	50	350	12.6

2.2 Rural water supply situation in Mbeya region

Mbeya region covers a total area of about 59 500 km^2 with a total population of 1.5 million according to 1988 census. Out of this, 75 % live in the rural areas. The region has 586 registered villages of which 237 are served by improved water supplies. This is about 40 % of rural coverage, a figure close to the national average (MAJI 1989). These figures, however, do not take into account the schemes not operating nor the proportion of population served.

Administratively, the region is further subdivided into six districts: Mbeya, Mbozi, Rungwe, Chunya, Kyela and Ileje. District water engineers are expected to operate and maintain all water schemes in the districts.

The DANIDA supported rural water supply programme has so far served about 100 villages, 40 % of total supplied villages (Sørensen 1989). Though the technology applied is very much depending on the water resources available, the implementation phases up to date have extended the financial support in the following technology mix (DANIDA 1987 a):

Gravity piped schemes	75 %
Handpumped schemes	23 %
Diesel pumped schemes	2 %

Priority was given to gravity schemes and only if there appeared to be no potential for gravity schemes, groundwater resources were surveyed. The diesel or electricity pump option was hardly applied because of difficult and costly O&M. MAJI (1989) encourages adoption of both gravity and handpumped schemes for future systems as low-cost technologies for long-term sustainability.

3 IMPORTANCE OF COST ANALYSIS

3.1 Objectives of cost analysis

The main objective of cost analysis is to provide appropriate cost information for the plans. More often, countries have to prepare development plans. These could either be on long-term, medium term or on annual basis. As these plans have to be quantified in financial terms, proper cost analysis techniques enable planners to draw realistic plans and budgets within available resources.

The cost analysis needs to be accompanied with assumptions adopted. The cost analysis should also be specific to the particular country or region and findings should not be extrapolated to other countries or regions.

The engineering approach to cost also includes an appropriate return or profit on the capital invested in the venture. This approach is necessary in evaluating the economics of a project. Cost, to be completely realistic, must refer to the entire economic activity (Park and Jackson 1984).

The discount rate used in cost analysis differs from country to country. In general, the World Bank applies discount rates in the range of 8 % to 15 % on loans for water sector to developing countries (Hofkes and Visscher 1986).

For government budgeted funds and loans with 100 % grant element, rarely rate of return is applied for cost analysis. When sufficient data is not available, it is advisable to calculate with several discount rates to get an indication of the effect of the selected discount rate on the results of the comparative cost analysis.

3.2 Relevance in rural water supply

Even within the water sector, the World Health Organization has reported during the mid-international water and sanitation decade review, the major funding constraint as threatening the 1991 goal of the decade.

Even within the present level of fund availability, Bates and Wyatt (1987) observed that the lack of trained personnel, inadequate cost recovery policies and insufficient allowances for O&M costs of water supply systems are major obstacles in sustaining water supplies.

Cost analysis can therefore be used to evaluate existing water supply systems, with the aim of planning for the most efficient ways of utilization of limited available resources.

In most cases there are several technical alternatives of providing improved water supply to a community. In Tanzania, several technologies have been used to supply rural communities with improved water supply, such as:

- dug wells with/without handpumps
- shallow and medium depth wells fitted with handpumps
- protected springs
- piped supplies, gravity-fed
- piped supplies, diesel powered/wind powered
- rain water harvesting, etc.

In different technologies, input resources, for example quantities of materials, labour and equipment are different. Some alternatives demand high amounts of initial resource inputs but low O&M requirement e.g. piped, gravity-fed systems. On the other extreme, other technologies require low amounts of investment initially but their future repairs and maintenance resources are high e.g. pumping water supply schemes.

The cost analysis tool enables planners and engineers to make an economic choice among several technically efficient alternatives. It offers opportunity of making technological cost comparison to facilitate engineering choice and later cost follow-up.

3.2.1 Types of cost

Basically, two cost categories are distinguished: capital costs and recurrent costs. Capital or investment costs are all costs incurred when the water system is purchased and installed ready for use. Brown and Yanus (1980) suggested to incorporate salvage value component while carrying out cost analysis. This is because some components can be reused at end of the design period, hence to be considered as benefits or negative cost.

Recurrent costs are incurred for operation, maintenance and repair throughout the lifetime of the water system. They include the cost of replacement parts, wages and transport.

3.2.2 Basis for cost comparison

The most useful single figure to facilitate cost comparisons of technologies is the total annual cost per capita or m^3 of water production. It should include both capital and recurrent costs. Because different technologies have different lifetimes, the per capita cost needs to be annualized. It should not be interpreted as an amount of money to be spent annually for a particular technology (Kalbermatten et al 1980).

To facilitate comparison, it is important that all cost estimates are referenced to one cost index, not only because prices are changing so rapidly but also to allow effective cost comparisons in future. Costs which are not referenced adequately have limited use (Tchobanoglous 1989).

Costs in engineering reports and literature can be adjusted to a common base with the relationship:

$$\text{Current cost} = \frac{\text{Current value of index}}{\text{Index value at time of report}} \times \text{Cost cited in report}$$

Indexes such as building cost index are regularly published in many countries. The national consumer price index (NCPI) of Tanzania has been used in this study.

3.2.3 Methods of cost analysis

Different engineering schemes required to meet the same objective can be compared economically by life cycle cost (LCC) analysis technique (Brown and Yanus 1980).

For a valid comparative cost analysis, the capital costs and recurrent costs have to be converted into comparable units. Two methods can be used for this purpose:

(i) Uniform annual cost method:
The capital cost is converted in a series of equivalent annual costs over the total lifetime of the water system. The total annual cost is obtained by adding the annual recurrent costs to the equivalent annual capital cost. This gives a figure which can be compared for various technological options.

(ii) Present worth cost method:
The present value of future recurrent costs can be calculated by discounting them at an discount rate. The present value of all recurrent costs to be incurred over the expected lifetime are added to the initial capital cost to obtain a total figure which can be compared for various technological options.

When comparing alternatives, the same choice will be made regardless of the method used in the analysis. The LCC analysis can also be used to study the sensitivity of design criteria parameters on different technology options whereby one of factors is changed and cost implications noted.

It has been observed that cost differences are particularly evident in the system head works, transmission and storage elements depending on the size of water scheme implemented (Saunders and Warford 1976).

4 MAJOR FEATURES OF DANIDA-SUPPORTED WATER PROJECT

4.1 Design criteria

Design criteria define the validity of the results. Cost analysis for rural water supplies is a tool which can be used to forecast future costs for similar projects.

Several parameters need to be considered and analysed thoroughly. Different studies have shown that most criteria are extremely cost sensitive. A slight change in these has resulted in considerable cost alterations.

Cost sensitive design criteria include water quality, raw water availability, water consumption rates and patterns, walking distance to public standposts or handpumps and reliability of supply i.e. storage requirements (Rehoj and Vesth-Hansen 1988).

Both water consumption pattern and peak factor are cost sensitive parameters. Some savings are associated with low peak factors. Rehoj and Vesth-Hansen (1988) demonstrated through computer optimizations of a rural regional network in Southern Egypt that by a mere reduction of the peak factor from 2.4 to 2.0 the pipe costs reduce by approximately 10 %.

Like other rural water projects in Tanzania, the DANIDA supported water project was bound by the Ministry of Water (MOW) design publication 'Design criteria for water supply schemes'.

Due to its great influence on costs of projects, the design criteria was studied during the water master planning phase. It was to ensure that no over-design is incorporated to minimize the wastes on resources or facilities.

Findings observed through village inventory by CCKK (1982) supplemented by the findings of the socio-economic surveys in the region jointly developed the following design criteria parameters:

* Design period is taken as 20 years for piped supplies and 10 years for handpump components. The period is much less compared to 30 years for Kenya (Musyoka 1986).

* Detailed studies at village level for the water consumption by the socio-economic study group reported an average of 25 l/cap/d including all losses and wastes (CCKK 1982). This compares fairly well with a specific consumption figure of 27 l/cap/d in rural areas of Malawi (Arlosoroff et al 1987). However, the difference becomes noticeable with Kenya criteria that in rural area, 70 % of population is rated at 25 l/cap/d, the rest planned for 50 l/cap/d, giving an average of 33 l/cap/d (Musyoka 1986).

* Peak factor of 3 is appropriate to the present rural village water supply schemes.

* Storage capacity of 50 % of the calculated daily demand i.e. 12 h storage, was found sufficient to balance peak requirements at projected future water demand.

* Maximum walking distance to public standpost or handpump is limited to 400 m.

* Service level is usually limited to supply through public standposts and handpumps 200 users/tap or pump. The peak flow to one stand-pipe is 1.2 m^3/h.

In terms of cost implications, both service level and design criteria are important factors to be considered. In Tanzania as the case for many countries, development targets are political ones including percentage of population to be served whether through house connections or standposts and preference on technology.

It is, however, very important to control the service level for water supply scheme. As the number of users per standpost or pump increases, the longer will be the queues at peak hours. This would enhance the risk of people returning to alternative traditional sources and also high frequency of water point breakdown resulting to high O&M costs (Arlosoroff et al 1987).

4.2 Implementation procedure

4.2.1 Village priority setting and programming

The water master plan made prior to project implementation, categorized all the villages according to the priority for an improved water supply. The highest priority has been given to villages with low accessibility or source capacity and/or high health risks (worst-first principle).

The evaluation report observed that the priority listing of villages was a useful tool for implementation. It created valuable means for defining the project policy and for coping with political pressures (IRC 1987).

Experience gained during the implementation indicates the validity of priority criteria, but flexibility is necessary to cater for changing conditions. Examples were on villages once served with high technology options like conventional pumping systems. When such systems break down, their priority is bound to change.

Closely related to financing limitations, CCKK (1982) considered both technology and cost aspects being major factors in relation to village selection for implementation. Certain scheme types cause particular obvious O&M problems resulting in high O&M cost budget. Similarly, cost criteria favour schemes serving as many people as possible at minimum investment cost.

Saunders and Warford (1976) observed that in developing countries, in addition to political pressures for service, the following factors are always cited and used as criteria in choosing the villages to receive improved supplies:

- cost
- economies of scale
- service quality
- growth-point strategies
- income distribution
- worst-first strategies
- financial viability
- community enthusiasm.

The trend today aims at implementation of improved water supply in highly enthusiastic communities. The emphasis is to achieve system sustainability regarding O&M cost recovery.

Villages should raise sufficient funds at least enough to cover local O&M costs. This practice has been found to reduce the needed government subsidy and create the sense of ownership and responsibility among the users.

4.2.2 Technology selected

The technology applied depends very much on available water resources.

Distribution of technologies as observed by the evaluation report (IRC 1987) attained during implementation is as follows:

Gravity piped schemes	78 %
Handpumped schemes	21 %
Other supplies e.g. diesel pump	1 %

Priority has been given to gravity schemes and only if there appeared to be no potential, handpumped schemes were constructed. Diesel pump or electricity pump option is hardly applied due to difficulties and costly O&M.

In all handpump supplies, a lever type locally manufactured handpump, SWN 80 has been fitted. Recently, direct action pump, NIRA AF-85 has been fitted on pilot basis.

Appraisal mission (DANIDA 1988 a) further recommends gravity-fed piped supplies, auger drilled handpumped supplies and hydrams as acceptable technologies for further DANIDA support. Furthermore, use of solar powered and wind powered pumps can be studied as possible technologies.

4.2.3 Implementation practice

The project is supported by DANIDA through the agreements signed between the two governments for five year periods. The executing agency for the project is the Ministry of Water through the Regional water engineer's (RWE's) office. The CCKK consultants assist the RWE in the execution of the project. The village participation component has been the major focus in the implementation of schemes at different stages of system developments. In the initial phase of the project, community involvement was limited only to provision of free labour during construction stage. Later, the village commitment extended to include planning, (choice of technology, service standards) and finally to own the water schemes. Community arranges all O&M activities (CCKK 1982).

The selection of villages to receive improved water supplies is compiled from the priority setting based on water master plans. Hence, it is not based on 'need' criteria. Implementation plan for five years is prepared and agreed upon depending on available funding.

The implementation of water schemes is centrally based. Supervision including monitoring is arranged from the regional centre, Mbeya.

All piping materials used in piped water supplies are imported. Sensitivity studies carried out on various constructional or design alternatives showed savings of 30 - 35 % on total scheme cost if imported pipe material was used (CCKK 1982).

4.3 Operation and maintenance practices

After completion the rural water schemes are handed over to the respective village to be operated and maintained. This is considered necessary to avoid problems caused by remoteness of villages and associated communication problems. The main aim is to establish a greater sense of responsibility within the villages for proper O&M of their water schemes.

Scheme attendants are selected from the respective villages and trained during the scheme construction.

The project supplies basic materials and tools at the completion of each scheme for initial O&M requirement purpose free of charge. Thereafter the village should pay for the maintenance.

Regional maintenance and mobile units visit water schemes for monitoring, co-ordination and training purposes. Piped supplies are visited once per two months, and handpumped supplies once per three months. This frequency should be reduced gradually as villages attain capability to run the schemes.

Villages should open a maintenance fund through special bank account. They should pay labour cost for scheme attendants and pay for the spare parts.

System extensions like new public standposts, handpumps or improvements desired on handed over schemes are to be paid by the village to promote ownership of water supplies.

5 WATER EXTRACTION AND CONSUMPTION IN DANIDA-SUPPORTED WATER PROJECT

The water master plans contain good water resources assessment studies based on processing of available hydrological and hydrogeological data. These studies portray a clear regional picture of the water resources. They also provide practical guidance towards proper source selection for water schemes.

Knowledge of water resources potential allows practical design of water extraction technologies. Availability of surface water resources for domestic utilization for rural water supply was referenced on a 10 years minimum flow estimates. Similarly, a groundwater potential classification was established to predict suitability for shallow and deep wells.

The scope of the water master plans being broader at the time of their preparations, data collection related to water resources had to be intensified during implementation phase. IRC (1987) recommends a yearly low flow gauging analysis for surface sources. As regards groundwater potential, geomorphological differentiation and classification approach is practised. Data from existing wells supplements the classification. Prior to deep wells implementation, a drilling campaign was run to confirm the validity of the hydrogeological classification established during the water master plan phase.

5.1 Water resources extraction

The O&M of water supply schemes has been seen to be of great significance in the successful implementation of the project. Study of existing improved supplies located in the region shows that certain scheme types cause particular O&M problems.

Furthermore, VLOM practice for rural water supplies calls for easy and simple extraction technology. CCKK (1982) advised delay of implementation for schemes involving diesel powered pumped systems unless alternatives can be devised.

Water master plans recommended priority for gravity schemes over groundwater schemes due to availability of surface water and uncertainties regarding groundwater. Slight shift in preference has been reported during implementation phase.

IRC (1987) listed the criteria to which the water resource extraction methodology should be based upon, as:

- costs
- water availability (i.e. quantity)
- water quality (including vulnerability for pollution
- acceptable or preferred technology
- maintenance requirements and affordability.

In the implementation phases up to date, in Mbeya region the technologies applied within 98 schemes built with project support are distributed as follows:

Gravity piped schemes	75 %
Handpumped schemes	23 %
Diesel pumped schemes	2 %

Other extraction methodologies such as hydraulic ram, solar pump, wind powered pump, water wheel, etc. are being promoted to substitute conventional pumping. It was, however, emphasized to carry out thorough studies before being adopted (CCKK 1982).

The groundwater lifting technology within the present project approach is limited to handpumps.

In the context of the ongoing programme, hand-drilled wells later fitted with handpumps are preferred as they require and give opportunity for village participation in construction. It is expected that this supports VLOM approach through promotion of sense of ownership.

The major part of water extraction in DANIDA-sponsored rural water supply programme is with gravitational tapping from surface sources. This has been successful as nearly all of the installed water supply systems function well throughout the year.

Bacteriological (mainly fecal) pollution upstream of almost all gravity intakes due to human activities is the point of concern related to this water extraction technology. The Government policy rules out the application of any water treatment for rural water supplies. IRC (1987) recommended the project to disseminate information regarding the health risk due to the high contamination levels and to include health education component. Introduction of home based water treatment methods could be studied for possible development.

Water quality sampling programme attached to the project has revealed that water from handpump wells is usually of excellent bacteriological quality in addition to satisfactory chemical and physical parameters.

The project evaluation mission recommended that if groundwater sources are exploitable, higher priority should be given to handpump schemes as compared to gravity schemes. Handpumped supplies being point water sources, it is easier to divide the costs between consumers than in piped systems. Higher potential for groundwater resources was identified than reported during water master planning.

Jordan and Wyatt (1987) noted that the type of water system to be installed should take into consideration the affordability of recurrent costs of a water system by users. Hence a fairly reasonable estimate of the cost of operating and maintaining the system must be made. This would ensure adequate availability of funds to operate and maintain the system properly.

DANIDA (1988 a) foresees future support geared to strengthen village capacity to monitor their own schemes as much as possible without technical assistance from outside.

The author's experience with the project supports the idea of selecting low-cost technology based on the beneficiaries ability and willingness to pay for the running expenses. The technology selected should also fit well the existing administrative and operational organization, otherwise necessary support measures should be taken.

5.2 Water consumption

Users draw water from public standposts for different purposes. House connections on piped supplies are outside the scope of the project.

The socio-economic group studied the amount of water hauled to the house and water consumed at the collection point for four different agro-ecological zones in Mbeya region during the water master planning stage.

Detailed studies at village level reported that the average water consumption in the rural areas for all domestic purposes varied from 11 to 18 l/cap/d (CCKK 1982).

If provision is made for institutional water demand and an estimated growth in demand, a resulting planning demand of 25 l/cap/d is obtained.

The per capita consumption of 25 l/cap/d was found to apply equally well for both piped and handpumped supplies.

Water demand figures are shown in Table 4 for variety of water extraction technologies.

Table 4. Options for community water supply (Arlosoroff et al 1987).

Step	Type of Service	Water source	Quality protection	Water use LPCD[a]	Energy source	Operation and maintenance needs	Costs	General remarks
5	House Connections	Groundwater Surface water Spring	Good, no treatment May need treatment Good, no treatment	100 to 150	Gravity Electric Diesel	Well-trained operator; reliable fuel and chemical supplies, many spare parts; wastewater disposal	High capital and O&M costs, except for gravity schemes	Most desirable service level, but high resource needs
4	Yardtaps	Groundwater Surface water Spring	Good, no treatment May need treatment Good no treatment	50 to 100	Gravity Electric Diesel	Well trained operator; reliable fuel and chemical supplies; many spare parts	High capital and O&M costs, except gravity schemes	Very good access to safe water; fuel and institutional support critical
3	Standpipes	Groundwater Surface water Spring	Good, no treatment May need treatment Good, no treatment	10 to 40	Gravity Electric Diesel Wind Solar	Well trained operator; reliable fuel and chemical supplies; many spare parts	Moderate capital and O&M costs, except gravity schemes; collection time	Good access to safe water; cost competitive with handpumps at high pumping lifts
2	Handpumps	Groundwater	Good, no treatment	10 to 40	Manual	Trained repairer; few spare parts	Low capital and O&M costs, collection time	Good access to safe water; sustainable by villagers
1	Improved traditional sources (partially protected)	Groundwater Surface water Spring Rainwater	Variable Poor Variable Good, if protected	10 to 40	Manual	General upkeep	Very low capital and O&M costs, collection time	Improvement if traditional source was badly contaminated
0	Traditional sources (unprotected)	Surface water Groundwater Spring Rainwater	Poor Poor Variable Variable	10 to 40	Manual	General upkeep	Low O&M costs (buckets, etc), collection time	Starting point for supply improvements

a. LPCD = liters per capita per day

Bates and Wyatt (1987) recommend a handpump specific consumption value of 20 l/cap/d to keep the frequency of replacing moving parts of a handpump components to a reasonable level.

It seems evident that even in rural areas, improved water supply system at better service level results in higher water consumption. Huisman et al (1981) demonstrated this fact in Table 5. Communal water point within 250 m is more subjected to water demand than to a further point in space.

Table 5. Typical domestic water usage (Huisman et al 1981).

Type of water system	Typical water consumption l/cap/d	Range l/cap/d
Communal water point (e.g. village well, public standpost)		
- at considerable distance (> 1000 m)	7	5 - 10
- at medium distance (500-1000 m)	12	10 - 15
Village well		
- walking distance < 250 m	20	15 - 25
Communal stand-pipe		
- walking distance < 250 m	30	20 - 50
Yard connection (tap placed in house-yard)	40	20 - 80
House connection		
- single tap	50	30 - 60
- multiple tap	150	70 - 250

To evaluate the validity of water consumption adopted in the water master plan, the project conducted a pre-evaluation study on "Water Use and Village Participation in Operation and Maintenance" (DANIDA 1987 b).

The study covered two villages in Mbeya region together with others from the rest of the project regions. Both villages have had piped water supply for more than a year and represent fairly well the climatic variations in the region. The water consumptions were measured by water meters, later used to compute the per capita consumption, peak factors, losses and storage demand.

Average per capita water consumption in the dry season was 20 - 30 l/cap/d, with a weighted average of 26 l/cap/d. The rainy season average consumption was only 2/3 of the dry season consumption (DANIDA 1987 b).

The study concluded that when other components of consumption such as losses, wastes and effect of daily variations are included, the specific consumption figure works out as 36 l/cap/d.

5.2.1 Gravity piped schemes

The author investigated water consumption from two water points, part of Ilongo gravity water scheme as part of this study. Flow meters were installed at 2 m away from the stand-pipe. Measurements recorded also included wastes at water points. The standposts were chosen so that one has maximum number of users in the village with no traditional source in the vicinity. The second standpost represented the other extreme, with least number of users and an irrigation channel passing by the settlement. Village scheme attendants were employed to take meter readings hourly during the first week and later twice a day.

Results from the consumption measurement are shown in Tables 6 and 7.

Table 6. Consumption data for piped Ilongo scheme (rainy season).
DP-14, No. of users 270

Date	Actual consumption incl. wastes	
	Total consumption l	Specific consumption l/cap/d
17.11.89	6400	24
18.11.89	7086	26
19.11.89	5058	19
20.11.89	4695	17
21.11.89	5073	19
22.11.89	6367	24
23.11.89	5068	19
24.11.89	8319	31
25.11.89	4011	15
1.12.89	3544	13
2.12.89	5479	20
3.12.89	3995	15
4.12.89	4558	17
5.12.89	3931	15
6.12.89	3472	13
8.12.89	6954	26
9.12.89	5394	20
10.12.89	4068	15
11.12.89	4633	17
7.1.90	5364	20
Average	5174	19
Range	3500-7100	12-30

Allowing 20 % to account for losses within the distribution network, the specific consumption on the standpost is approximately 23 l/cap/d.

Figure 1 shows the daily water consumption diagram. The water collection pattern indicates two distinct peaks occurring before 9 am and another after 4.30 pm.

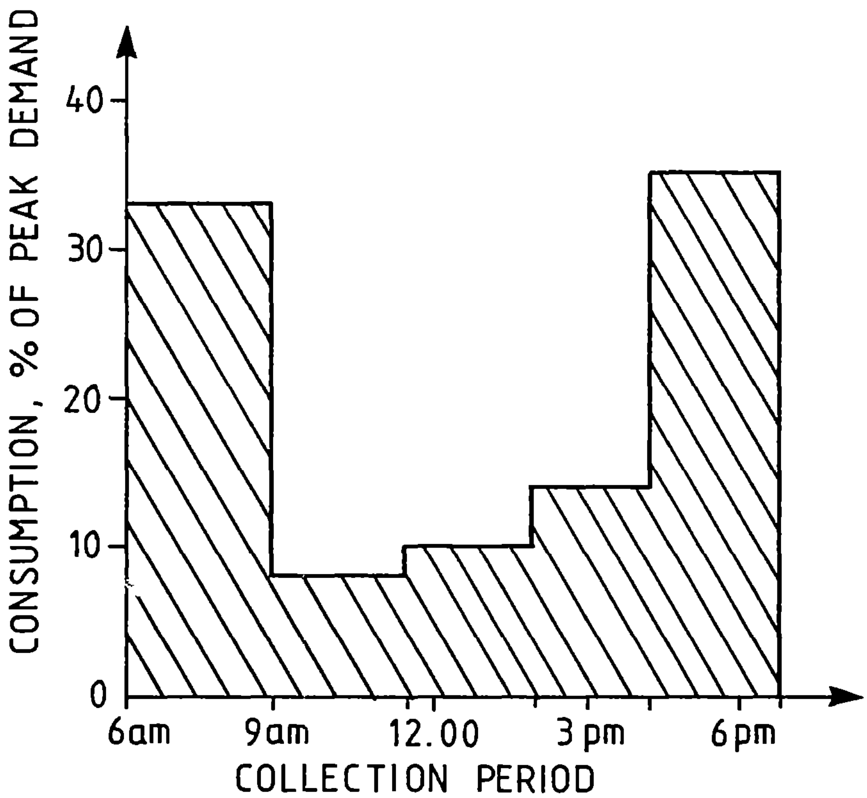

Figure 1. Daily water consumption diagram.

Table 7. Consumption data for piped Ilongo scheme. DP-5*), No. of consumers 120

Date	Actual consumption incl. wastes	
	Total consumption l	Specific consumption l/cap/d
16.11.89	1384	12
17.11.89	1378	12
18.11.89	1465	12
19.11.89	2222	19
20.11.89	831	7
21.11.89	2131	18
22.11.89	1035	9
23.11.89	927	8
24.11.89	853	7
25.11.89	1150	10
1.12.89	1198	10
2.12.89	1498	13
3.12.89	1918	16
4.12.89	1712	14
5.12.89	1522	13
6.12.89	1319	11
7.12.89	1397	12
7.1.90	1130	9
Average	1393	12
Range	831-2222	5-20

*) This standpost is located in an area with several local irrigation furrows, no wonder it shows minimum water consumption compared to the other. Washing, bathing and other water uses take place from such furrows. However, the collection pattern is similar to the other water point (Figure 1).

The average dry season consumption works out as 34 l/cap/d, close to the water-use study findings. DANIDA (1988 a) recommends a daily per capita demand (including losses and wastes, etc.) of 33 l, similar to present MAJI design criteria.

5.2.2 Handpumped schemes

Enumerators were posted to two handpumped wells to count and classify all people collecting water. Nyeregete scheme was chosen for this study. Counting took place from 6 am until late in the evening.

There were differences between three categories of collectors:

- Adults (assumed to use approx. 20 l capacity containers)
- Children using approx. 20 l capacity containers
- Children using smaller containers

Enumerators used their judgement to decide on container capacities other than 20 l. Results of observation are summarized in Table 8.

Table 8. Summary of data on water collected from handpumped wells.

	Weekday			Weekend		
	Adults	Children Large cont.	Children Small cont.	Adults	Children Large cont.	Children Small cont.
Total number of collections	496	248	330	420	270	370
Estimated average volume used/ collection	18	18	5	19	18	5
Percent of total volume %	60	30	10	54	33	13
Percent of total volume collected by adults and children %	60	40		54	46	

Specific consumption from the well was

$$\frac{15042}{180x4} = 21 \text{ l/cap/d}$$

This amount is slightly lower than expected as it also covers the amount of water used at the handpump for washing the bucket, etc.

6 CAPITAL COSTS IN DANIDA-SUPPORTED WATER PROJECT

The implementation of rural water supply programme in Mbeya region with DANIDA support is presently limited to auger drilled shallow wells equipped with SWN 80 handpumps and gravity-fed piped supplies from streams and springs. Only two diesel powered pumped systems have been implemented during the last decade of implementation.

It is envisaged to retain the same technology choices during the next phase of implementation support. Allowance for utilization of hydraulic rams, solar powered and electric driven pumps where relevant and feasible has been provided (DANIDA 1988 a).

The implementation of rural water supplies with DANIDA support started in 1981. The project has, since January 1986 operated its own accounts. The main purpose has been the costs follow-up for each water scheme during the construction period of the same scheme.

Cost information prior to 1986 are project estimated data. Scheme expenditure includes charges for use of vehicles and workshop facilities by schemes. Depreciation on vehicles is charged evenly over three year period (i.e. 33 % per year) (DANIDA 1986, DANIDA 1987 a, DANIDA 1988 b).

Pipes and fittings for all p_ped schemes are procured from abroad. Handpump components are locally procured but paid in hard currency. DANIDA (1988 a) foresees local production promotion through import support and technical assistance. It is to achieve long-term savings of foreign costs.

Transactions incurred in currencies other than Tanzanian shillings are translated into shillings (TZS) at average annual exchange rate (termed as DANIDA rate).

All foreign costs have been recorded in terms of Danish crowns (DKK) and later translated into local currency with respective average annual exchange rate. Average TZS/DKK rates during 1984-88 implementation period were 1.40, 1.60, 3.65, 8.65 and 14.65 respectively.

For cost control reasons during scheme construction phase, it was necessary to break the total scheme cost into several cost elements. Major shares on scheme direct cost were observed to be constituted by the following cost elements (DANIDA 1988 a):

- pipes & fittings (for piped supplies) or hand-pump components (in case of handpumped supplies)
- cement
- other local materials
- labour (other than free labour from users)
- transport costs.

6.1 Capital cost estimates in water master plan

Investment costs of different water supply schemes were estimated during the water master planning stage. The basic pricing system was formulated from elemental costs of the main units of the water supply scheme. The range of scheme sizes was very extensive covering from small single village scheme to large group schemes.

CCKK (1982) carried out cost sensitivity studies over a variety of design and construction options. Major particular observations having influence on the overall scheme investment were identified.

Unit costs were mainly compiled from the Ministry of Water, contractors, manufacturers/suppliers and previously compiled water master plans in Tanzania. The use of contractual methods of construction increased the overhead cost for small projects tremendously. Use of village participation resulted in 10-15 % scheme savings depending on the scheme size (CCKK 1982).

CCKK (1982) observed that the use of imported materials reduced the overall scheme costs by 30 - 35 % depending on scheme size.

The cost estimates of the water supply scheme proposals have been based on the use of local materials, wherever available, construction by Ministry of Water staff and using design criteria explained in Chapter 4.

Scheme proposal costs are given in Tanzanian shillings, TZS and based on July 1981 price level. The per capita costs are based on the design population (CCKK 1982).

Same schemes were analysed to compare the water master planning capital cost estimates and the actual implementation costs. Total of nine piped gravity schemes covering 59 villages and 13 handpumped schemes were considered (Figure 2).

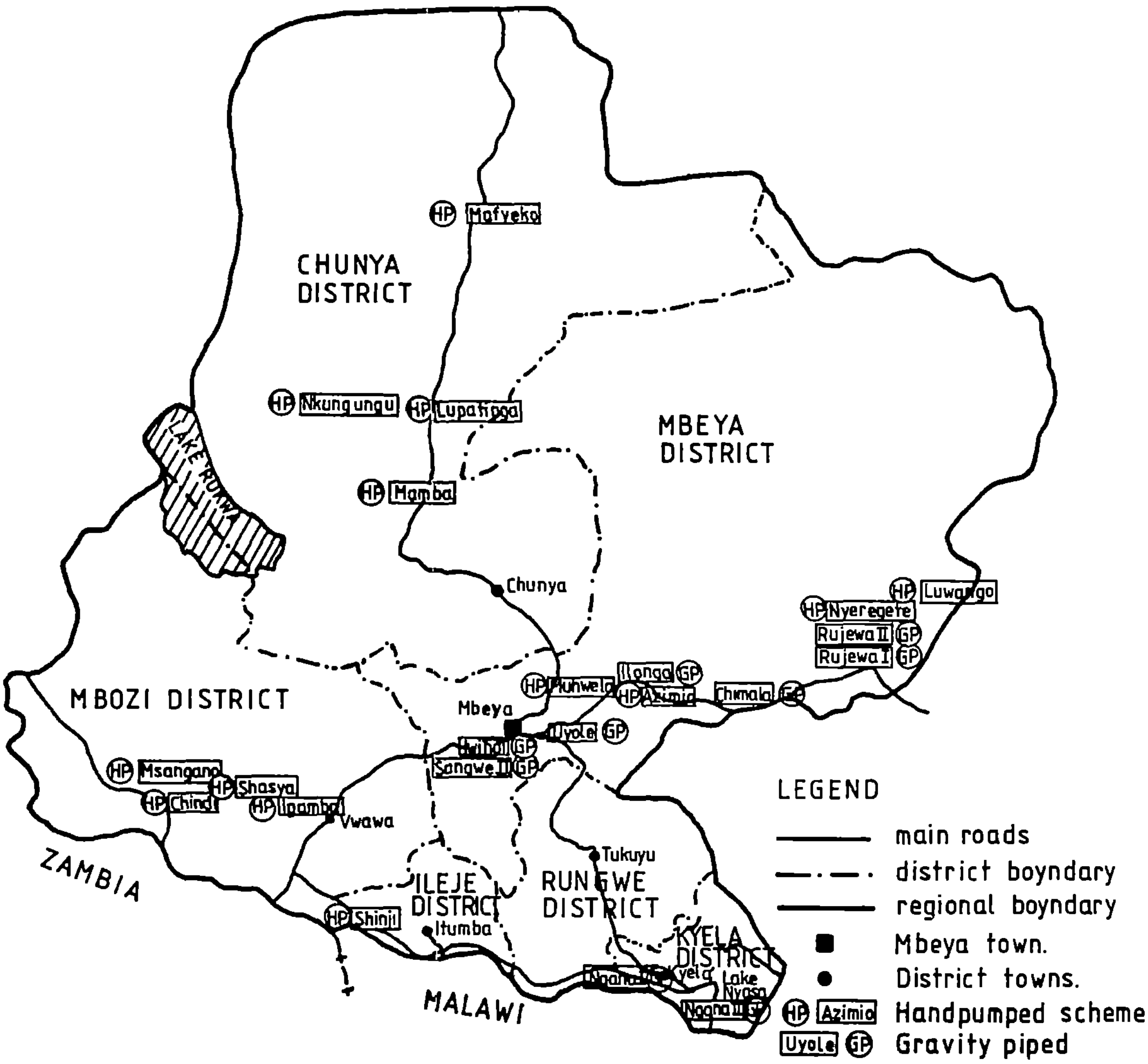

Figure 2. Location map of water supply schemes in Mbeya region.

The 1981 cost estimates during the water master planning stage have been updated to 1989 price level using the National Consumer Price Index (NCPI) (Agriculture 1986, Agriculture 1989).

Per capita costs are referenced to 1988 population census being more realistic compared to the design population.

Evaluation of average per capita cost for each technology (Tables 9 and 10) excludes special categorized systems. Current rate of exchange between US dollar and Tanzanian shilling of 1:160 has been adopted (1989 level).

Table 9. Gravity piped schemes cost estimates in water master plan (CCKK 1982).

Scheme	1981 cost 10^3 TZS	1989 cost 10^6 TZS	1988 population	Per capita cost TZS (1989)	
Iwindi	2 070	14.8	27 020	545	*)
Chimala	7 040	50.1	12 160	4 120	
Uyole	1 340	9.5	15 360	620	*)
Ilongo	9 870	70.2	13 760	5 100	**)
Rujewa I	10 580	75.3	23 690	3 200	
Rujewa II	8 560	60.9	16 000	3 800	
Ngana I	6 510	46.3	10 060	4 600	
Ngana II	9 920	70.6	18 140	3 900	
Songwe II	660	4.7	5 560	845	*)
Range				3 200 - 4 600	
Average				3 900	

*) Rehabilitation systems with or without new village extensions

**) Originally planned to have more coverage, later reduced during implementation phase

*) or **) Special condition category and not considered for average cost estimations

All the above analysed piped schemes are group systems covering 2 - 10 villages.

The project half-yearly progress report quotes the average construction cost in 1988 as DKK 174 per capita (TZS 2 600) for direct scheme cost, piped schemes (DSU 1988).

Table 10. Handpumped schemes cost estimates in water master plan (CCKK 1982).

Scheme	1981 cost 10^3 TZS	1989 cost 10^6 TZS	1988 popu-lation	Per capita cost TZS (1989)	Remarks
Mafyeko	300	2.2	1 200	1 840	REHAB
Mamba	4 120	29.3	3 300	8 900	M/D
Lupatinga-tinga	6 840	48.7	4 600	10 600	M/D
Nyeregete	550	4.0	3 500	1 140	SHW
Muhwela	2 740	19.5	2 250	8 700	GR/IL
Igamba	4 100	29.2	2 800	10 400	M/D
Nkungungu	3 700	26.3	1 400	18 800	M/D
Msangano	360	2.6	3 650	710	REHAB
Shinji	410	2.9	1 600	1 810	SHW
Luwango	590	4.2	1 300	3 200	SHW
Azimio	330	2.3	2 150	1 070	GR/IL
Chindi	510	3.6	1 500	2 400	SHW
Shasya	4 360	31.0	2 650	11 700	M/D
Range	Hand auger + handpump			1 000 - 3 200	SHW
Average				2 200	
Range	Machine drilled + handpump			9 000 - 20 000	M/D
Average				12 000	

Remarks:
SHW - Original supply proposal was auger drilled shallow wells equipped with handpumps
M/D - Proposed for machine drilled boreholes of medium depth and equipped with handpumps
GR/IL - Estimates based on piped supply extension from Ilongo group water scheme
REHAB - Estimates of rehabilitation cost for existing diesel powered pumped supplies

Table 10 points out a clear difference in per capita cost estimates between hand auger and machine drilled wells in Tanzania. Per capita cost estimates for hand auger and machine drilled wells are TZS 2 200 (USD 14) and TZS 12 000 (USD 75) respectively (in 1989 prices).

However, actual capital cost for machine drilled handpumped schemes cannot be established. The project has so far financed only manually drilled handpumped schemes.

DSU (1988) reported an average per capita real cost of TZS 1 000 (USD 6.2) (in 1989 prices) for handpumped schemes based on manual drilling in Mbeya region.

6.2 Actual capital costs

6.2.1 Gravity piped schemes

A sum of 75 villages within Mbeya region have so far been supplied with improved piped water schemes, two of which through diesel powered pumped supply, the rest by gravity-fed piped systems. Several others are under implementation.

Most of these villages are supplied through group schemes i.e. schemes covering more than one village, rather than single village schemes. It has been observed that many group schemes constructed in Mbeya region cover high population and short distances between the villages as compared to other project regions. This observation is associated with reduction in per capita construction cost (DSU 1988).

The capital cost analysis has been done on nine group water schemes covering a total of 59 villages. This is over 75 % of all schemes constructed under the project support. Because of the topographic nature of the region and the location of villages, in many cases it was found necessary to introduce group village supplies to achieve gravity systems.

Rehabilitation of existing village water supplies has also formed part of the project financial support. IRC (1987) noted that rehabilitation activities, in most cases, resulted in complete reconstruction of schemes. The situation was attributed to limited village coverage with respect to the approved design criteria.

Unlike handpumped schemes, most of gravity piped schemes are located in Mbeya district except two group schemes constructed in Kyela district. Saunders and Warford (1976) seem to encourage such implementation concentration in one geographic area rather than scattering village water supply projects throughout the region. The option, however, tends to give the impression of district bias. Table 11 describes the analysed schemes.

Table 11. Gravity piped schemes included in the study.

Scheme	No. of villages	District	Distance from Mbeya km	Year of constr.	1988 population
Songwe II	2	Mbeya	40	1986-89	5 600
Iwindi	5	Mbeya	30	1984-89	27 050
Rujewa I	8	Mbeya	130	1985-88	23 700
Rujewa II	8	Mbeya	160	1987-89	16 000
Chimala	6	Mbeya	80	1984-86	12 200
Ilongo	6	Mbeya	45	1986-89	13 800
Uyole	6	Mbeya	30	1985-88	15 360
Ngana I	7	Kyela	140	1984-87	10 100
Ngana II	11	Kyela	150	1986-89	18 200
Total	59				142 000

Actual costs for piped supplies at current and 1989 price level are respectively shown in Tables 12 and 13.

Table 12. Piped scheme costs: Mbeya region (at current prices).

1000 TZS

Scheme	1984 P	1984 O/E	1985 P	1985 O/E	1986 P	1986 O/E	1987 P	1987 O/E	1988 P	1988 O/E	1989 P	1989 O/E
Songwe II					1480	69	1315	2231	840	3025	125	1165
Iwindi	150	322	43	1240	820	1970	550	821	260	695	928	650
Rujewa I		46	2190	1350	10980	3450	1140	3705	117	1790		
Rujewa II				31			22070	3450	5225	9880	-750	2930
Chimala	1570	445	220	813	490	592	8	224		4		
Ilongo				33	1050	1655	26820	6120	9800	5380	-170	1655
Uyole			1509	537	2680	2109	1384	1997	448	132	19	
Ngana I	2555	493	115	1250	646	684	9	16		111		
Ngana II			4147	0	5913	3000	3668	6287	16707	5930	1590	950

P - cost of piping material
O/E - cost of other expenses other than pipes

NCPI used from Bureau of statistics to update the current cost were as follows: 1977 = 100, 1984 = 501, 1985 = 710, 1986 = 817, 1987 = 1 025, 1988 = 1 285, 1989 = 1 611 (January 1989 before major devaluation, not yearly average).

Table 13. Piped scheme costs: Mbeya region (at 1989 price level).

Scheme	Cost, 1000 TZS: Other exp.	Cost, 1000 TZS: Total cost	Percentage of pipes to total %	Cost/cap. TZS	Water demand m^3	Cost/m^3 1000 TZS
Songwe II	8 600	14 765	42	2 650	140	105
Iwindi	10 540	14 865	30	550	675	20
Rujewa I	18 070	43 055	58	1 820	590	70
Rujewa II	22 810	63 300	64	4 000	400	160
Chimala	4 800	11 330	58	930	300	40
Ilongo	21 360	77 700	72	5 630	350	220
Uyole	8 690	20 144	57	1 310	390	50
Ngana I	5 940	15 700	62	1 550	250	60
Ngana II	24 190	64 890	63	3 570	450	145
Range			30 - 70	1 000 -5 000	100 -700	40 - 160
Mean value			55	2 500	400	90

Table 14 gives details on construction cost per village and per capita. It is assumed that NCPI allows for both inflation and devaluation.

Table 14. Piped scheme costs in Mbeya region.

Scheme	Avg. cost per village 1000 TZS	No. of stand-post	Avg. pop. per village	Service level cap/stand	Cost per capita TZS
Songwe II	7 380	21	2 800	265	2 650
Iwindi	2 970	81	5 410	330	550
Rujewa I	5 382	115	2 960	205	1 820
Chimala	1 890	66	2 030	185	930
Ilongo	12 950	94	2 300	150	5 630
Uyole	3 360	89	2 560	170	1 310
Ngana I	2 245	81	1 440	125	1 550
Ngana II	5 900	138	1 650	130	3 570
Average	5 520	13 per village	2 400	180	2 300

Construction cost per village varies from TZS 2 000 000 to 8 000 000 (1989 price level) and per capita cost TZS from 500 to 5 500.

Capital cost distribution for gravity piped schemes is shown in Figure 3.

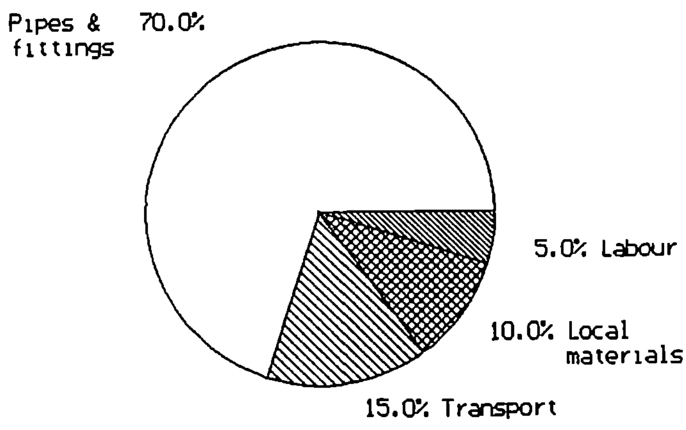

Figure 3. Capital cost distribution for gravity piped schemes.

Variation of capital cost for piped supplies with scheme size and location with respect to Mbeya are also shown in Figures 4 and 5 respectively.

The per capita cost of a water supply scheme is depending on the size of the system (Figure 4). This is in agreement with the economies of scale for conventional piped systems. Larger schemes with similar circumstances exhibit smaller per capita cost. However, Ilongo scheme shows deviation from the hypothesis due to high pipe to total cost ratio (Table 13). Villages connected to this scheme are distant apart as compared to other schemes.

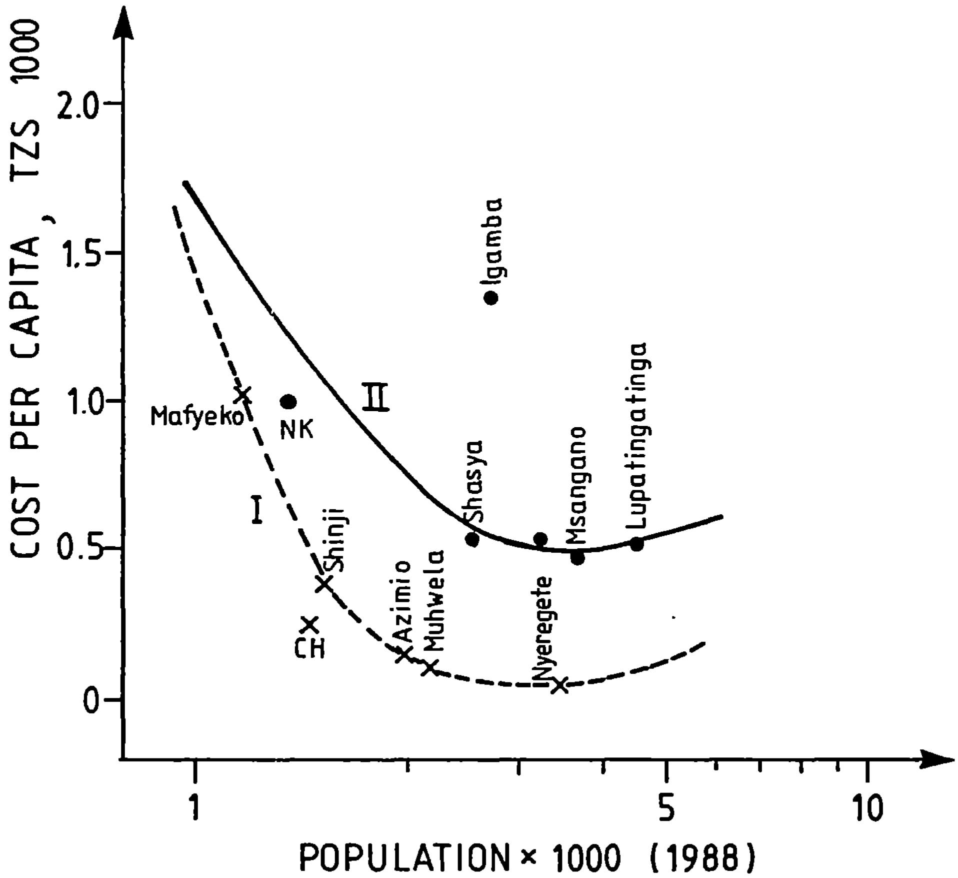

Figure 4. Capital costs of rural water supplies in Mbeya region, Tanzania (1989 prices).

Figure 5 shows relatively wider variation of cost for gravity piped schemes than for handpumped schemes. This confirms that transport cost is not a significant element of the total scheme cost as depicted in the distribution chart (Figure 3).

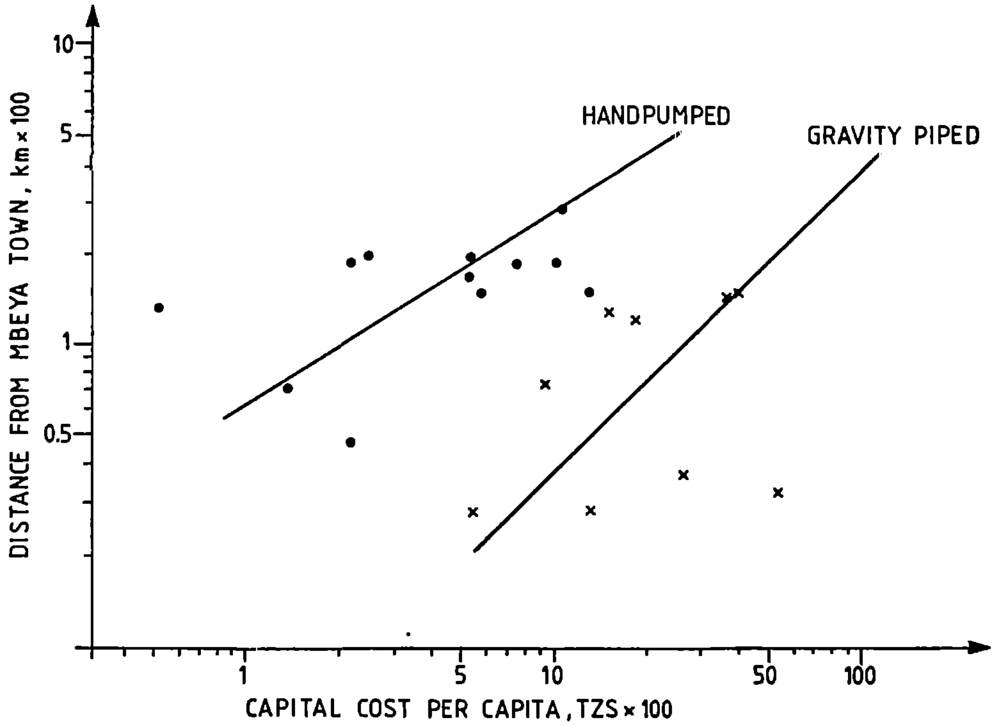

Figure 5. Unit investment cost of rural water supplies in Mbeya region, Tanzania (1989 prices).

6.2.2 Handpumped schemes

By the end of the year 1989 the project financed 26 handpumped schemes in Mbeya region. Hand-drilled wells were preferred in all schemes because they require and give good opportunity for village participation in construction.

Capital costs of handpumped schemes (50 % of total schemes) have been analysed by the author. The schemes are well distributed over the region, except for Rungwe and Kyela districts where circumstances limit use of ground water (Table 15).

Cost data only refers to direct scheme costs excluding overheads (DANIDA 1986, DANIDA 1987 a, DANIDA 1988 b).

Table 15. Handpumped schemes included in the study.

Scheme	District	Distance from Mbeya km	Year of con-struction	No. of hand-pumps	1988 popu-lation
Mafyeko	Chunya	300	1987	4	1 200
Mamba	Chunya	225	1987	8	3 300
Lupatingatinga	Chunya	180	1987	15	4 600
Nkungungu	Chunya	200	1989	5	1 400
Nyeregete	Mbeya	140	1987	6	3 500
Muhwela	Mbeya	50	1986	8	2 250
Luwango	Mbeya	200	1986	3	1 300
Azimio	Mbeya	15	1986	8	2 150
Igamba	Mbozi	160	1988	19	2 800
Msangano	Mbozi	200	1987	8	3 650
Chindi	Mbozi	210	1988	4	1 500
Shasya	Mbozi	160	1987	10	2 650
Shinji	Ileje	135	1989	5	1 600

Actual costs for handpumped supplies at current and 1989 price level are respectively shown in Tables 16 and 17.

Table 16. Handpumped scheme costs: Mbeya region (at current prices).

Scheme	1986 10^3 TZS	1987 10^3 TZS	1988 10^3 TZS	1989 10^3 TZS
Mafyeko		559	61	261
Mamba		755	43	479
Lupatingatinga		1 119	5	637
Nkungungu			316	1 006
Nyeregete	45	40	7	
Muhwela	231		9	
Luwango	138		2	
Azimio	134		9	
Igamba		692	1 554	785
Msangano		955	626	457
Chindi			285	
Shasya		856	91	
Shinji	102	66	10	299

- direct scheme expenses excluding overheads

Source: Annual financial reports 1986, 1987, 1988, DANIDA water project - Tanzania.

Table 17. Handpumped scheme costs: Mbeya region (in 1989 prices).

Scheme	1986 10^3 TZS	1987 10^3 TZS	1988 10^3 TZS	1989 10^3 TZS	Total 10^3 TZS	Cost/ cap.	Service level users/well
Mafyeko		880	75	260	1 215	1 020	300
Mamba		1 190	55	480	1 725	525	410
Lupatingatinga		1 760	6	640	2 406	525	310
Nkungungu			400	1 006	1 406	1 000	280
Nyeregete	90	65	9		164	50	580
Muhwela	455		11		466	210	280
Luwango	270		3		273	210	430
Azimio	265		12		277	130	270
Igamba		1 090	1 950	785	3 825	1 370	150
Msangano		1 500	785	455	2 740	750	460
Chindi			360		360	240	375
Shasya		1 345	115		1 460	560	265
Shinji	200	105	12	300	617	385	320
Range						100 - 1 000	150 - 400
Average						530	310

The handpump wells constructed under the project are relatively shallow, the pumping lift being on average about 5 - 6 m and rarely exceeding 10 m.

The handpump well is planned to serve about 250 users. Due to several reasons including geological formations, Table 13 indicates an average of 310 users per well for schemes analysed during the study. However, Mbeya regional summary on handpumped schemes shows 390 users per well assuming everybody to be using the facility (Sørensen 1989).

The average cost per handpumped well excluding overheads is TZS 165 000 (1989) or USD 1 000 equivalent to TZS 530 per capita if the level of service is averaged on 310 users.

FINNIDA (1984) quotes construction cost including technical assistance and project overheads per well as TZS 32 000, equivalent to TZS 105 000 (1989) or USD 650. The cost per capita is TZS 340 (USD 2) as compared to project rate of USD 3.3 per capita.

Overall handpumped scheme cost analysis for three years for Mbeya region has revealed the following cost distribution (DANIDA 1986, DANIDA 1987 a, DANIDA 1988 b):

Handpump components	25 %
Local materials	5 %
Labour	20 %
Transport	50 %

Figure 5 shows the variation of scheme costs with scheme location with respect to Mbeya town. Transport cost constitutes the major share with respect to direct scheme cost. Variation of capital cost of handpumped scheme with size has also been studied (Figure 4). It has been verified that hand auger drilled wells are less costly compared to machine drilled ones.

Study of handpumped scheme costs revealed the cost distribution pattern as shown in Figure 6.

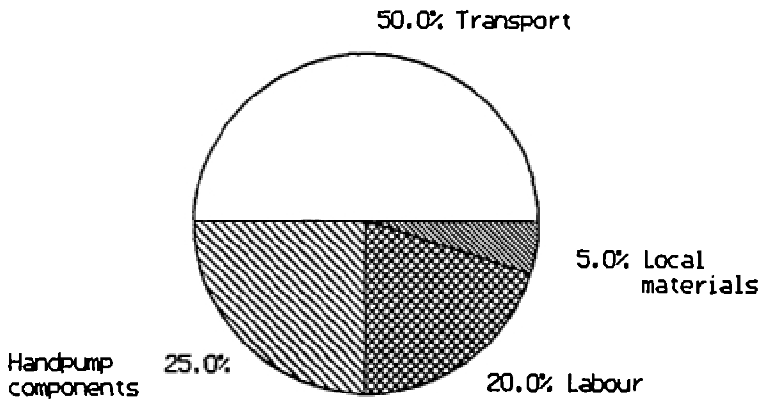

Figure 6. Capital cost distribution for handpumped schemes.

7 OPERATION AND MAINTENANCE COSTS IN DANIDA-SUPPORTED WATER PROJECT

The Government of Tanzania (GOT) had approved a water sector policy in 1971 as 'Water to all by 1991 within 400 m of the homestead as a free public service'.

A lot of funds have been attracted towards establishment of new schemes in additional villages. All this also fitted donor preferences for new schemes.

As a free public service, the central government was to allocate recurrent budget to operate and maintain all water schemes. Arusha seminar (1986) revealed that as much as 40 % of the completed schemes, for one reason or another, are not operating. It simply shows that the centralized maintenance system has failed to secure adequate funding.

Experience for over 10 years prior to the commencement of the DANIDA-supported water project has clearly shown that a 'maintenance free' water scheme does not exist. Also, many schemes spread over a wide area cannot be maintained centrally. So villages must somehow be involved.

A DANIDA-supported water scheme is handed over to the respective village at the end of the construction phase. O&M of water scheme is arranged by the village through a trained scheme attendant. Few spare stocks are left behind the village after construction to ensure a year's trouble free operation. This is sort of a guarantee to take care of any construction fault (Sørensen 1988).

The village organization with respect to water scheme management responsibilities receives support through regular visits. Mobile monitoring and training units, regionally based, visit village schemes quarterly to advice and sell spare parts. Efforts are geared to monitor these schemes at district level to reduce both down time and transport cost (DANIDA 1988 a).

The first six water schemes in Mbeya region were handed over to village ownership during late September, 1985. The project started to follow up and monitor O&M costs of schemes from June 1987 to date. The cost data is still restricted to spare parts sold from the mobile units to villages. The spares purchased directly from the local market are not registered. However, due to extremely high charge rates from the open market for spares, most of the stock for O&M spares are acquired through the project. The operation costs of the mobile units are usually missing. However, the author made necessary estimates.

It has been observed that not many villages pay scheme attendants on regular basis. Even in cases where these get paid, the amount fluctuates. Labour charges for O&M of schemes are yet to be monitored. For the purpose of my study, a minimum salary scale has been assumed on a monthly basis.

7.1 Operation and maintenance cost elements

Principal components contributing to O&M costs of rural water supply systems are labour, transport, replacement parts and energy. Variation in reported O&M costs among different rural water supply programmes is mainly due to extent of full costs of transport, labour and support provided by donor agencies considered. Most cost presented in the literature are not only difficult to compare because they are based on different economic conditions, but also because very often it is not clearly stated what costs have been included. For example, DANIDA-supported village water schemes O&M cost calculation for Mbeya region is based on cost of replacement parts. Full costs of transport, staff and donor support are not included (Sørensen 1989).

Possible cost elements for O&M are (Bastemeyer and Visscher 1987):

1) At local or village level:

- salary costs for caretaker(s) and village mechanics
- spare parts, if locally purchased
- fuel and grease
- material for repair of system (e.g. cement, gravel, etc.)
- upkeep of tools and repair equipment
- cost of revenue collection
- cost of major repairs by private contractor (if any)

2) Regular high level support:

- cost of monitoring including salary, transport, data analysis and overhead
- salary of repair team (if available) including overhead and administration
- transport of repair team
- cost of spare part distribution system
- cost of workshop for maintenance and repair of pumps equipment and vehicles
- cost of offices
- training aspects

3) Irregular high level support:

- replacement of major components including salaries, transport and overhead
- cost of external support (often carried by donor organizations).

In all cases the annual maintenance cost greatly depends on the type of water supply system, the technology and the selected maintenance organization.

DANIDA-supported rural water supply programme implements systems which can as much as possible be operated and maintained at village level (VLOM). Regular regional level support is still in force, mainly for monitoring, training and spare part distribution reasons.

The project has standardized the construction materials for both piped and handpumped supplies. For example, only SWN 80 handpumps are used to limit the number of spare parts. This has also considerably reduced the need for training.

To enable project planners to establish accurate O&M costs of water supplies, Jordan and Wyatt (1987) listed the following elements as main constituents:

- labour
- materials
- transport
- chemicals, for water treatment processes
- utilities to support the O&M of a water system.

Due to varying nature of each individual cost element, it sounds incorrect to assume that O&M costs for different schemes will be equivalent. It is nevertheless useful to evaluate both the average and the range of O&M costs for several different projects utilizing similar water supply technologies. This allows project planners to better forecast O&M costs prior to implementation.

Recording of O&M costs starts up only after the scheme is handed over to the beneficiaries. This implies that scheme delayed for handing over, has part of its O&M cost absorbed into capital cost.

7.2 Operation and maintenance cost data

O&M cost data for piped supplies at current prices is shown in Table 18, whereas the O&M cost elements are presented in Figure 7. Table 18 shows how cost of running water supplies builds up with scheme age.

Table 18. Operation and maintenance costs for gravity piped schemes at current prices (1000 TZS).

Scheme	1987			1988			1989		
	Material	Labour	Transp.	Material	Labour	Transp.	Material	Labour	Transp.
Songwe I								10.0	2.6
Iwindi								30.0	5.4
Rujewa I					48.0	13.5		120.0	40.5
Rujewa II								465.0	23.3
Chimala	3.0	58.2	20.0	10.7	115.5	54.0	8.2	52.5	27.0
Ilongo							2.6	33.0	10.8
Uyole	2.8	25.0	1.3	84.0	330.0	13.5	15.8	150.0	2.3
Ngana I		70.0	15.0	5.5	231.0	81.0		105.0	67.5
Ngana II								60.0	31.5
Sub-total	5.8	153.2	36.3	100.2	724.5	162.0	26.6	607.0	210.9
% yearly total	3	78	19	10	73	17	3	72	25

	Materials	Labour	Transport
Range	3 - 10	72 - 78	17 - 25
Average	5 %	75 %	20 %

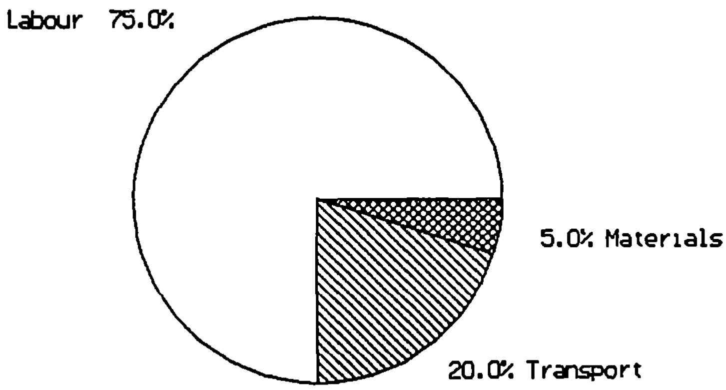

Figure 7. Operation and maintenance cost distribution chart for gravity piped schemes.

Summary of annual O&M cost for piped schemes is shown in Table 19.

Table 19. Annual operation and maintenance cost analysis for gravity schemes (in 1989 prices).

Scheme	Annual O&M cost TZS	O&M cost per capita TZS	Capital cost per capita TZS	O&M cost per cap. cost %
Songwe II	78 000	15	2 650	0.5
Iwindi	210 000	10	550	1.5
Rujewa I	410 000	15	1 850	1.0
Rujewa II	180 000	10	3 970	0.3
Chimala	225 000	20	930	2.0
Ilongo	300 000	20	5 640	0.4
Uyole	460 000	30	1 310	2.3
Ngana I	405 000	40	1 560	2.6
Ngana II	360 000	20	3 580	0.5
Range		10 - 40		0.3 - 2.6
Average		20		1.2

Based on direct scheme costs without overheads, annual O&M cost of rural piped water schemes constructed in Mbeya region with DANIDA funding averages to 1.2 % of capital cost. The percentage would increase to 2 % when overheads were included.

This observation can be judged to match fairly well with usual planning percentages in common use of 5 - 20 % of capital cost while estimating the cost of operating and maintaining the water system (Jordan and Wyatt 1987).

IRC (1987) estimated O&M cost for gravity piped schemes constructed with DANIDA support as TZS 20 per capita (1986).

Similar cost information for handpumped schemes is shown in Table 20 and Figure 8, with summary of annual O&M cost in Table 21.

Table 20. Operation and maintenance cost for handpumped schemes at current prices (1000 TZS).

	1987			1988			1989		
	Mat.	Lab.	Transp.	Mat.	Lab.	Transp.	Mat.	Lab.	Transp.
Nyeregete		5.0	7.5		45.0	30.0		25.0	27.0
Muhwela		18.2	5.6		45.0	7.5		25.0	6.8
Shasya				2.6	37.5	18.0		25.0	21.6
Azimio		18.2	7.5		45.0	11.2		25.0	7.0
Luwango		9.0	20.0	5.2	22.5	30.0		12.5	36.0
Sub-total	0	50.4	40.6	7.8	195.0	96.7	0	112.5	98.4
% yearly total	0	55	45	3	65	32	0	53	47

	Materials	Labour	Transport
Range	0 - 3	50 - 65	30 - 50
Average	2	60	40

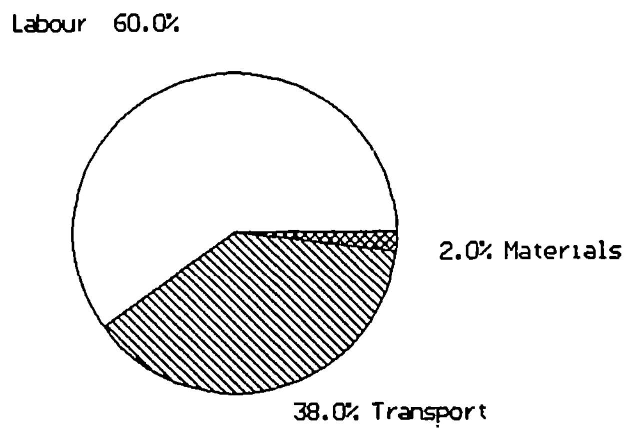

Figure 8. Operation and maintenance cost distribution chart for handpumped schemes.

Table 21. Annual operation and maintenance cost analysis (in 1989 prices).

Scheme	Annual O&M cost TZS	O&M cost per capita TZS	Capital cost per capita TZS	O&M cost per cap. cost %	Distance from Mbeya km
Nyeregete	104 600	30	50	60	150
Muhwela	65 000	29	210	14	50
Shasya	102 300	39	560	7	160
Azimio	68 600	32	130	25	75
Luwango	80 000	62	210	30	200
Range		30 - 60		10 - 30	
Average		45		20	

Nyeregete scheme is not considered for average value due to low service level, hence making result not representative.

Based on limited O&M cost data for handpumped schemes, annual recurrent cost for DANIDA-supported handpumped schemes roughly averages to 20 % of capital cost. The percentage could increase to 30 if overheads were taken into consideration.

IRC (1987) estimated O&M cost for handpumped schemes built with DANIDA support as TZS 31 per capita (at 1986 price level).

7.3 Summary of cost analysis for rural water supplies

It is essential to combine construction costs with O&M costs to compare an expensive type with a cheaper one which costs more to run.

- Annualized capital cost per capita has been computed using the 'Zero' rate of return, because the source of funds has 100 % grant element.

- Design period for piped and handpumped schemes assumed as 20 and 10 years respectively.

Annualized costs of gravity piped schemes and handpumped schemes are summarized in Tables 22 and 23 respectively.

Table 22. Costs of gravity piped schemes (in 1989 prices).

	Capital cost TZS/cap.	Annualized cost TZS/cap.	O&M cost TZS/cap.	Total annual cost TZS/cap.	
Songwe II	2 650	130	15	145	
Iwindi	550	30	10	40	*)
Rujewa I	1 820	90	15	105	
Rujewa II	4 000	200	10	210	
Chimala	930	45	20	65	*)
Ilongo	5 630	280	20	300	
Uyole	1 310	65	30	95	
Ngana I	1 550	80	40	120	
Ngana II	3 570	180	20	200	
Range	500 - 4 000	60 - 300	10 - 40	100 - 300	
Average	2 300	150	20	170	

* Schemes started earlier than the establishment of detailed account system for monitoring scheme cost. These schemes had their old system rehabilitated. The accuracy of cost estimation prior to 1986 could not be guaranteed.

Table 23. Costs of handpumped schemes (in 1989 prices).

Scheme	Capital cost TZS/cap.	Annualized cost TZS/cap.	O&M cost TZS/cap.	Total annual cost TZS/cap.
Nyeregete	50	5	30	35
Muhwela	210	20	30	50
Luwango	560	55	40	95
Azimio	130	15	30	45
Shasya	210	20	60	80
Range	100 - 1 000	10 - 60	30 - 60	40 - 100
Average	530	55	45	100

In view of scarce data with respect to O&M cost of handpumped schemes, it limits the accuracy of the final result.

When the individual numbers in an estimate are relatively inaccurate, arithmetic operations such as subtraction, multiplication and division increase the inaccuracies. However, adding numbers together improves the accuracy of their total (Park and Jackson 1984).

The annual cost per capita of providing improved water supplies to rural population in Mbeya region based on DANIDA implementation set-up is about TZS 170 for gravity piped and TZS 100 for handpumped schemes respectively. Data analysis is based on direct scheme costs excluding overheads.

The overheads including equipment, supervision costs, consultancy fee excluding expatriate salaries are calculated to be 70 % of direct scheme cost.

8 CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

Particularly O&M activities should be decided at the lowest possible administration level. The community should be motivated to take care of the routine maintenance as much as possible, quite limited support coming from the districts and regions. This decentralized system approach depends on the type and level of technology. Introduction of advanced technology on rural water systems such as windmill, solar powered pumps, diesel powered pumping, etc. would encourage lateral shift toward centralized support. The existing motivation of villagers should be one selection criteria when thinking of implementation priorities.

Villages must contribute some portion of the construction cost of their system, a contribution to be made in terms of money, labour or both. This is bound to reduce the capital cost and promote sense of ownership and improve cost recovery regarding recurrent expenses.

Level of service provided by an improved water system to the consumers should realise envisaged benefits. It should be such that it would avoid users going back to polluted traditional sources. Consumption figures of two metered water points have reflected this fact. Lower water consumption figure due to unsatisfactory level of service reflects higher unit cost (TZS or USD per m^3).

An average capital cost of handpumped well with a pumping lift of about 6 m would be TZS 165 000 (1989) or USD 1 000 excluding overheads. Transport cost accounts for over 50 % of the total cost. Capital cost per capita is TZS 530 or USD 3.3 (at 1989 price level).

Service level of handpumped schemes in Mbeya region averages at 310 users per well which is considered too low.

Pipes and accessories make the big cost share (50 - 70 % of total cost) in case of gravity piped schemes. Control of the overall cost should be geared on this cost element through hydraulic design optimization.

Average cost per capita for gravity piped schemes in Mbeya region is approximately TZS 2 500 or USD 15 (at 1989 price level). The cost per m^3 of water produced excluding overheads is about TZS 100 000 (USD 600).

Handpump technology is the least expensive in terms of investment, however, exhibits higher running costs than gravity piped schemes. A summarizing graph of the total annual costs is shown in Figure 9.

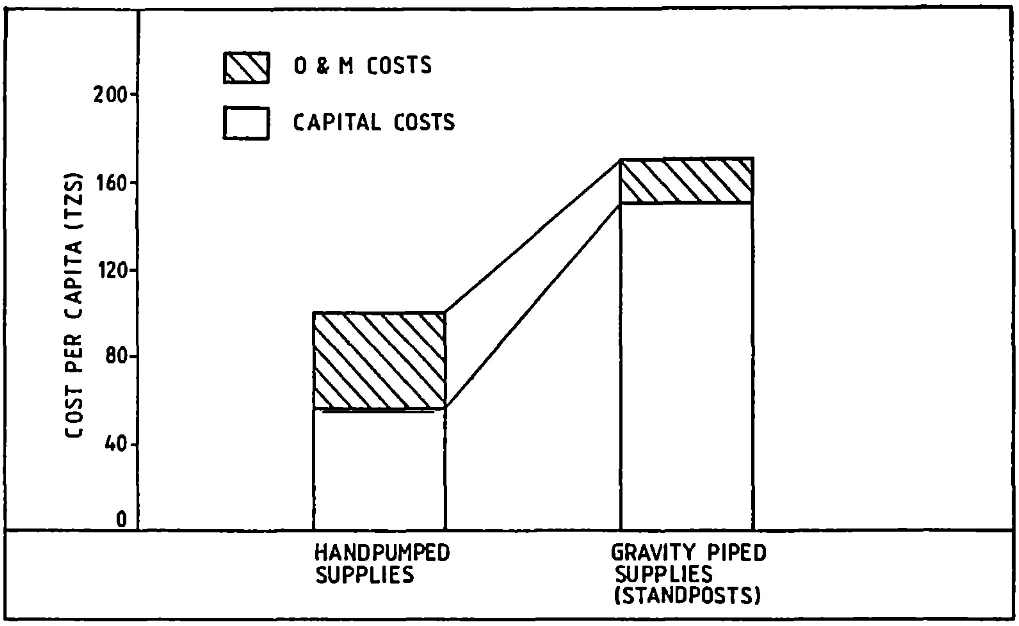

Figure 9. Distribution of annual costs of community water supplies in Mbeya region in Tanzania 1989. (All costs exclude overheads.)

Cost analysis is a useful tool for financial planning, because it shows the level of investment required to achieve the government's stated objectives in the field of rural water supply.

Actual O&M cost per capita will be slightly higher than the reported figure due to the fact that total village population has been assumed to use the system, which is not the case in most villages.

8.2 Recommendations

The cost per cubic metre of water produced was calculated based on a specific consumption of 25 l/cap/d as stipulated in the design criteria guidelines issued by the project. However, the author studied the water consumption behaviour in two separate villages served by a common piped water supply during the research period. The amount of data being limited to one season and one agro-ecological zone, cannot provide reliable information to recommend any change to the design criteria parameters. However, the fact that the research findings of my study agree fairly well with the water use study carried out by project in 1987, one could see the need to confirm the reported higher water demand figures.

The DANIDA-supported project accumulates the O&M costs per installation for several years and computes the per capita cost based on national population census figure. It is recommended that O&M costs are shown separately, year by year, so that probable trends in unit costs can be indicated. This procedure has an extra advantage of accounting for inflation and devaluation effects which differ year after year. Realistic O&M cost per capita should be based on actual number of users rather than village population data.

The economic analysis showing clearly what shadow prices are assumed is only necessary where there is a choice to be made on alternative technologies with different O&M cost implications. This has to be done when windmill, solar powered and electric driven pumps are considered as alternative pumping technologies. Otherwise cost analysis is adequate for VLOM technologies.

The DANIDA-supported water project in Tanzania covers Iringa and Ruvuma regions in addition to Mbeya region. The project area of 177 200 km^2 is approximately 19 % of total area. The accuracy of the cost analysis can be improved by considering the whole project area. It is recommended to extend the cost study to cover the other regions for comparison purposes.

The results obtained from this study can be used to forecast future costs of projects, planned for implementation while preparing the preliminary design report. The following action is recommended:

- to identify a recent project of known cost with similar characteristics to the one under consideration
- to convert the cost of previous project to a current basis using an appropriate NCPI to correct historical cost for time and location
- to define the relative size of the two projects in terms of resources consumed (e.g. m^3/d of water)
- to take the three known quantities - size and cost of previous project A and the size of project B, then the cost of the planned project can be worked out

$$C_A/C_B = (S_A/S_B)^x$$

where x defines cost capacity relationship (varies, 0.6 - 0.8).

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