Costing Calculation of Operation and Maintenance in Community Water Supplies.

By

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Declaration

I, Patrick Nduati Mwangi declare that unless otherwise indicated, this dissertation is my work and has not been submitted for degree purposes at another University or Institution.

Signed

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Abstract

Studies of community water have been on the increase since the International Drinking Water Supply and Sanitation Decade, 1981 – 1990. However there is some key areas of community water supply that still require research as the literature survey in this thesis illustrates. The Operation and Maintenance of community water supplies has been identified to be as important in sustainability of the services as the institutional factors.

Due to the increased number of failure of the community water supplies to continue operation after short periods of time compared to urban water supplies, effort is required to identify the least amount of in puts to ensure continued operation. Through literature survey and field collection of data on management of existing projects a model was developed in order to calculate the minimum amount of funds required for the operation and maintenance. The research showed that the current monthly charges by water committees were sufficient to operate and maintain the systems. The initial calculations using the model also revealed that the current charges would not be sufficient to pay replacement costs. The presence of subsidisation through materials and labour by the central government requires planners to study each project thoroughly before the determination of monthly costs.

The conclusion was that further research and data collection was required for the determination of the replacement cost. The model was found to be capable of assisting planners, managers and engineers in the calculation of the cost of operation and maintenance of community water supplies.

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Chapter One

Introduction

During the International Drinking Water Supply and Sanitation Decade, 1981-90, some 1600 million additional people were served with safe water. However by the end of the Decade there were still over 1 billion people without safe water. Figures of 1994 (WHO, 1997) show about 1.1 billion people were still without safe water. In terms of percentages of the population, the worst regions are in Africa (WHO, 1997).

When the coverage figures for 1994 were assembled, the population of the developing countries was about 4.4 billion. In 1995, the United Nations estimated the total population of developing countries at 4.53 billion, about 37% urban and 63% rural. Africa and Asia and the Pacific were predominantly rural. The United Nations projections for the year 2025 foresees a population increase in developing countries of nearly 2.6 billion people, adding 50 percent to today's population (United Nations, 1994).

As outlined above we cannot hope to meet the problems of water and sanitation sectors by massive investment programs. This is the negative lesson from the Decade 1981 to 1990. According to Middleton, 1998 the following lessons learnt however offer the possibility that by changing our approaches, services and coverage may be improved substantially.

- Sustainability is critical
- Sustainable systems fit the needs of the people who are going to use them.
- Systems should be upgradable.
- Water supply and sanitation development should be balanced.
- Planning and implementing balanced water supply and sanitation is difficult.
- Affordability needs to guide development choices.
- Subsidies are undesirable; if they are essential, they should be carefully targeted.
- The public sector has not made enough use of the capacity of the private sector.
- Privatization needs strong, honest regulation.
- The role of the government should move from that of provider to that of facilitator and regulator.
- Full use should be made of community capabilities.

- Public education is essential.

Over the last few years, a consensus has also emerged on the principles to guide the provision of rural water supply. International policies call for treating water as an economic and social good managed at the lowest appropriate level. For the provision of water supply this requires that consumers be
engaged in the process of selecting, financing and operating systems that meet their demands and willingness to pay.

Managing water as an economic good has strong implications for the establishment of proper financial arrangements for a project. Financial policies should send out correct signals linking service levels to actual cost, maximize cost recovery by capturing community willingness to pay, and make efficient and equitable use of subsidies. No matter how simple a given project might be on a technical level, provision of rural water services is always institutionally complex, involving a wide range of stakeholders. The community should always play a leading role, selecting and employing various goods and services providers through an incentive structure, which exploits the comparative advantage of all participating organizations. The existence of a legal framework including property rights for all resources and facilities, and legal recognition of the community organization charged with managing the facilities is crucial.

Water has come increasingly to be viewed as an economic good. This change in thinking has contributed to the shift away from top-down, supply-driven approaches to service delivery. Demand-responsive approaches provide greater choice for users and encourage scope for private sector and non-governmental organization involvement in the implementation of rural water projects. Sustainable rural water supply in a demand – responsive approach involves more than giving communities choice about service levels. It requires changing the way projects are implemented so that they shift to community management and financing (UNDP-World Bank Water and Sanitation Program, 1998).

This research investigated existing water supply costing structures. The research objectives are outlined later in this chapter under Study objectives. One of the techniques investigated is the model in Help for Rural Water Credit by Mvula Trust. Mvula Trust is a leading South African NGO in the water and sanitation sector .The manual consists of four components, all independently applicable but taken as a collective, all dependent on one another. The components are:

- Local Level Demand Analysis (Social Survey).
- Technical Options.
- Rural Water Supply Financial Model
- Program and spreadsheet disk

The manual is intended as a guideline and help for planners and informal financial institutions exploring the possibilities of providing credit to poor, rural households. This study concentrates on the input costing and estimates of capacities of households to afford on-site services.

A model developed by Palmer Development Group for the Water Research Commission was studied next. This is an investment-tariff model. The purpose of the model is to assist the agencies responsible for water supply in urban areas of South Africa in the development and evaluation of investment scenarios and tariff policy. The key focus of the model is on the financial viability and sustainability of the water supply service. There are a number of tariff options available.

The model as shown in figure 1 consists of four parts.

Section 1: This is the interactive section of the model. Essential information is entered and the water supply service options are described. An investment program is designed. The user then sets annual tariff increases to meet the service provider's cash flow requirements. Key outputs on the capital and operating accounts are shown.

Section 2: The user is requested to enter information to replace values that are used in the absence of local information. Replacing default values will affect the output in section 1, which can be finalized only once local information has been entered.

Section 3: Output information is presented in greater detail, in formats suitable for printing.

Section 4: This is the 'engine' where most of the calculations are conducted. A user would access this section only to trace the model's calculations, if desired.

A DWAF's Study to determine a Cost Effective and Sustainable Method to provide Rural Communities with Yard or House Connections (Ninham Shand, 1998) was studied next.

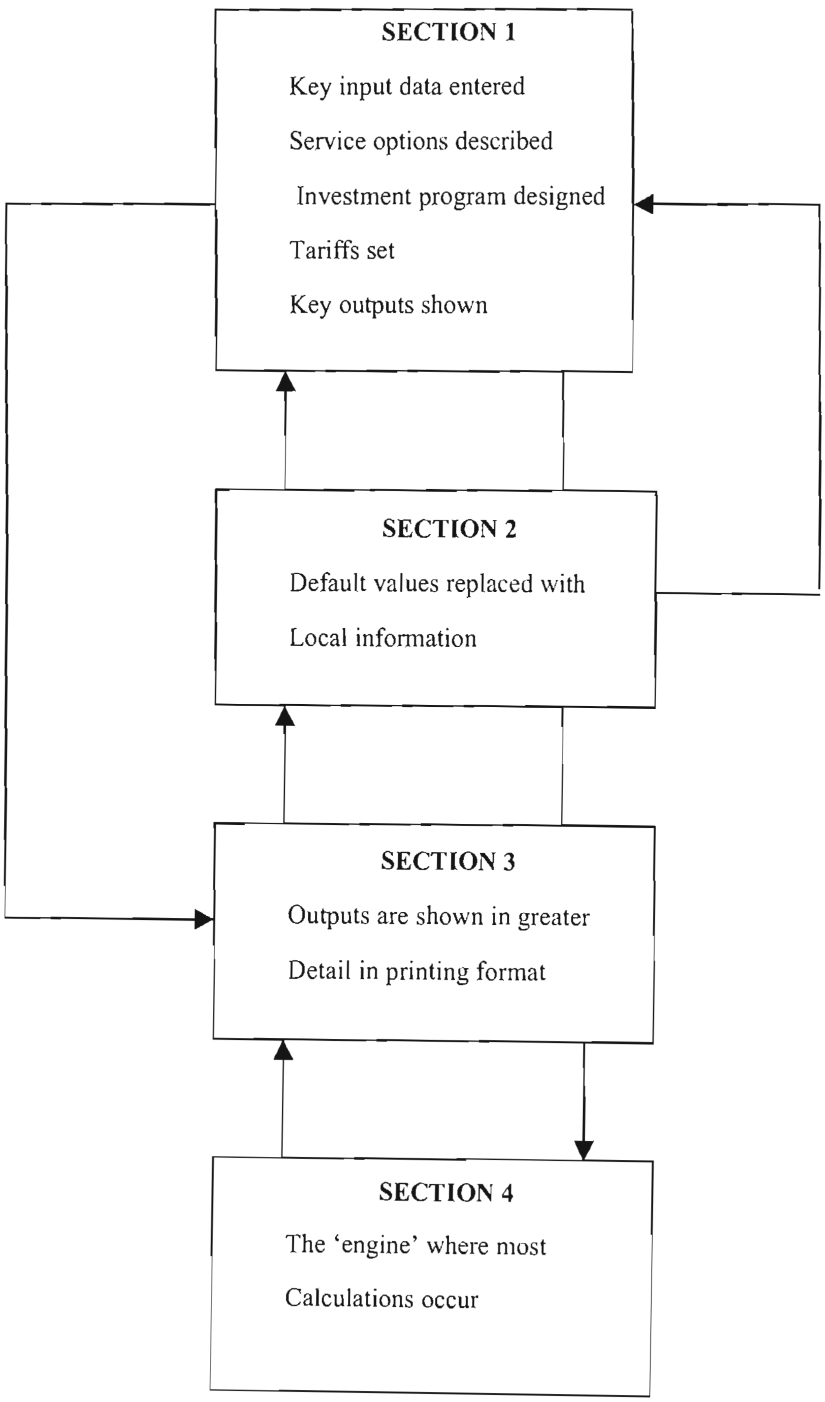

Figure 1: The model structure (PDG, 1998).

This study was conducted through a survey of available systems and strategies for the provision of high levels of service and cost recovery focusing on the following four broad systems.

- Unregulated storage tanks.
- Regulated storage tanks (Equity valve and Trickle feed).
- Prepaid meters.
- Conventional metering and billing.

After evaluation, a summary suitability matrix was developed to help consumers understanding of options available and the costs involved. The costs analysed were in terms of initial capital costs and operation and maintenance. The Raftelis Model (Ernst & Young) for Water Pricing Structure was studied next. The Raftelis model was developed for pricing of water and wastewater services in the USA using well-known economic models. The main feature of the model is the fact that pricing structure is based on the trade-off between revenue requirements and the total cost of services. Raftelis's model breaks down the water pricing to either conservation based or

non-conservation based. The conservation-based model has an in-built objective of optimising on the water conservation. On the other hand, non-conservation based pricing structure does not optimise on the water conservation.

The Cost recovery to Developing Urban Communities was also studied: A comparison of different approaches in the Umgeni Water Planning Area (Hazelton and Kondlo, 1998) was also studied. This study on cost recovery was undertaken to assess what can be done practically to ensure the economic viability of water supply schemes to Developing Urban Communities. The research was carried out with communities obtaining their water from Umgeni Water reticulated schemes in the urban fringe around Pietermaritzburg in South Africa.

1.1. Study Objectives and Activities

The objectives of the research were:

- To determine the minimum factors which constitute the monthly running costs of stand-alone community supply schemes to ensure that the schemes are operated and maintained in a sustainable manner utilising local resources.
- To obtain empirical data for the monthly running costs from existing water supply schemes, hence
- Develop a financial framework, which provides guidelines to consultants, planners, and local authorities on the basic monthly running costs of such schemes.

In order to attain the research objectives, the following activities were envisaged as necessary and were to be covered during the project period:

- Carry out a comprehensive literature review on costing of community water operation and maintenance in general.
- Benchmark the existing costing calculation techniques and models through literature search.
- Focus on water costing structures applicable to community water supplies with low-income consumers.
- Model the relevant cost calculation models.

1.2. Thesis Layout.

Chapter 2 gives a review of the current management for sustainability techniques. The focus of policy towards sustainability is covered from the international perspective to the South African one.

In Chapter 3, a review of the costing models in the water supply sector is presented. The aspects involving operation and maintenance are highlighted in each model. This chapter also gives a review of other studies involving costing of operation and maintenance.

Chapter 4 presents the research methodology and experimentation. The pilot data acquisition, preparation and the stepwise development and performance evaluation of the model are given. A questionnaire is developed to facilitate the collection of pilot data in 10 existing stand alone community water supplies managed communities with assistance from Mvula trust a leading non governmental organisation in KwaZuluNatal province of South Africa.

Chapter 5 gives the research methodology, data analysis and the computer based model development. An algorithm coded in a computer program is developed for use in calculating the monthly costs payable depending on the requirements of the individual communities. The developed model is compared to the existing costing models.

Chapter 6 presents the summary, conclusions and recommendations of the model developments and comparisons.

The list of references and the Appendices comprises the end of the thesis.

Chapter Two

Literature Review.

2.1. Water supply coverage.

The most recent WHO statistics indicate that in 1994, 1.1 billion people, or 25% of population in developing countries, did not have access to safe water. There is a need not only to provide new facilities but also to sustain existing ones through adequate operation and maintenance systems and ensure their proper utilisation. Making water supplies a sustainable reality in the developing world is a major challenge, especially in small water systems, which often lack technical, financial and human resources for proper and efficient operations. When the coverage figures for 1994 were assembled, the population of the developing countries was about 4.4 billion. In 1995, the United Nations estimated the total population of developing countries at 4.53 billion, divided about 37% urban 63% rural. Africa and Asia and the Pacific were predominantly rural, while the other regions of the developing world were largely urban (World Health Organisation, 1997).
It foresees a population increase in developing countries of nearly 2.6 billion people, adding 50 percent to today's population (United Nations, 1994).

In 1990 dollars, World Health Organisation figures suggest that the requirement to eliminate the present backlog would be about US$81 billion. To provide universal coverage by the year 2025, these costs would increase to US$247 billion. This figure of US$ 20 billion /year in 1990 dollars is compared to US$ 13 billion /year which was what was spent in the International Drinking Water supply and Sanitation Decade, 1981-90. As the figures illustrate the solutions to the problem of water supply coverage will not be provide by monetary investment in sector alone. This due to the large amounts of investment required compared to the water decade and its limit success during the period 1981 to1990 (Middleton, 1998).

2.1.1. Information in developing countries.

Access to information in developing countries is limited. There are multiple reasons for this, ranging from economic, social, cultural and political factors to lack of an adequate infrastructure that allow information flows within the country. In general, national governments have been in a privileged position in most developing countries when it comes to getting information on specific developmental issues. Even so, many key decision makers in government cannot obtain the up-to-date information they need to implement policies. Other sectors of civil society like non-governmental organisations (NGO's), academia and national businesses, who can and should also play a key role in development issues within their countries, have had an even more restricted access to information. For many years developing countries have been net exporters of information. It is common to find more information for a specific developing country on an Internet server located in Washington D.C., for example, than in the country itself. Moreover, within most countries the little information that exists is either in private hands and/or it does not flow out of government institutions. This lack of information impairs the ability of water managers in developing countries to make informed decisions (Kibata, 1996). There is a need to equip water and environmental sanitation managers in these countries with information capable of assisting them in formulating solutions for a range of water and environmental sanitation challenges (Urbanisation Working Group of Water Supply and Sanitation Collaborative Council, 1993). On the other hand, while exchange of information between developing countries is low, the most practical solution to water and environmental sanitation challenges is to be found among the developing countries themselves. In the past, transferring first world technology to the realities of developing countries, has at times proved inappropriate, costly or both.

2.2. Promising Solutions.

The Water and Sanitation decade has demonstrated that massive investment programs cannot solve problems in the sector only. The following lessons learnt however indicate that changing the approach may improve service and coverage substantially.

- Sustainability is crucial.

  There is no point in building systems that fail on commissioning due to lack of funds, skills, spare parts, or competent management of operation and maintenance.

  Sustainable systems fit the needs of the people who are going to use them. This means those people have to be involved in planning. Community participation is needed in order to ensure that systems are culturally acceptable, affordable, and meet people's expectations.

- Systems should be upgradeable.
- Water supply and sanitation development should be balanced.

  The health and environmental impacts of providing more water without sanitation considerations are negative.
- Planning and implementing balanced water supply and sanitation is difficult.

  Ways should be found of co-operation between organisations responsible for the two sectors.
- Affordability needs to guide development choices.

  Planning should always start from the needs of the community. The affordability must also be considered. This should be based on a reflection of all the costs including wastewater and the environment.
- Subsidies are undesirable; if they are essential, they should be carefully targeted.

  The needs for subsidies should be minimised by designing affordable systems.
- The public sector has not made enough use of the capacity of the private sector.

  Many water supplies in developing countries are intermittent, and with leaking pipes. The prices paid to water vendors by the people who have no municipal service exceed charges by a monopolistic water company. Using the private sector, or converting municipal utilities to private or publicly owned commercial enterprises, can bring substantial efficiency benefits that should eventually translate into better, more widespread service.
- Privatisation needs strong, honest regulation.

  Due to the monopolistic nature of water supply services there is always a risk of abuse in terms of poor quality of service, discrimination in the provision of service, or excessive profiteering. To avoid this, strong control by a government agency is needed. The lack of sufficient capacity to draft or enforce regulations in developing countries makes it difficult. This is especially so where inexperienced developing countries are negotiating long term contracts with highly experienced expatriate companies. Due to the expensive nature of expatriate companies, it would be more cost effective to train local staff to form their own management companies with external assistance, rather than hand over national assets for a period of years to expatriate companies reporting to overseas shareholders. Small systems in particular may be better managed by community-based organisations, provided that they are properly trained.

- The role of the government should move from that of provider to that of facilitator and regulator.

  The role of the government should be in setting more appropriate standards for the sector, establish revolving funds for sector development and encourage the flow of private funds into the sector. The control of the use of water resources to ensure efficient utilisation and conservation is also the government's responsibility.

- Full use should be made of community capabilities.

  Whichever mechanisms adopted to improve community water supply, the community must be involved. Players in the sector will have to judge the appropriate role and the correct time.

- Public education is essential.

  Communities need to be kept informed on what is happening in the sector, what their technical options are what these will cost them, how they can get help and how they can participate in planning affecting their lives (Middleton, 1998).

2.3. The Demand – Responsive approach.

The four overarching principles, which form the basis of the demand-responsive approach are:

- Water should increasingly be managed as an economic as well as a social good.
- Management should be focused at the lowest appropriate level.
- A holistic approach to the use of water resources should be employed
- Women should play a key role in the management of water

(UNDP-World Bank Water and Sanitation Program, 1998).

2.3.1. Understanding the Demand-Responsive Approach

2.3.1.1. Managing water as an economic good: The transition from supply-oriented to demand –responsive services.

Water has come increasingly to be viewed as an economic good. This change in thinking has contributed to the shift away from top-down, supply-driven approaches to service delivery. Demand-responsive approaches provide greater choice for users and encourage more for private sector and non-governmental organisation involvement in the implementation of rural water supply projects. Successful transition from supply-driven to demand-responsive approaches to service delivery require stakeholders to:

- Develop rules that give users the incentive to reveal their demand and give supply agency incentive to act on that information.
- Develop implementation procedures that encourage adherence to the rules and transparency in their application.
- Actively monitor performance and test hypothesis.
- Give regular feedback on performance results to users and supply agencies so that they can modify rules and implementation procedures accordingly.

2.3.1.2. The link between demand-responsiveness and sustainability: Evidence from a global study.

The UNDP-World Bank Water and Sanitation Program carried out a study in six countries. The study aimed to clarify what is meant by demand-responsiveness in theory and in practise and to measure, as well as quantify the impact of demand-responsiveness on the sustainability of rural water systems. The study was carried out over a one-year period by field-based teams in Benin, Bolivia, Honduras, Indonesia, Pakistan and Uganda. The study found that employing a demand-responsive approach at the community level significantly increases the likelihood of water system sustainability. However it also found that even projects that have adopted this approach tend to apply it inconsistently among the communities where they work (UNDP-World Bank Water and Sanitation Program, 1998).

Set up a supportive scheme for small water supply systems, facilitating the availability of specialised services required for the operation, maintenance and management of those systems.

Define and establish a decentralised scheme to supervise the operation of these systems, using institutions close or next to them that would act in compliance with official regulations.

Incorporate water supply projects into income generation projects, or establish co-ordination among them.

Assemble an interagency group to prepare guidelines for the formulation of small drinking water supply system projects taking into account the proposed measures.

Identify and evaluate projects with twofold objectives: drinking water supply and income generation, and disseminate the results so that other countries and communities can benefit from the experiences of successful projects.

2.3.1.5. Paraguay's approach.

In some countries the traditional administrative water boards operating rural areas are a good example of sound management. In Paraguay, their recognition is well established. To strengthen them, they are being grouped together under associations to provide technical assistance to smaller boards and even to install and operate new systems.

The strengthening of the boards will occur within a process in which the government will progressively leave its role as constructor.

The study shown in Table 2.1 was conducted in 1991. Socio-economic studies and surveys were conducted in 13 rural communities of different population sizes. Monetary amounts are given in thousands of Guarani (G/.), which had a conversion rate of G/. 1320 = US$ 1.00 as of September 1991. The total cost represents a water system consisting of a deep well, pumping equipment, elevated water storage tank, a distribution system, and housing. Connection cost represents the capital cost per family for the water system. Family income represents an average monthly income for the families in the community. Total monthly payment includes payment of the loan plus the cost for the operation and maintenance and a reserve of equipment. Percentage of family monthly income represents the percentage of family income dedicated to payment for water supply.

This analysis shows the ability and capacity of the community to meet costs of the system. This links drinking water services to the development process of the community i.e. the process that improves income levels in the communities (Caporali, 1998).

Table 2.1. Paraguay Third Rural Water Supply and Sanitation Project Affordability Study. (Caporali, 1998)

Family Income	Community	Pop.	House Conn.	Total Cost	Conn. cost	Initial Contribution		2.3.2. o a n			O& M Costs	Total Monthly Payment		Electrical Tariff
						%	Conn. (G/.)	%	Yrs	Monthly Payment (G/.)	Conn. (G/.)	Conn. (G/.)	% of Family Income	
280	San Cristobal	221	67	79108	1181	15	177.11	30	10	6.86	6.5	13.36	4.78	24.5
189	Itanara	421	86	96246	1119	15	167.87	30	10	6.50	7.0	13.50	7.14	NA
308	A. Tranquera	2015	395	278008	704	15	105.57	30	5	5.6	3.7	9.3	3.02	28.00
348	Capitan Miranda	836	190	149714	788	15	118.20	30	5	6.72	5.5	12.22	3.51	33.94
142	San Pablo	537	116	107021	923	15	138.39	30	10	5.35	6.8	12.15	8.58	NA
141	Yataity del Norte	1156	236	189098	801	15	120.19	30	10	4.63	3.9	8.53	6.05	7.59
116	Lopza Moreira	942	190	177973	937	15	140.51	30	10	5.44	5.3	10.74	9.23	6.74
249	Bolon	1008	221	222852	1008	15	151.26	30	7	6.73	5.3	12.03	4.83	8.24
251	Los Cedrales	1716	330	185443	562	15	84.29	30	5	4.47	3.5	7.97	3.18	20.00
307	Piquata Cue	3261	649	275620	425	15	63.70	30	5	3.38	3.4	6.78	2.21	13.33
276	Cazadita	2451	462	274529	594	15	89.13	30	5	4.73	3.9	8.63	3.13	11.73
255	Caaguazu	2451	473	263057	556	15	83.42	30	5	4.43	3.9	8.33	3.26	13.46
345	Laureity	7017	1493	822119	551	15	82.60	30	7	3.67	3.9	7.37	2.13	12.27

2.4. Guidelines on cost effectiveness of community water supplies.

Regardless of how the capital required for water supply projects is financed, recurrent costs should be borne by the community. Community management, including financial management, of system operation and maintenance is the only way to achieve acceptable reliability at an affordable cost (CSIR, 1991). Table 2.2 shows the operation and maintenance costs of various water supply systems supplies in rural areas of South Africa. The cost range of the systems is within the income range in rural South Africa which ranges from R50 to R500 per month. The recurrent costs charged to the consumer should reflect this economic fact. This however ignores non-monetary payment possibilities, which are beyond the scope of this research.

To ensure commitment of the community and information dissemination is necessary to ensure representation in the planning and decision making aspects of the project from an early stage. The overall cost recurrent costs on the water supply schemes depends on the caretaker costs (DWAF, June 1998). This is especially so in the case of supply systems comprising of pumps. The costs in this case are brought about by the increased requirements in the capability of the caretaker (s).

Table 2.2. Operation and maintenance costs of various water supply systems in rural areas (excluding caretaker allowance/salary) (1990 prices). (CSIR, 1991)

SYSTEM	**COST RANGE (R/annum)**
System Protection Works	30 – 250 / system
Rainwater Collection Systems	10 – 50 / household
Hand Pump on a Borehole	50 – 150 / pump
Diesel Pump on a Borehole	500 – 5000 / pump
Electric pump in a borehole	400 – 4000 / pump
Wind pump on a Borehole	150 – 800 / pump
Package Treatment Plant (< 100 kl/day)	200 – 4000 / system
Distribution Network	50 – 1000 / system

Note. Costs associated with diesel and electrical pumps, as well as treatment plants, are governed by running costs for the purchase of diesel, electrical, and chemicals respectively.

2.5. Management of water supply projects

The provision of a reliable, safe and accessible supply of domestic water for a rural community who may be poor, are without a conventional statutory authority and have relatively informal arrangements with regard to property boundaries and public space, poses a different dimension to project management for the engineer or planner. Aspects of sustainability related to operation, maintenance, local management and financial were identified during the course of the international Drinking Water Supply and Sanitation Decade to be the greatest challenge to developers. These lessons are as follows:

- Reliable operation and maintenance must be undertaken as a collective responsibility for the system to function satisfactorily. Central to reliable operation and maintenance is the question of sufficient revenue from water to cover recurrent costs.

- Finance is usually limited, and therefore the lowest cost solution compatible with continuous reliable operation must be found. Self-help projects are advocated as ways of extending limited funds. Part of the project finance maybe in the form of a loan, but then the system must be designed in such a way that loan repayments can be met by the community.
- Control of water distribution is necessary if water wastage is to be avoided and consistent supplies are to be assured. Control is also to prevent conflicts between water users from arising. (Cairncross et al, 1980 and World Bank, 1980).

2.5.1. Emergency Fund (Replacement costs)

The issue of expanding, upgrading, or carrying out major repairs to the water supply system in the future requires special attention. These needs require the generation of finances to create a reserve fund within the system. This is crucial for the sustainability of the scheme. The understanding of the importance of such a reserve or emergency fund is difficult for a community who often require cash just to secure the basic needs. Accountability is a factor, which plays a decisive role both in terms of financial planning and in terms of how payment is extracted equitably from the beneficiaries of a water supply scheme.

For a water supply scheme to be implemented and to continue to function, an administrative structure needs to be established. Community water committees are essential prerequisites for the success of projects of this nature. In South Africa governmental and non-governmental organisations are complementary in this aspect (Cairncross et al, 1980 and World Bank, 1980).

2.5.2. Operation and Maintenance.

The effective operation of a community water supply depends upon the competence of the water committee elected from the local community. Maintenance costs on public standpipes systems have been calculated at between 1 and 3 percent of the capital cost per annum (Rivett- Carnac, 1984). This implies that there is need to train local maintenance personnel.

2.5.3. Financial considerations.

The principle of collecting sufficient revenue to cover the recurrent costs of community water supply is now adopted across the world. The recurrent costs include operational costs, maintenance costs, and loan repayments if applicable. The principle of recurrent cost recovery is critical to project sustainability.

In community water supply projects, operational expenditures usually represent a large share of total project life costs. Cost coverage relates primarily to operational activities to meet operation, maintenance, and replacement expenses (International Reference Centre Newsletter No. 177, 1988).

2.6. Relative water costs.

In common with other commodities, which have unit production, wholesale, and retail costs, water too has a unit cost structure in the form of a tariff structure. Water in its natural occurrence is, in general terms, free. The water availability in the tap is due the processes that the water has been through in order to reach that point. These processes include:

- Impoundment
- Abstraction
- Pumping
- Storage
- Treatment
- Distribution
- Marketing

Each of these processes have implications on the on the cost of water in the scheme. The knowledge of the variables is implicit in the calculation of the unit costs or tariffs. The running costs are in the case of community water supplies would be affected by some of these parameters. Examples of these are quantity of water supplied, pumping costs amongst others.

Table 2.3. Relative unit costs of various water supply technologies. (Rivett-Carnac, 1984).

SOURCE	RANGE OF UNIT COSTS (relative to municipal tariffs)
Protected springs	0.098 to 0.213
Wells (6m deep)	0.114 to 0.454
Boreholes (30m deep with hand pump)	0.187 to 0.748
Municipal tariff	1.0
Public standpipes (connected from municipal system)	3.34
Rainwater collection and storage	3.58 to 7.78
Mobile tanker supply	9.17

Notes.

1) Unit costs are relative to municipal water tariff applicable at this time assumed to be unity (in Table 2.4). The public standpipe supply was buying water at the municipal tariff and redistributing it from public standpipes controlled by a paid attendant. All maintenance and some capital repayment were covered from the sale of water.
2) Unit costs are for equal volumes of water and have been arrived at from analysis of the installation costs, the number of users, the per capita consumption and the design life of the system, in the case of springs, wells, boreholes, and rainwater systems.
3) Unit costs in the case of mobile tanker supply were based on installation costs plus operating costs divided by the volume of water supplied in 1980.

Comparative analysis of the cost/supply ratio of various supply technologies conducted in Natal/KwaZulu during the period 1980 to 1984 yielded the following results as shown in Table 2.4 (Rivett-Carnac, 1984).

Of interest in the above figures is the large range of costs from the lower to the upper end of the scale (protected springs and mobile tankers) both of which would be considered of low amenity and accessibility value. In contrast municipal water supplies, which have the greatest amenity, occupy the middle ground in terms of cost. The extremely important reason for determining accurate cost structure and tariffs is for the equitable cost recovery (selling the water) to achieve economic operation of the water supply system. As stated previously some process costs may affect the cost of water supply more than others may. In developing regions these are chemicals, energy, and operational salaries (CSIR, 1991).

2.7. Cost recovery in Water Schemes to Developing Communities.

The cost recovery cover here involves water schemes in developing urban communities in South Africa. 10 million people live in these communities approximately half of which live below the Poverty Datum Level (PDL). The combination of poverty and low water consumption (less than 30 l/day) calls for substantially increased effectiveness in the use of moneys recovered to ensure that these moneys cover the total cost of water delivered to the communities (Hazelton and Kondlo, 1998).

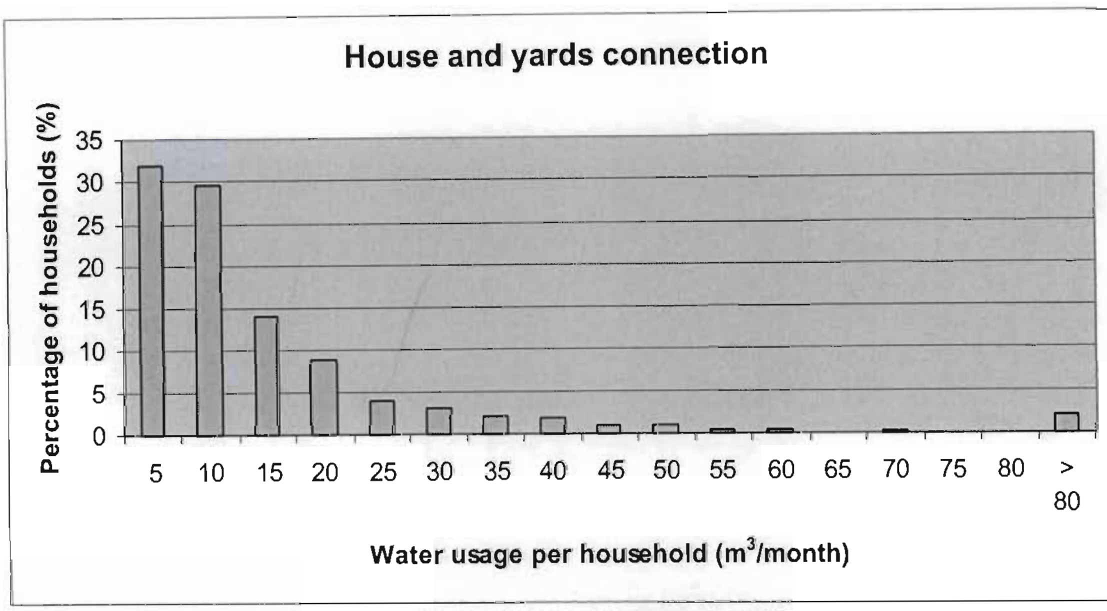

Figure 2.1. Household water usage for house and yard connections in the study area (Hazelton and Kondlo, 1998).

Notes: The study area comprises of developing communities in Umgeni Water Area, sample size: 1847 households, Average consumption: 14 m^3/month, Median consumption 8 m^3/month.

Table 2.4 gives a clear indication of the importance of different categories of clients with respect to account values and numbers of accounts as well as indicating the current situation with respect to Umgeni water's general success with respect to cost recovery. The first column gives a short description of the account type. The first group of accounts is related to water supplies delivered exclusively to developing communities. The second group relates to bulk supplies delivered exclusively to developing communities and some to established communities. The third or last group relates to water supplies delivered exclusively to established communities. The first group is further subdivided into three groups.

- Supplies where Umgeni Water accepts responsibility for the operation, maintenance, and management of the distribution system and therefore interacts with all the individual consumers in the area including households with individual private connections, metered standpipes operator, individual institutions such as schools and churches;
- Supplies to village level water committees where Umgeni Water has no direct contact with individual customers but accepted responsibility for institutional capacity building and general skills training so the Water Committees can carry out responsibilities as village level water service providers; and
- Bulk supplies where Umgeni Water has no responsibilities for distribution and no contact with village level committees or with individual consumers.

Table 2.4. Analysis of Umgeni Water debtors for a typical month in 1994. (Hazelton and Kondlo, 1998)

Account Type	Total current month debt R/c	Percent of total current debt		Number of accounts	Percent of total number of accounts		Average account value R/c	Total debt R/c	Debt ratio Total / Cur
		Indiv %	Cum %		Indiv %	Cum %			
Developing Communities									
Private connection	23629,99	0,09	0,09	1151	88,13	88,13	20,53	77782,22	3,29
Metered standpipes	10487,35	0,04	0,13	36	2,75	90,88	291,32	85811,92	8,18
Water kiosks	173,55	0,00	0,13	4	0,31	91,19	43,39	260,75	1,50
Individual Inst.	2496,96	0,01	0,14	48	3,67	94,65	52,01	15942,95	6,39
Water committee	23939,96	0,09	0,23	7	0,54	95,43	3419,99	200276,84	8,37
Bulk inst.	7640256,44	28,41	28,64	16	1,23	96,63	477516,03	17957604,42	2,35
Sub. Total Dev. com.	**7700983,77**	**28,64**	**28,64**	**1262**	**96,63**	**96,63**	**6102,21**	**18337679,10**	**2,38**
Mixed communities									
Bulk inst.	10255730,32	38,14	38,14	2	0,15	0,15	5127865,16	13929915,09	1,36
Sub-Total Mixed Com.	**10255730,32**	**38,14**	**38,14**	**2**	**0.15**	**0,15**	**5127865,16**	**13929915,09**	**1,36**
Est. Communities									
Private Conn.	3410,78	0,01	0,01	19	1,46	1,46	179,51	6050,87	1,77
Individual Inst.	261342,66	0,97	0,98	9	0,69	2,15	29038,07	693184,24	2,65
Bulk Inst.	8667077,85	32,23	33,22	14	1,07	3,22	619076,99	9790421,50	1,13
Sub-Total Est. Co	8931831,29	**33,22**	**33,22**	**42**	**3,22**	**3,22**	**212662,65**	**10489656,61**	**1,17**

The columns on percent of total current debt examines the Umgeni Water debt, which equals the total invoiced amounts. This indicates that in excess of 28% of Umgeni Water income is derived from water delivered to developing communities. However all but 0.23% of this debt was with major institutions such as the KwaZulu Government Service and the Edendale Complex Town Manager. Thus whilst developing communities are a major client, Umgeni Water is only responsible for recovering costs directly from customers representing 0.23% of the total turnover.

The columns on percent of total number of accounts illustrates that whilst the value of accounts for which Umgeni Water is responsible for recovering costs directly from consumers residing in developing communities is small, these accounts do represent over 95% of all accounts related to water sales. The last sets of columns relate to the average and median value of individual account types and the outstanding debts associated with them. Important items to note from these columns are the low average account values for the private connections and the individual institution connections associated with developing communities and the even lower corresponding median values. These low account values have been one of the many criteria which has made the administration of schemes delivering water to developing communities difficult and which has resulted in Umgeni Water trying various methods of cost recovery and community participation to overcome these difficulties.

2.8. Cost Recovery Methods in Umgeni Water.

2.8.1. Flat Rate Standpipes.

This type of standpipe was first installed in a few communities like Ntshongweni and Geogedale during the advent of drought, which was followed by the 1982 cholera epidemic. The standpipes were situated along the roads in public places. The responsibility for collecting the fixed flat rate monthly charge from customers was given to the tribal authorities controlling the different areas. Community members at the magistrate's court made payment and the magistrate was then responsible for paying Umgeni Water. The system worked until the mid-eighties when political unrest set in and consequently broke down. In addition the flat rate system was found to be unpopular due to the different proximity of the water supply to various people. Lack of metering also resulted to lack of sufficient information on cost of the supply. The standpipes were therefore converted to metered community standpipes and water kiosks (Hazelton and Kondlo, 1998).

2.8.2. Metered Community Standpipes and Water Kiosks.

With metered community standpipes the overall control is the responsibility of he Community Water Committee and it is the committee's responsibility to collect the money from any person they identify to run the standpipe in their name. For the water kiosk system a water shop is created at a standpipe. The community through its water committee identifies a local entrepreneur who is allocated a kiosk. This entrepreneur is responsible for the collection of money for water sold and for the payment of accounts to Umgeni Water. The tariff paid at the kiosk is set with Umgeni Water's advice with the aim of making the whole exercise worthwhile for the entrepreneur whilst keeping the price within what the customers will accept.

The disadvantage of these systems is that to be economically viable they should be positioned in such a way that the number of households using each standpipe or water kiosk is large. This should be enough to enable the attendant to earn sufficient income without charging the customers too high a tariff for the water. Due to the low population density of the communities and the irregular opening hours the kiosks have been found to have low acceptance and prone to vandalism. Metered community standpipes present large debt ratios (Figure 2.2). There are some which show good service and payment situation (debt ratio > 1 to 2). The environmental factors and type of management are in this case the causes ((Hazelton and Kondlo, 1998).

2.8.3. Metered Shared Standpipes.

This relates to an intermediate level of service between a metered community and standpipe and private connection. The main difference between a shared standpipe and a community standpipe is that shared standpipes are in the name of individuals who control them and are

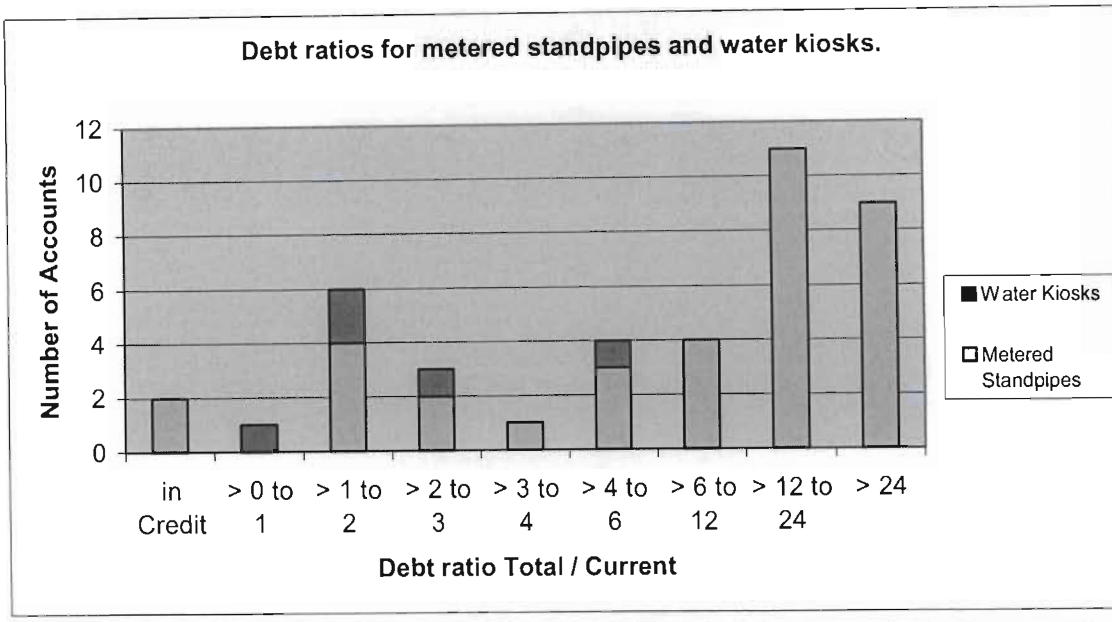

Figure 2.2. Frequency and value distribution of debt ratios for metered standpipes and water kiosks for developing communities supplied by Umgeni Water (Hazelton and Kondlo, 1998).

Notes. Credit in this case means that no debt is owed. The debt ratio is calculated from the Total debt which is the historical monies owed divided by the current debt which is the previous month monies owed.

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fully responsible for them whereas community standpipes are usually in the name of a Water Committee which controls them and is responsible for them. Shared standpipes are situated in the responsible person's yard rather than in a public place. Shared standpipes are operated in two ways. The standpipe owner can either sell water at profit or divide the bill equally amongst the households that get water from the standpipe (Hazelton and Kondlo, 1998). Whilst Umgeni Water indicated that these standpipes have higher acceptability and applicability than other communal options. This is however challenged by the high outstanding debts. Due to metered shared standpipes being registered as private connections, more thorough analysis is difficult.

2.8.4. Private Individual Household Metered Connections.

In this type of connection meters are read monthly and the invoices sent to each individual household by Umgeni Water. There are indications that the cost recovery for these connections is high and table 2.5 previously shows that full operation and maintenance costs are not recovered from any of Umgeni Water's community schemes. As the figure 2.3 indicates 73% of customers pay their accounts within 90 days. It also indicates that there are a significant number of customers from whom obtaining payment is difficult. Some of these are customers whose bills were above average and have now reduced their consumption to pay off their debt whilst others are those water has already been cut off and are therefore currently being billed the minimum R5,70 /month charge. The coverage of private connections in community water supplies is low (10% of a representative selection of communities in 1993). The cost recovery would therefore change with increased coverage (Hazelton and Kondlo, 1998).

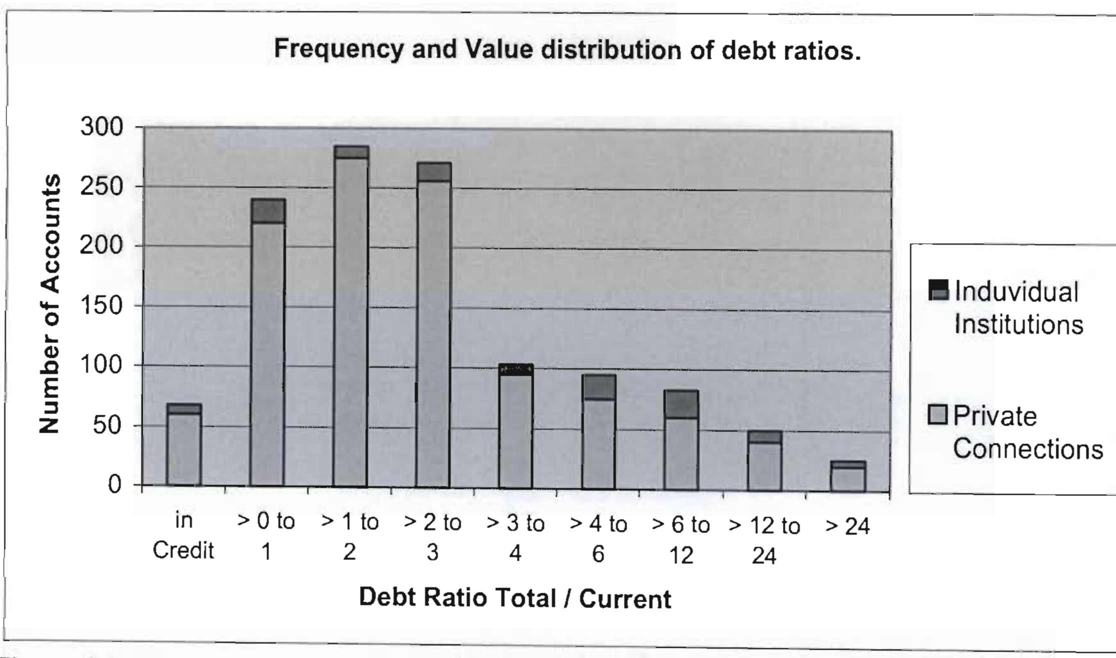

Figure 2.3. Frequency and value distribution of debt ratios for metered standpipes and water kiosks for developing communities supplied by Umgeni Water (Hazelton and Kondlo, 1998).

Notes. Credit in this case means that no debt is owed. The debt ratio is calculated from the Total debt which is the historical monies owed divided by the current debt which is the previous month monies owed.

The main disadvantage of this type of connection is the high costs associated with the construction, operation and maintenance.

2.8.5. Community Operated Water Supply Systems.

These are the long term supply schemes aimed at by water authorities like Umgeni Water. For such schemes a locally elected Water Committee is responsible for the governance and thus for organising the management of the reticulated pipe work, the collection of revenue from the community members and the payment of bulk water delivered by Umgeni Water.

Schemes operated in this way are QadiNyuswa, Lower Ngcolosi, Mpolweni, Inqunqulu, Embo and Mseleku. These schemes have been owned by the communities since construction. Two of this communities do sometimes seek advice from the Umgeni Water to solve their maintenance problems but otherwise maintain a high degree of self-reliance and consistently maintain a surplus with which to pay for their bulk water supplies indicating close to full financial self-sufficiency. The consistent existence of an operating surplus would indicate a satisfactory level of approval in two of them and confirms the claims in the literature that the higher the level of community participation the greater the possibility of sustainability. The Figure 2.4 gives an indication of the sort of profile required to keep any water service provider in business and therefore can be used for setting final targets that are to be achieved over time with adequate capacity building, ongoing monitoring and support, appropriate levels of service and good cost recovery methods (Hazelton and Kondlo, 1998).

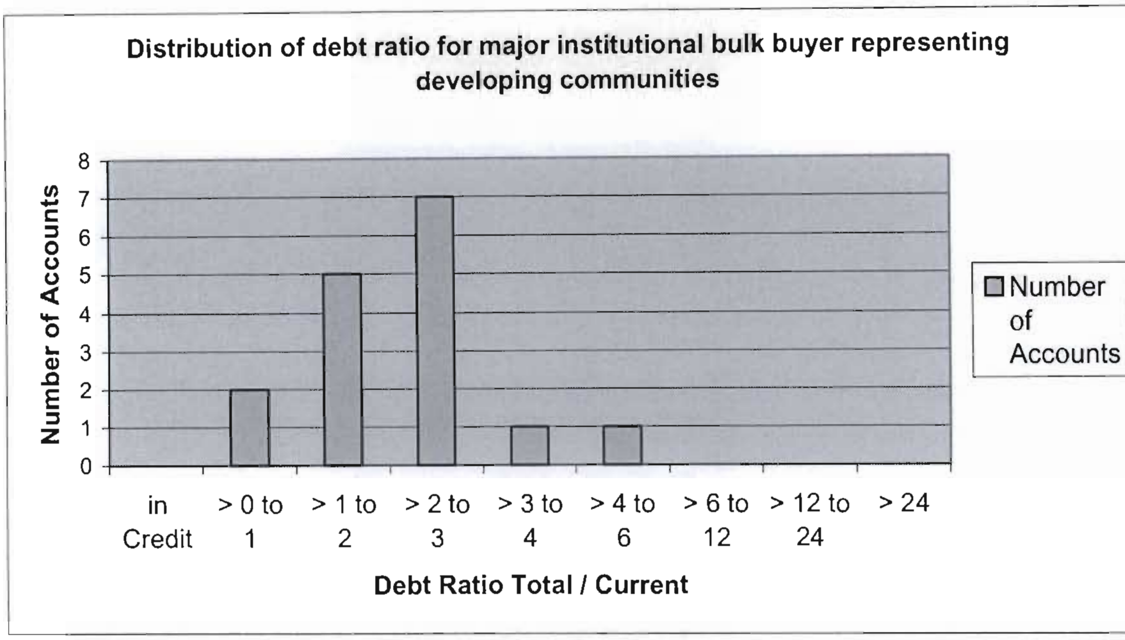

Figure 2.4. Frequency and value distribution of debt ratios for major institutional bulk buyer representing developing communities supplied by Umgeni Water.

Notes. Credit in this case means that no debt is owed. The debt ratio is calculated from the Total debt which is the historical monies owed divided by the current debt which is the previous month monies owed.

2.8.6. Operation and Maintenance costs.

Involvement of statutory bodies in operation and maintenance work of community water supplies has been found to be ineffective and costly. Communities should operate, monitor, care for, and manage their own schemes but leave all major maintenance work to local properly trained professionals. The contribution of the statutory bodies is then limited to facilitating an enabling environment and being a mediator between communities, maintenance companies, and materials suppliers. Shortage of funds and its management has not been studied.

2.8.7. Cost Recovery.

It now accepted that developing communities in general should pay for water (and other services) but there not little agreement on whether such communities can be self sufficient even when only operating and maintenance costs are considered. Communities value goods they pay for more than free goods; it reduces wastage; ownership and a sense of caring for an installation can be transferred to a community.

This can be done when the community accepts a central role in paying the operating and maintenance costs.

There is general agreement that once a minimum level of service has been provided the charges for higher levels of service should be related to the real costs of supplying the water but again not necessarily covering the full cost when minimum levels of consumption are being discussed.

The literature is however very inconsistent with respect to estimating different communities ability to pay for these costs in full. A study carried out by the Netherlands Economic Institute (van Wildenburg 1991 p.20 and 21) reports that rural communities in Bukina Faso not only pays for all operation and maintenance but also sets aside reserves for the replacement or extension of village water supply schemes. On the other hand another study done about the same time in the Netherlands (Besselink, 1992. p25) reports that generally maintenance costs exceed the financial capacity of villagers. It is therefore clear that each individual water supply scheme characteristics need to be assessed thoroughly the sustainable tariffs are imposed on the community concerned.

2.8.8. Classifying water scheme operating and maintenance costs.

The cost of operating water schemes can be subdivided into three classes of costs:

I. costs which vary roughly proportional to the quantity of water delivered,
II. costs which are fixed and mainly depend on design capacity of the scheme,
III. costs which are unaffected by the capacity of the scheme or the quantity of water delivered but are roughly proportional to the number of connections installed.

Type I costs include: bulk water costs and the cost of internal reticulation boosting not included ion the bulk tariff. Type II cost include: redeeming capital and / or building up a capital works replacement fund, and main reticulation maintenance costs including any additional maintenance costs due to vandalism. In the case of Umgeni Water peri-urban schemes Type III costs include: costs associated with meter reading, computer billing, general accounting and administration, carrying out disconnections, security arrangements where application, community branch accounting offices and officers, maintenance of meters and connections, and unaccounted for water.

2.8.9. The effect of lower water consumption levels on the economic viability of water supply schemes.

Assuming schemes for developing communities are designed with a 50% higher initial space capacity factor than used for established urban schemes to allow for a higher percentage growth in sales and that average sales per connection are 14 and 34 kl/month respectively for the developing schemes, Table 2.5 represents typical charges required to ensure economic viability of two schemes in the same area. These charges are based on 1993/94 costs applicable to Pinetown Water [1] before incorporation into Durban Water [2]. In the table above no allowances have been made for additional costs such as vandalism, thefts, additional disconnection costs, or higher unaccounted for water due to unauthorised connections or poor maintenance. The results indicates that householders in developing communities with individual yard connections would be required to pay 42% more per kl for their water than urban communities assuming full cost recovery is implemented and that conventional methods of billing and payment are used. At a tariff of R3,69 /kl the cost of 14 kl is R51,66.

Table 2.5. The effect of water consumption levels on the cost recovery.

Cost centres	Typical water costs at a demand of 34 kl/month per off-take		Typical water costs at a demand of 14 kl/month per off-take	
	R/kl	%	R/kl	%
a) Bulk water costs	1,45	56	1,45	39
b) Redemption / capital fund	0,36	14	0,54	15
Maintenance	0,21	8	0,31	8
c) Cost of cost recovery (R 14,00 per connection)	0,41	16	1,00	27
UAW (R 5,44 per connection)	0,16	6	0,39	11
TOTAL	R2,59	100%	R3,69	100%

2.8.10. Costs for and income from Umgeni Water schemes to Developing Communities.

The Table 2.6 shows the average monthly operation and maintenance costs for a number of Umgeni Water schemes supplying developing communities as supplied by

Table 2.6. Average monthly operation and maintenance costs during the period June 1994 to May 1995 for 10 Water schemes. (Hazelton and Kondlo, 1998).

Scheme name	Bulk water sold R/month	Unaccounted for water R/month	Administration R/month	Operating R/month	Maintenance R/month	Total costs R/month
Fredville	10180	4682	6497	346	19798	41503
Georgedale	8594	2368	2531	210	5680	19383
Groutville	2162	3563	6164	616	8275	20780
KwaXimba	11847	4698	7123	3229	26787	53684
Manyanu	1119	984	1286	240	46	3675
Ndwedwe	3534	897	3173	85	6100	13789
Ntshongweni	5432	1293	1391	331	4851	13298
Phayiphini	5989	2445	6189	5324	10291	30238
Sankontshe	5984	2771	594	86	5227	14662
Table Mountain	2275	808	3774	936	2838	10631
Sub-totals	57116	24509	38722	11403	89893	221643
% of Total	26	11	17	5	41	100
Average R/connection	12,43	5,33	8,43	2,48	19,56	48,23

Umgeni Water Finance and Administration Department. The Umgeni Water costs reflect lower administration charges and higher maintenance costs shown in Table 2.6 but overall the charges are similar.

Table 2.7 represents the total operation and maintenance costs for the same schemes and compares these totals with the income received. This income represents between 80 and 90 %

of the billed amount over the same period. Thus even with 100% recovery of the billed

<1> Pinetown is an industrial town in the outskirts of Durban city.

<2> Durban is the principal urban centre and harbour of the KwaZuluNatal province.

amount the gross income would be less than 29% of the total O&M costs. This low percentage in turn reflects the need for high tariffs when water usage per connection is very low. The average water usage per connection for the ten schemes recorded in

Table 2.7. A comparison between the average monthly operation and maintenance costs and the income during the period June 1994 to May 1995 for 10 Water schemes. (Hazelton and Kondlo, 1998).

Scheme name	Water used kl/month	Number of conn	Total O&M costs			Gross Income			Subsidy	
			R/month	R/Kl	R/conn	R/month	R/Kl	R/conn	R/kl	R/conn
Fredville	7021	845	41503	5,91	49,12	7996	1,14	9,46	4,77	39,66
Georgedale	5927	441	19383	3,27	43,95	10571	1,78	23,97	1,49	19,98
Groutville	1491	780	20780	13,94	26,64	2811	1,89	3,60	12,05	23,02
KwaXimba	8170	896	53684	6,57	59,92	10065	1,23	11,23	5,34	48,69
Manyanu	772	212	3675	4,76	17,33	780	1,01	3,68	3,75	13,65
Ndwedwe	2437	165	13789	5,66	83,57	3770	1,55	22,85	4,11	60,90
Ntshongweni	3746	179	30238	3,55	74,29	3372	0,90	18,84	2,65	55,45
Phayiphini	4130	637	14662	7,32	47,47	5785	1,40	9,08	5,92	38,39
Sankontshe	4127	246	10631	3,55	59,60	3951	0,96	16,06	2,59	43,54
Table Mountain	1569	195	3774	6,78	54,52	1687	1,08	8,65	5,70	45,87
Totals and Averages	39390	4596	212119	5,63	48,23	50788	1,29	11,05	4,34	37,18
Water used / connection & percentage of total	8,57kl/month		100%			23%			77%	

Tables 2.6 and Table 2.7 including shares connections is only 8,57 kl/month.

Significantly less than the average 14 kl/month usage reflected for the sample used to plot Figure 2.2 and to calculate the estimate breakeven tariff shown in Table 2.7.

2.8.11. Planning and Institutional Arrangements.

With adequate capacity building and training at a level of small communities, stand alone schemes and the reticulation pipework for villages supplied with water from larger schemes are best managed and cared for by the communities themselves.

Management covers cost recovery, bookkeeping and financial reporting. Caretaking covers operation, day to day care and routine monitoring of the facility. If the community itself pays for these services it is expected that as the size grows the situation would gradually change from work on voluntary basis, to part time on a nominal pay and then full time on payment based on economic and social needs. For the smaller communities it makes sense to train additional personnel to reduce the workload on individuals who are being paid very little and to minimise the disruptive effects of people leaving the community. Being in full control of and participating in the construction of the capital works paves way for more meaningful sustainable self reliance.

Table 2.8. Institutional arrangements for the operation and maintenance of water supplies within developing communities not integrated with established urban communities. (Hazelton and Kondlo, 1998).

Local Water or Development Committee	The elected committee appoints local community members to operate the scheme, care for it and implement cost recovery.
Ward Development Forum	Operates as a 'stokvel'<3> for the management of maintenance funds from a number of communities. Is responsible for procuring spares and employing maintenance personnel from the private sector.
Local Government	Acts as the trustee for the management of loan finances and / or the building up of a capital fund for hardware replacement and upgrading. Local Government implement capital works with the assistance of consultants and contractors committed to labour intensive construction where practical.

Preventive maintenance and major repairs are a special case in that timely spares procurement, the expertise required to effect the work and often the level of payment are all beyond the scope of individuals communities. This work is probably best carried out in the public sector, ideally by small enterprises although the servicing agents of larger businesses are also suitable. Ward level forums operating like stokvels are suited

<3> Stokvel is a organisation of community members which is recognised as a business entity

for short to medium term to handle the payment and spares procurement. Bulk schemes are best undertaken and operated by water boards whilst the private sector retains responsibility for major maintenance work.

2.9. White Paper on a National Water Policy for South Africa.

This document expands on broad principles, a framework, and detailed proposals for financing the provision of services. The paper deals with first "tier" water, namely the abstraction and provision of bulk raw water from a catchment. It does not deal directly with the second and third tier water i.e. water processed (often by water boards) and transport to households.

In the new approach to water pricing, it is proposed that the full financial cost of supplying water should be recovered from water users. Full financial cost recovery cannot, however, be understood separately from social/equity objectives. The recovery must be based on the principle that those who drive the marginal cost must pay the marginal price. The application of this principle is discussed below.

Financial cost recovery requires a financial unit cost of water to be calculated by apportioning the total costs of each water supply scheme to the total volume of water sales from that scheme.

The following components are incorporated into the calculation of this unit cost;

2.9.1. Capital costs.

This comprises amounts required to recover the costs of assets consumed through the abstraction, impoundment and distribution of water. Such costs would be determined through the mechanism of depreciation. Depreciation is the loss in value of facilities not restored by maintenance. It occurs through wear and tear, decay, inadequacy, or obsolescence (becoming outdated). Provision needs to be made to retain the capacity and functionality of all water schemes. This is done by making projections of future replacement and refurbishment costs for the depreciable portion of all property, plant and equipment.

2.9.2. Financial costs.

These represent the cost of borrowing funds to purchase water infrastructure (interest and allied costs).

2.9.3. Direct operations and maintenance costs.

Direct costs typically include the administration costs, operations and maintenance costs, pumping costs, labour costs and overheads that can be attributed directly to a particular water scheme.

2.9.4. Indirect costs (overheads)

These are costs which can not be directly attributed to a specific scheme but contribute towards the management and operation of the water resources of the entire country. An example is DWAF head office costs.

2.9.5. Catchment management costs.

Catchment management involves the activities that are required and maintain a water resource in a state that is satisfactory from both ecological and water supply points of view. Costs will typically be incurred for the eradication of alien vegetation, soil erosion protection, hydrological measurement, pollution control, regulation and law enforcement.

2.10. Draft Tariff Regulations for Water services tariffs in South Africa.

2.10.1. Revenue requirements

The South African Government operates in the context of limited resources and large service backlogs. Given these constraints, it is important that the water services sector becomes financially autonomous, in order to ensure the long-term sustainability. In order to achieve financial autonomy, it is essential that the full financial cost of supplying water be recovered from water users, including the cost of capital. Fixed assets (i.e. reservoirs, pumps, pipes, etc) represent a major cost component in the supply of water services. Therefore it is vital that some provision is made for the supply of these assets. Recipients of capital grants in the future will be required to take responsibility for the refurbishment and replacement of these assets. In order to sustain water services provision, it is therefore crucial that the refurbishment and replacement costs of water assets be built into tariff structures (DWAF, 1999).

2.10.2. Fixed Charges.

Regardless of the amount of water consumed there are fixed costs that are incurred by a water services authority, which need to be recovered. These fixed costs could be made up of, amongst others, the costs of meter reading, availability charges and fixed management and administration costs. The fixed charges may be considerable and are over and above the tariffs that are referred to above. Moreover these costs are defined as fixed in the sense that they are not related to the amount of water consumed.

2.10.3. Connection fees.

The cost of connecting new water users to systems is significant and therefore important that the service authority ensures that these costs are recovered. This can be done through direct connection fees. This is to avoid imposing costs on the rest of the water system.

2.10.4. Water supply services to households provided through communal water services works.

The common type of communal water services is a communal standpipe. Sustainability of water supply systems is highly dependent on maintenance. Hence, local commitment to maintenance through the local contribution of resources (monetary and/or human) may be essential to the sustainability of water supplies. There are many different ways in which communal participation in the maintenance of communal water supply systems can be ensured. Meters can be installed on communal standpipes or a water bailiff can be used to ensure that funds are recovered. Alternatively, community members can agree to share the overall costs of operating the water system, and contribute a fixed monthly payment. Whatever system is used, it is important that tariffs for water services reflect the cost of supply so that abuse and wastage are discouraged (DWAF,1999).

2.11. Existing Computer based Cost Calculation Models.

2.11.1. DWAF's Study to determine a Cost Effective and Sustainable Method to provide Rural Communities with Yard or House Connections.

The study was conducted through a survey of available systems and strategies for the provision of high levels of service and cost recovery focused on the following four broad systems.

- Unregulated storage tanks.
- Regulated storage tanks (Equity valve and Trickle feed).
- Prepaid meters.
- Conventional metering and billing.

After evaluation summary suitability matrix was developed to help consumers understanding of options available and the costs involved. The costs analysed were in terms of initial capital costs and operation and maintenance. The costs were described as estimates and summarised as follows.

Staff costs, Buildings, Administrative systems, Operation and Maintenance, and other disbursements.

The relevant results of this model are the following;

- Operational cost recovery is not taking place in many completed RDP schemes, and is insufficient in others. The main factor causing this is the lack of will to pay. The result is that in some regions more than 50 % of the systems are either partially working or not working.
- Payments of between R17 and R26 per month per household are required to supply and operate yard connections.(excluding capital costs.1998)
- Existing systems that supply yard connections rely heavily on cross subsidisation from other conventional consumers. This presents a question of equity. The option of Water Kiosk especially prepayment systems bring about cost recover (Ninham, 1998)

The costing aspects of this model are listed in the comparison matrix.

2.11.1.1. Observations.

This model classifies the projects in the terms of incorporated infrastructure. The monthly costs include capital costs, monthly costs, and subsidies. Calculations of capital costs and subsidy are well illustrated. The administrative part of the monthly costs is calculated with the shared assets between water supply schemes in mind. This may not be applicable in some cases. The operations and maintenance costs source is not clear. The monthly costs in this model are however high compare to the existing average of R10 flat rate (see Chapter 5). The pure O&M costs in this model for communal standpipe per household is R 11.69. More information is required from Ninham Shand on the calculation of O&M costs. This is necessary in order to examine the parameters comprising the costs. The Ninham Shand model does not therefore give all required for the cost calculation of operation and maintenance. It does however give thorough analysis of the reticulation costs including the yard connections and labour cost.

2.11.2. Mvula Trust's Help Manual for Rural Water Credit.

The manual consists of four components independently applicable. The components are:

1. Local Level Demand Analysis (Social Survey).
2. Technical Options.
3. Rural Water Supply Financial Model.
4. Program and spreadsheet disk.

The first two components, namely the Social Survey and Technical Options feed into the financial model, which in turn is dependent on the computer program supplied with the manual. The manual assesses the viability of the prospective loans and their credit risk by using the financial model to calculate the potential annual deficit or profit, taking into account the willingness and capacity of their potential clients to pay. The financial model also gives two different calculation options regarding the information derived from the Social Surveys. The defaults used as a calculation option were reached through surveying 1200 rural households in the four poorest of South Africa's nine provinces.

The manual contains a financial model which has been developed for application in rural villages where new water supply systems are to be provided, or where water supply systems have been provided to the level of a standpipe service and are to be upgraded to provide on-site services. Capital and running costs are included in the model. The running costs are divided into asset replacement, operation and maintenance expenditure. The operation and maintenance costs include Pumping costs, Water treatment, Bulk purchases, maintenance, staff costs, unpaid bills and overheads (Hildebrand, 1998).

2.11.2.1. Social development dimensions

This section describes the estimation of the effective demand for household connections. The method is used to develop a market analysis that contributes to a greater understanding of the willingness and ability of poor rural residents to pay for improved water services. The methodology approach falls within the broad category of contingent valuation (CV) surveys, with the core of the research being a household CV survey which aims to elicit information from respondents on what they would be willing to pay for the hypothetical situation of improved water services to their households. The rationale of the contingent valuation approach is to estimate consumer demand for improved services that is being increasingly used to estimate the benefits of goods that do not have available market prices, such as environmental improvements and other public.

2.11.2.2. Technical options.

In this model four generic groups are considered for the provision of on-site water services whilst ensuring cost recovery. The groups are;

1. Yard connections with prepaid meters,
2. Yard connections with conventional metering and billing systems,
3. Yard connections leading to individual storage tanks with an equity valve or trickle feed system

4. Yard connections leading to individual storage tanks with the supply controlled from a manifold supplying a cluster of homesteads.

2.11.2.3. Financial model.

This model assesses the financial viability of water supply schemes in rural villages when on-site services are provided to all or some households. It is also a tool for deciding on financing options for such schemes. The model can be used to determine the tariff that will need to be charged by the service provider.

The model calculates the amounts that households will be required to pay to make the service financially viable. These amounts include both payments to the service provider and payments on private loans. It compares these payments with the amounts that households are willing to pay for water. The total amount that will remain unpaid during the course of a year is then calculated, on the assumption that households pay no more than their maximum indicated amounts. The summary indicator of viability is the net cash flow of the scheme for the year. If this is negative, the scheme is not financially viable and must be reconsidered.

For simplicity only standpipes and on-site services are considered. The model works in an Excel worksheet, and requires a windows environment.

2.11.2.4. Structure of the model

The model is organised on ten sheets, numbered 1 to 10. Inputs and outputs are ordered in a logical progression, as described below. The number and heading of each sheet is given in brackets in the description that follows.

The model is organised as follows:

- A description of the area, planning year etc. (1. Project description "Des").
- Demographic and income data (2. Demography and income "ResCUs").
- Three scenarios for the provision of services, and the capital costs associated with each scenario (3. Investment scenarios and capital costs "Scenarios").
- Financing options for each scenario (Capital grants and finance to be raised "Capsubs"; 5. Sources of finance "CapFin").

- The consumption associated with each scenario including, asset replacement, pumping, treatment an other operating and maintenance costs (7. Asset replacement, operating and maintenance expenditure (R per year) "O&M);
- The payment required of households to ensure full cost recovery (8. Monthly bills "Bills");
- The likelihood of unpaid bills if the payments required exceed the amounts that households are able/willing to pay (9. Willingness to pay and total amounts unpaid "WTP"); and
- A summary sheet of the key input and output variables, in a format suitable for printing (10. Summary "Summary") shown in Figure 2.10.

Key outputs are the amounts of finance to be raised per household and the monthly payments required. The indicator of viability is the total expected amount of unpaid bills: where unpaid amounts are predicted the investment option is not likely to be financially sustainable and changes need to be made.

2.11.2.5. Asset replacement, operating and maintenance expenditure.

This are the recurrent costs dealt in this sheet as follows in Figure 2.9;

- Asset replacement costs are entered as percentage of the construction cost of the infrastructure, the secondary network and terminals. The total costs per year for the three scenarios are shown in the last three columns of the table.
- Pumping costs are recorded by entering the percentage of average daily flow is to be pumped in each scenario and the cost of diesel and/or electricity in terms of the cost per kl of water pumped (c/kl). The average daily flow for each scenario is displayed at the top of the table. The total annual costs are displayed in the row in which costs are entered.
- Treatment costs are recorded by entering a cost per kl of water treated (c/kl). The total annual costs are displayed as above.
- Bulk purchase costs are recorded by entering a cost per kl of water bought (c/kl), and the percentage of the total amount used that is purchased. The total annual costs are displayed as above.
- Other expenditure is entered as an amount per annum for each scenario.

- Maintenance costs are entered as a percentage of the construction cost of the infrastructure, as in the case of asset replacement
- Staff costs are calculated for each scenario by entering the number of staff employed in each of four categories, at salaries entered by the user.
- Provision is made for overheads as a percentage of staff costs. A default value of 10 percent of staff costs is provided.

The model then calculates total cost per annum for each of the scenarios, in Rands. It also calculates the cost per kl of water sold and of water used, the latter including physical losses (R/kl).

2.11.2.6. Observations.

The asset replacement, operation and maintenance expenditure part of this model is the most relevant to the research. The assets replacement costs are calculated as a percentage of the construction costs as indicated in the previous section. This will be used as guideline in the calculations of the operation and maintenance. The source of the percentages is however not given. The percentages can only be taken as indicative.

The pumping, treatment, and bulk purchase cost calculations are clearly explained. These costs are dependent on the water pumped, treated and purchased. This is acceptable since these cost are directly determined by the amount of water in question.

The maintenance costs are calculated as a percentage of the construction cost of the infrastructure, as in the case of asset replacement. The lack of clarification of the calculation of the percentages implies once again that they can only be taken as indicative and as a guideline.

The model is effective as a guideline and help for planners and financial institutions in the provision of credit rural communities. The emphasis is therefore on financial aspects. The research will therefore use it as indicated earlier on as a guideline for cost calculations of operation and maintenance.

Table 2.9. Asset replacement, operating and maintenance expenditure (R per year)

Bulk and distribution infrastructure						**Scenario 1**	**Scenario 2**	**Scenario 3**
					Average daily flow (kl/day):	**72**	**85**	**98**
Asset replacment	% of construction cost					Cost (R pa)	Cost (R pa)	Cost (R pa)
	Primary	Secondary	Terminals					
						5,310	9,289	13,027
Pumping	% average daily flow pumped			diesel cost	electricity			
	Scenario 1	Scenario 2	Scenario3	c/kl	c/kl			
		203.0				0	0	0
Treatment	Cost of chemicals (c/kl)							
	0.0					0	0	0
Bulk purchase	c/kl	% purchased	Scenario 1	Scenario 2	Scenario3			
	0.0					0	0	0
Other general expenditure								
Maintenance	% of construction cost							
	Primary	Sec net	Terminals					
						5,310	9,289	13,027
Staff costs	Staff category	Average salary (R pm)	Number of staff per category					
			Scenario 1	Scenario 2	Scenario3			
	category 1	**150**				0	0	0
	category 2	**500**	**1.0**	**1.0**	**1.0**	6,000	6,000	6,000
	category 3	**1,000**		**1.0**	**1.0**	0	12,000	12,000
	category 4	**2,000**				0	0	0
	TOTAL STAFF		**1.0**	**2.0**	**2.0**	6,000	18,000	18,000
Overheads	as % of staff costs							
	Primary	Sec net	Terminals					
	0.5					30	1,800	1,800
Total						**16,650**	**38,377**	**45,855**
Cost (R/kl of water sold)						**0.72**	**1.42**	**1.48**
Cost (R/kl of water used, including physical losses)						**0.63**	**1.24**	**1.28**

Table 2.10. Summary of Key input and output variables.

	Scenario 1	Scenario 2	Scenario 3
SERVICES			
% households with on-site connections	0%	50%	100%
CAPITAL COST			
Cost of shared infrastructure per h/hold	na	R 125	R 75
Cost of terminal per h/hold, full purchase cost	na	R 946	R 946
Cost of terminal per h/hold, after contributions	na	R 512	R 512
FINANCE			
Finance for primary infrastructure per h/h	R 0	R 0	R 0
Finance for secondary network and terminals per h/h	na	R 637	R 587
Upfront payment per h/h for Yard tanks	na	R 100	R 160
Private loans for h/holds for Yard Tanks	na	R 537	R 427
OPERATING AND MAINTENANCE COSTS*			
Monthly O&M cost per h/h with standpipes only	R 2.90	R 5.68	na
Monthly O&M cost for h/holds with Yard tanks	na	R 7.67	R 7.98
MONTHLY PAYMENTS			
Total for h/holds using public standpipes	R 2.90	R 5.68	na
Payments on private loans per h/h with Yard tanks	na	R 38.42	R 30.55
Payment to service provider per h/h with Yard tanks		R 7.67	R 7.98
Total monthly payments per h/h with Yard tanks		R 46.09	R 38.53
UNPAID BILLS (TOTAL, RANDS)	**R 0**	**R 0**	R -20,990

	rate (%)	years
Conditions for private loans (interest rate, repayment period):	45%	2

*Note: O&M cost per h/hold calculated as (average cost per kl) X (monthly consumption per h/hold)

2.11.3. Water supply services model manual.

The next model studied is the water supply services model manual developed by Palmer Development Group for the Water Research Commission. This is an investment-tariff model. The purpose of the model is to assist the agencies responsible for water supply in urban areas in the development and evaluation of investment scenarios and tariff policy. The key focus of the model is on the financial viability and sustainability of the water supply service. There are a number of tariff options available.

The model as shown in Figure 2.5 consists of four parts.

Section 1: This is the interactive section of the model. Essential information is entered and the water supply service options are described. An investment program is designed. The user then sets annual tariff increases to meet the service provider's cash flow requirements. Key outputs on the capital and operating accounts are shown.

Section 2: The user is requested to enter information to replace values that are used in the absence of local information. Replacing default values will affect the output in section 1, which can be finalized only once local information has been entered.

Section 3: Output information is presented in greater detail, in formats suitable for printing.

Section 4: This is the 'engine' where most of the calculations are conducted. A user would access this section only to trace the model's calculations, if desired (Palmer Development Group, 1998).

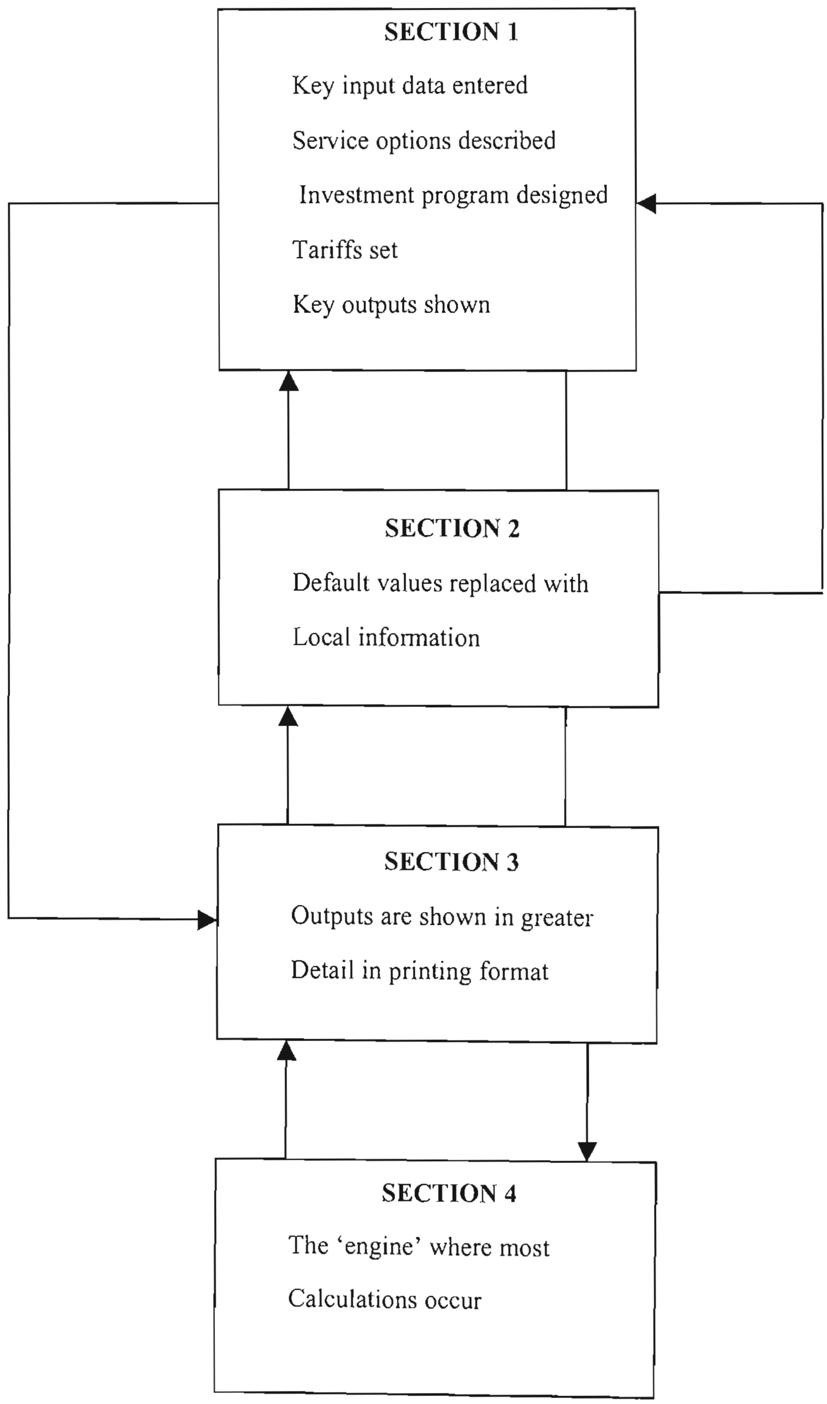

Figure 2.5: The model structure (PDG, 1998).

2.11.3.1. Model Description.

The model use spread sheets similar to the Mvula Trust model. The following are the sections making up the structure shown above in the computer based- excel format.

Description.

The purpose of the "Description" input page is to identify the area and model user, set the base year and record details unique to the particular run of the model. The user should input: Local Authority, type, run, scenario and base year.

The current environment.

The information on this page should be as accurate as possible. Where information is not available estimates would be required.

Household and residential consumer units.

The entries needed are total population, number of households on formally serviced sites, number of households in informal settlements, number of households in backyard shacks, formal sites required for households in informal areas, formal sites required for households in backyard shacks, total number of residential consumer units, people per household, residential consumer unit income distribution, and non-residential consumer units.

The future environment.

The entries needed are residential and local economic growth, residential consumer unit income distribution, inflation rate, and responsibility for capital expenditure.

Types of service.

The services entered here are residential services and non-residential services.

Existing service provision.

The data entered here is the residential consumer units and the non-residential consumer units.

Water consumption.

The information entered here is the current consumption, water purchased and purified, water sold and used, water used by service provider, physical water losses, current capacity of bulk infrastructure, macro-estimates and projects.

Accounts-expenditure.

The essential inputs in this page are the amounts spent by the service provider in the base year, in the function categories shown. The allocations are required for administration (including overheads and sales), bulk (i.e. purchase and/or purification costs), storage (i.e. reservoirs, water towers etc), and reticulation.

Accounts-tariff and income.

Income accrued by the service provider from the sale of water is calculated by the model from the tariff entered as follows. Tariff charges (fixed and consumption), other income, received income, and cash reserves.

2.11.3.2. Investment program.

An investment program is designed on three separate screens, which respectively allow the user to:

- Provide for new residential consumer units;
- Eliminate the residential backlog and upgrade exiting services;
- Provide for non-residential consumers;
- Plan a meeting program for existing residential services.
-

Investment targets: new residential consumer units.

Information is entered as service types provided. The percentages of new low income consumer units for each type of service are entered.

Investment targets: backlog and upgrading.

In this section data is entered on services to be provided including the backlog and time frames.

Capital requirements.

This is an output screen which shows the capital requirements in nominal and real terms for a five and ten year period.

Setting tariffs.

Setting tariffs to meet cash flow requirements is the final step in the modelling procedure. The tariffs, and the resulting monthly bills, can be used as the final indicator of he affordability of the investment program. The tariffs are set in four sheets that show various fixed and consumption charges.

2.11.3.3. Net cash flows, non-payment, costs and prices.

This is the final output sheet which shows the following;
Annual and cumulative cash flows (with reference to recurrent income and expenditure only), in both nominal and real terms.

- Non-payment rates
- Budgeted surpluses/deficits
- Debt-service ratios, which show interest and redemption charges on long-term loans as a percentage of income billed and income received respectively
- Cost and income information, in c/kl.

Whilst the model is designed for use in large urban water supply systems, there are several attributes which are suitable for the smaller community water supply systems.

2.11.4. Raftelis Model for Water Pricing Structure.

The Raftelis model was developed for pricing of water and wastewater services in the USA using well-known economic models. The main feature of the model is the fact that pricing structure is based on the trade-off between revenue requirements and the total cost of services.

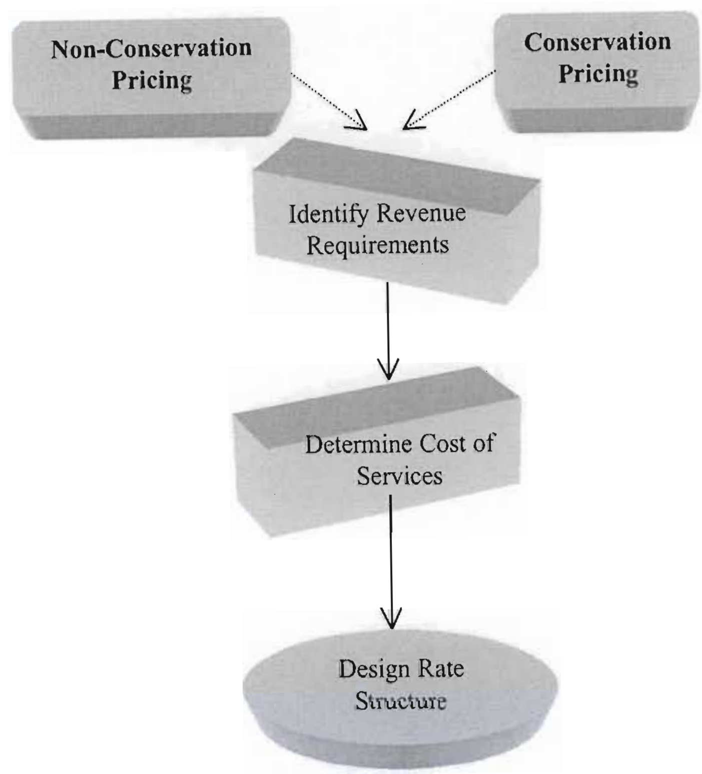

Figure 2.6. Raftelis's Approach to Water Pricing Structure.

Raftelis's model breaks down the water pricing to either conservation based or non-conservation based (Figure 2.6). The conservation-based model has an in-built objective of optimising on the water conservation. On the other hand, non-conservation based pricing structure does not optimise on the water conservation. This can be elaborated by considering a rate structure with different blocks of consumption and rates. The motive in the conservation model would then be to charge in manner that discourages waste. On the other hand the non conservation structure would only have higher income generation for the different rates among the blocks (Raftelis, 1996).

2.11.4.1. Water Utilities as Enterprises.

The Raftelis rate structure is based on the concept of *enterprise funds* as applied to water utilities. Raftelis has defined enterprise funds as funds established to account for operations that are financed and operated in a manner similar to private business enterprises where the intention of the governing body is that the costs (expenses including depreciation) of providing services to the general public on a sustainable basis be financed or recovered primarily through user charges;

1. Where the governing body has decided that periodic determination of revenues earned, expenses incurred and / or net income is appropriate for capital maintenance, public policy, management control, accountability or other purposes.
2. As an enterprise, fund, water operations are viewed as businesses. Thus, appropriate business principles relating to cost identification, cost effectiveness and financial reporting are addressed and enterprise level.

2.11.4.2. Characteristics of an Effective Pricing Structure.

According to Raftelis, the 2 issues that ought to be addressed by utility managers[1] are: -

1. Which costs should be recovered through user charges, and
2. How a pricing structure should be designed to ensure that the issues of sustainability vs. community objectives are adequately addressed.

Raftelis list the following as the factors to be considered when designing an appropriate rate structure: -

1. Revenue Stability,
2. Impact on the users i.e. communities,
3. Social Equity,
4. Conservation – the community structures have to determine the extent to which they would like to ensure optimal use of the available water resource-taking cognisance of the availability.
5. Legality and litigation potential,

[1] Within the context of community water supply, utility manager could refer to water committees or other responsible community organisations.

6. Simplicity – the simpler the rate structure is, the easier it is to implement,

7. Rate stability – the rate (as opposed to revenue) have to be stable over time. A feeling of rate stability helps in continuity of rate payment. Stability in this case does not imply a stagnation of the costs but the stability of the rate structure.

8. Implementation – implementation issues include collecting data for initial and future modification to consumer billing systems, consumer billing procedures and policies and rates updates.

9. Competitiveness – the billing structure has to be competitive with those of the adjacent communities.

Several of those pricing criteria can be conflicting. The process of setting the rate structures is thus an exercise in trade-off of the above factor (Raftelis, 1996).

2.12.4.3. Approach to Establishing User Charges (Tariffs).

Rate (tariffs) structures can vary from relatively simple structure to very complex one. The process of establishing the structures involves 3 steps. These are: -

1. Identifying revenue requirements,

2. Determining cost of services, and

3. Designing a rate structure.

2.12.4.4. Identifying Revenue Requirements.

In this important step, those costs that will be recovered through user tariffs are determined. Typically, these are the operating and capital charges. It is essential that the revenue requirements be sufficient to provide for adequate facilities, to allow for proper maintenance and replacement and to ensure that the facility is running on a self-sustaining basis.

It is also important to project the operating and capital costs over an extended period in and hence evaluate possible fluctuations in the revenue requirements and plan accordingly.

2.12.4.5. Determining Cost of Service.

Once the revenue requirements have been determined, the next step is to allocate the cost to various categories of consumers. These include: -

1. Individual private consumers,[2]
2. Institutional consumers such as schools and clinics,
3. Government institutions,
4. Bulk consumers such as adjacent water supply schemes.

The allocation of cost to various categories of consumers should in as much as possible strive to reflect the relative costs of providing services to those classes of consumers. However, this is not always practical and once again requires a certain level of ingenuity and trade-off in order to make an equitable cost allocations.

2.12.4.6. Designing a Rate Structure

The designing of rate structure is probably the most complicated of the processes and requires the designers to take cognisance of the cost allocations decided upon. The various options available are: -

1. Fixed Charges,
2. Multi-block structure – Normally used where the cost of providing services to individuals is more or less uniform within the given block,
3. Volume charges (quantity consumed)
4. Combination of fixed and metered charges.

[2] It is expected that in community water project, an overwhelming majority of the consumers will be individual households.

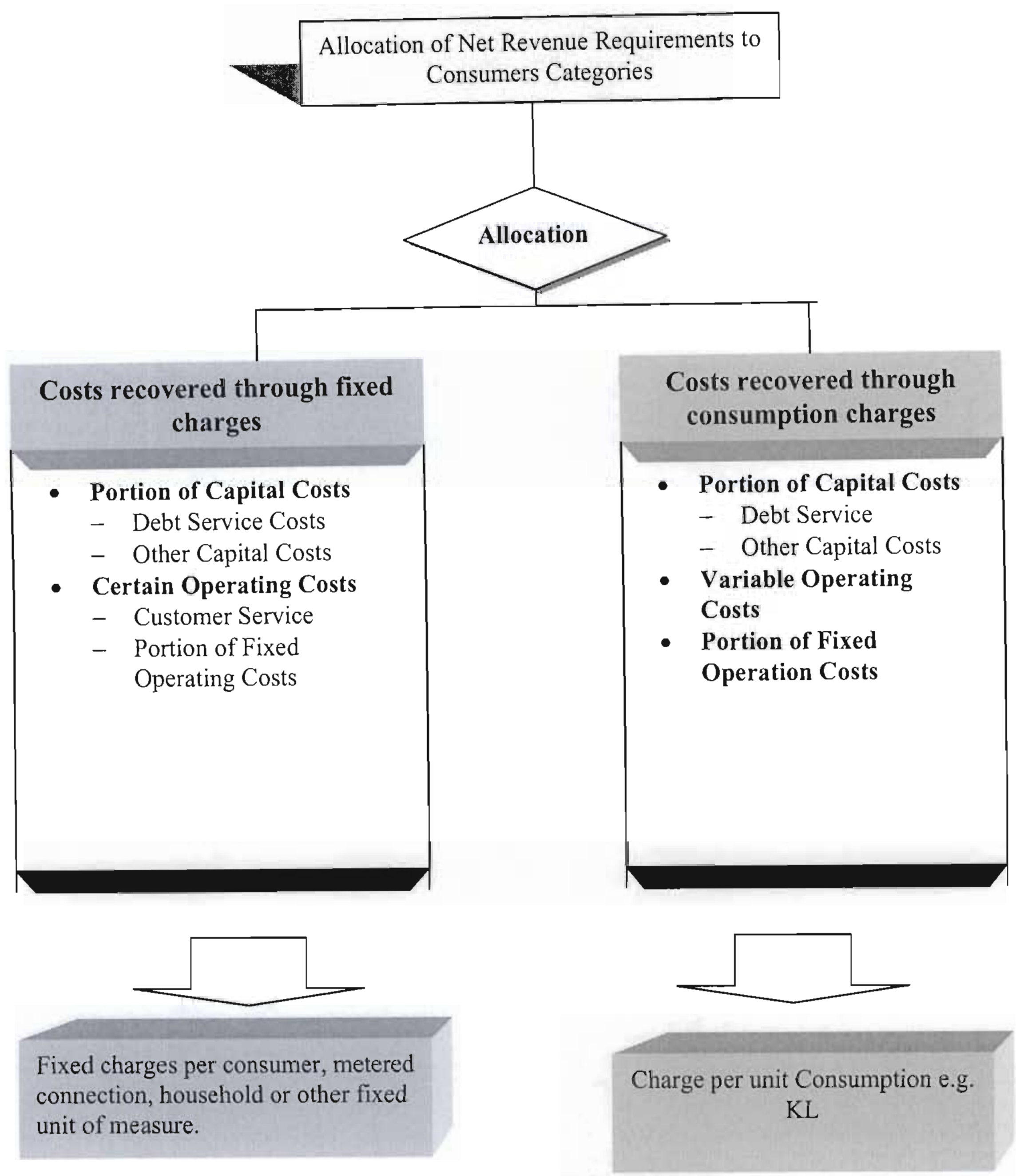

Figure 2.7: Sample Rate Setting Process

It is important to recognise that rate setting process should be dynamic that is it should cater for the 'environment' it works in and structured to address the pricing philosophies of the water project as well as those of the communities. Figure 2.7 shows a simple rate setting process (Raftelis, 1996).

2.13. Discussion.

The existing models are mainly based on capital based analysis of water supplies. Here capital analysis implies analysis where investment capital is being sort for project implementation or extension. The overall attention to operation and maintenance is inevitably low in all models. The use of unqualified percentages is a common feature in the estimation of these costs. A detailed analysis is therefore required through field data collection in order to calculate these operation and maintenance costs.

Chapter Three

Methodology and Data collection.

3.1 Summary.

This chapter describes the methodology used to create the Cost calculation computer based model. The model was developed to calculate cost per litre and cost per household for a given community water supply. In order to attain the research objectives, the following activities were envisaged as necessary and were covered during the research period: -

- Focus on costing models applicable to community water supplies with low-income consumers.
- Develop of a research questionnaire.
- Identify projects for data collection.
- Model the relevant operation and maintenance cost calculation models.
- Data collection from the projects.
- Cost calculations and model development based on long-term sustainability and cost effectiveness.
-

3.2 Identification of Projects for data collection

During the research period, 16 projects in 2 provinces were identified for use in data collection. Proximity and diversity were the main criteria used in the identification. The type of source, treatment process, management and willingness to provide information defined the diversity. All the projects were existing stand alone community water supply projects supported by Mvula Trust. They varied in population served, size of scheme, type of water source, energy used and level of sustainability. They had been in operation for over 6 months and serve less than 10000 persons.

3.3 Data Collection from the Water supply schemes.

The establishment of a benchmark in so far as the tariff collection practices had to be conducted using data from the field. To this end, a questionnaire designed to collect information on the cost elements of stand-alone water supply projects was designed. The philosophy adopted in the design took cognisance of the fact that it might not always be possible to gather data on the diverse cost elements directly. Thus, questions aimed at indirect

data extraction were placed side by side with direct questions. For example, the questionnaire would ask for the costs associated with pumping and at the same time take dimensions of the pumping equipment. Thus if the costs are not available, one would be able to calculate them using standard techniques. A sample Questionnaire is attached in **Appendix 1.**

The data collection exercise was carried out in conjunction with consultants who are active in the water and sanitation projects of the province. Mvula Trust also collected data in some projects. This arrangement was found to work well because the consultants collected data from project in which they were familiar with the existing conditions. Initial results were found to be encouraging. In 2 out 16 projects, the data collected was judged to be insufficient. Most of the projects also needed to be visited twice to clarify some of the data collected.

3.4 Operation and Maintenance costs calculations.

Elements considered in the calculation of operation and maintenance costs were developed into a base algorithm that was subsequently used to develop the research questionnaire. It contained the following elements.

Notation	Element
A	Fuel costs
B	Operator Salary
C	Committee Salaries
D	Committee Transport costs
E	Routine Repairs
F	Number of Households

Where diesel is used,

Fuel cost (A) = consumption rate (l/hr) * number of hours pumping / day (hrs)* cost of diesel (cents/l)

Where electrical power is used,

Fuel cost (A) = local unit price (cents/KWH) * Electric motor rating * number of hours

Operator salary (B) = R 500 (typical salary in the Northern province)

Committee Salaries (C) = depends on the operation and management set up of the project.

Transport Costs (D) will depend on the following costs. Number of bank visits, costs of fuel transportation, sand transportation for filters, accounts payment related costs, and spares purchase related costs.

Routine Repairs (E) will depend on the following costs. Pipes used per annum, total number of taps in scheme replaced per annum, cement used, operator / plumber repair costs

Number of Households (F) = households supplied by the scheme

The monthly cost therefore calculated as follows:

$$monthly\ household\ \cos t = \frac{A + B + C + D + E + F}{F * \%\ \text{of Paying Community}}$$

3.5 Water Supply Scheme Variants.

In order to design a costing model, all water supply scheme variants needed to be included. This was accomplished by using a matrix whose objective was to cover the various possible variations and types of community water supply schemes. The variables included were:

Water source, energy source, pumping head, reservoirs, service level, treatment type, proximity to other systems, billing basis, revenue collection method, reservoirs, and reticulation.

3.6 Model Conceptualization.

The model is based on the financial framework used in the Water Supply Services Model and Help Manual for Rural Water Credit, which are described in the literature review. In order to analyse the cost parameters, which contribute to the operation and maintenance a rural water supply scheme, a financial framework, which incorporates all this costs, is required. The costs therefore need to be separated and broken down to their elements, which can then be costed individually. This cost centres may be for example in a pump station. The Figure 3.1. Illustrates this concept. As shown the pump house can be divided into cost centres which can also be broken further. The aim here is to accurately allocate costs and expenditure. This is necessary in order to cover all costs. Where future costs of water are required then having costs divided into the costs centres is necessary to allocate interest rate, depreciation, and inflation as required. This is the technique used in terms of financial analysis. The costs are then linked with the factors influencing them for example the water production of pump house.

The framework is divided into spreadsheets, which deal with the various aspect of the water supply scheme. The spreadsheets are in an 'Excel' format. This allows interlinking in order for data to be used from one sheet to another. An example is data on the number of household connections entered in the Project description sheet can then be accessed by all sheets through equations link in the cells of the spreadsheet.

Once the framework of sheets is set up, data collection on the various water supply projects is now entered into the cells. The model calculates the current cost of water per kilolitre and cost of water per household per month.

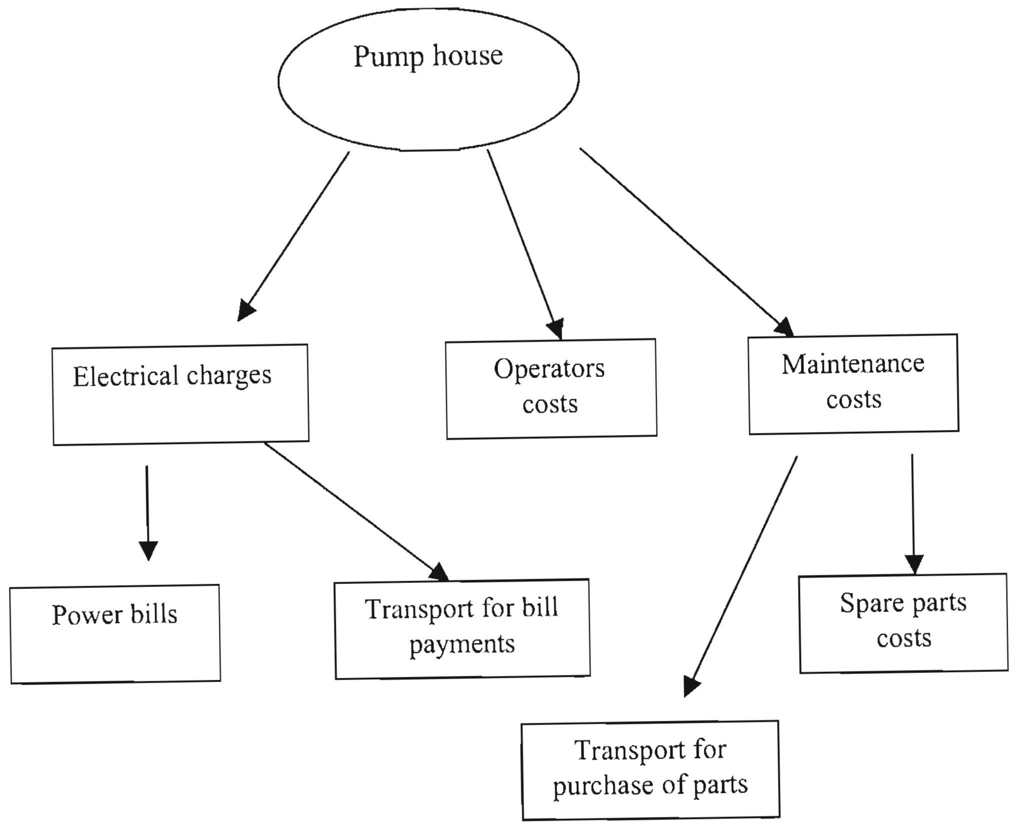

Figure 3.1. Costs centres model concept development

Chapter four

Model development.

The model is composed of spreadsheets in excel software whose cells are programmed. The spreadsheets are then linked to each other using the formulae in the cells. This is done in order to use the information in individual sheets in the entire model.

4.1. Model Guidelines and Operation

The model layout is illustrated in the flow cart in Figure 4.1. Using information gathered through the questionnaires the sheets were programmed to breakdown all the 'running' costs of a standalone community water supply. The following were the guidelines used in the model development and programming.

1. Indicate the source, distribution of flow, consumer connections, income, and community size, costs of operation and maintenance. Express operation and maintenance costs as average per home per month and cost per m^3 of water.
2. Include cost of management structures including community structures, activities and involvement.
3. Record and compare the levels of consumption and payment.
4. Compare pumping hours with operating costs.
5. Compare consumption patterns to management and controls.
6. Include levels of service; direct indirect operational efficiency and types of distribution losses.
7. Model should contain variables for all scenarios.
8. Identify and classify costs. Separate running and fixed costs.
9. Develop economic structure / framework of the costs.
10. Use explicit assumptions and formulae.
11. Describe cost in proportion to consumers.

12. Calculate operation and maintenance costs referring to energy, transport repairs, equipment and staff.
13. Complete a sensitivity analysis, and add other elements (defaulters).
14. Reflect the number of consumers in comparison to the number of paying consumers
15. Allow for emergency savings.
16. Prepare mechanisms by which to measure the cost of water losses.
17. Establish operation and maintenance, capital, and funding costs. Incorporate fixed costs relating to capital, interest/depreciation, operation and maintenance.
18. Extrapolate from costs to tariffs.
19. Examine the Mvula Trust tariff policy.
20. Interpret the influence of consumer type on tariff structure.
21. Distinguish between the value of water resource and the cost of provision.
22. Model to provide scenarios based on different income of service providers.

4.1.1 Model Outlay.

Figure 4.1. illustrates the model in the form of a flow chart.

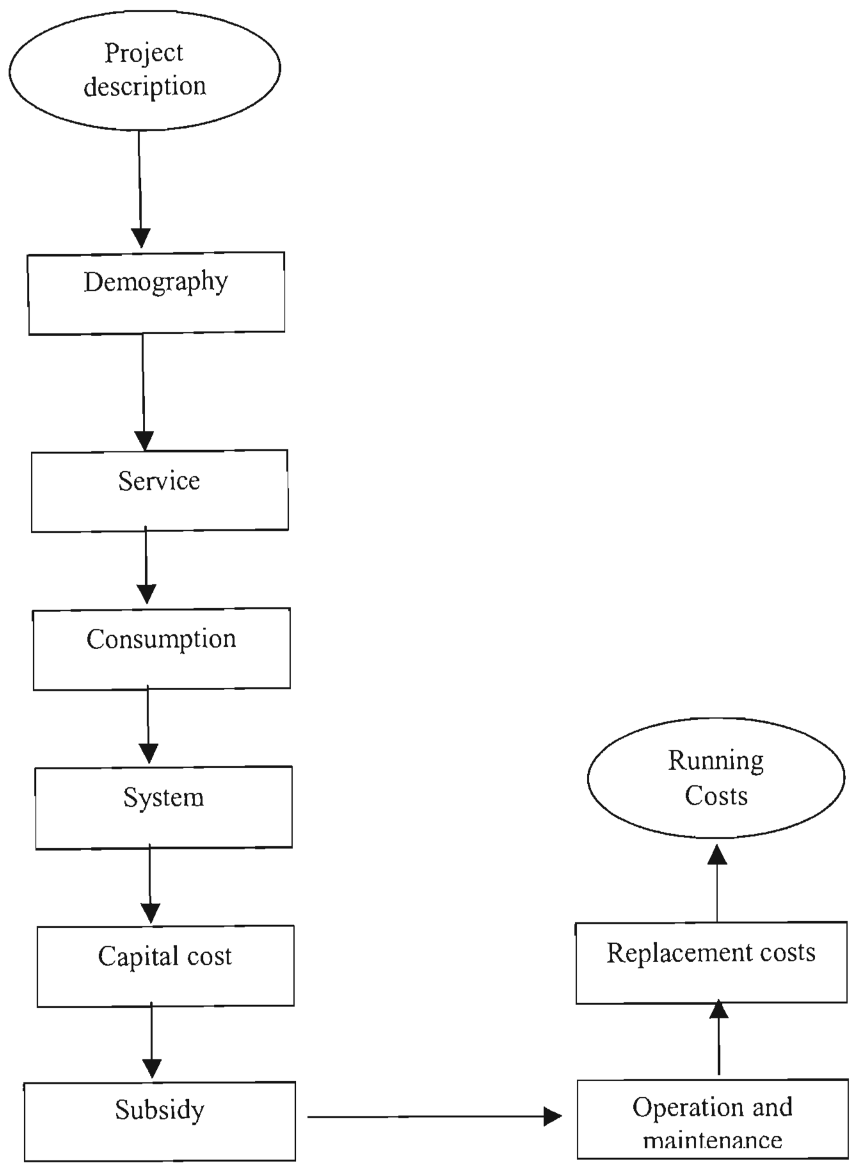

Figure 4.1. Flow Chart of the Model

4.1.2 Project description.

This work sheet on project description contains a general scheme overview. It gives the location with a short description of the region served including the project name, description of the project area, capital cost, construction date, date of data collection, and the name of the data collector.

4.1.3 Demography.

In this sheet the population size is entered. The total number of households is indicated and the number of persons per household can then be calculated. The non-residential consumers are also entered in this sheet. The demography is required in order to apportion costs later to the consumer units once the total water supply scheme costs are calculated.

4.1.4 Service Level.

This sheet contains the level of service in terms of types of consumer connections. The number of non-residential connections is also entered. It includes institutional and commercial consumers. It is necessary to record the types of service in the water supply scheme in order to accurately allocate costs associated to their specific operation and maintenance costs.

4.1.5 Meter reading.

The sheet contains monthly inputs of the water consumption. The readings are divided into bulk and consumer meter readings. Where bulk meter readings are available the records show the transmission loses through a subtraction of the consumer consumption. The losses must be taken into consideration since they are a cost incurred by the supply scheme as a whole.

4.1.6 Consumption.

The consumption is broken down into the various service levels. The non residential consumption is separated from the residential consumption. This required in order to allocate a cost on that portion of the water supplied. As some of the water may be used for commercial purposes the cost would then need to reflect it. In the case where water is used in institutions the quantity is normally high. The revenue collection is therefore strongly influenced by those institutions and the consumption would also require to be known. The physical losses are also included here in order to keep track of their costs.

4.1.7 System description.

The system description sheet contains the various specifications of the entire water supply system. This sheet gives the capacities, sizes, lengths, and quantitative aspects of the system. By breaking down the system into its components the cells in the sheet contain the reference values of the system that are used in the rest of the model.

4.1.8 Capital costs summary.

The estimated capital costs are categorised into the bulk and distribution aspects of the water supply scheme. The costs are entered as monetary value and as a percentage of the total costs. The cost per consumer unit is then calculated. Where the scheme is required to pay loans used in the construction then the cost per consumer unit is a major factor of the running costs. The costs are normally available in the water supply scheme project documents. Where these documents are not available engineering estimates on the ground can be made.

4.1.9 Capital cost.

This gives the capital cost of the scheme together with the capacities of the components. This sheet gives the details of the scheme capital costs in relation to capacity, materials, and other specifications. This breakdown is necessary in understanding the nature of the maintenance costs later in the model.

4.1.10 Tariffs and income.

The rates charged to the various service levels of the water supply are listed in this sheet.

Where the tariffs are in the form of blocks they are subdivided further. The revenue collection is also recorded. The collection efficiency is calculated from the actual income compared to the expected income. This efficiency is used later in costing of the water as an added factor to the administration costs.

4.1.11 Expenditure.

The expenditure is allocated to the various cost centres the water supply scheme. The cost centres in this case are the activities which use cash resources in order to be achieved. This will therefore include all bills and monies paid by the scheme. The reserve or emergency fund also falls under the category of expenditure. In order to achieve further analysis of expenditure, the division in to the various stages of water supply is done. This includes administration, bulk water supply, storage and reticulation.

4.1.12 Subsidy.

In this sheet the subsidy is taken to be any funds that are paid to the scheme form another institution. This funds may be for the operation and maintenance of the scheme or construction loan repayment where applicable. It is therefore an income which is entered into the income sheet discussed earlier.

4.1.13 Operation and Maintenance.

This sheet contains the daily costs incurred by the water supply scheme. Apart from the operational costs the maintenance costs are recorded. The maintenance costs include the replacement of parts of the system which takes place over a period of time and in most cases years. The shared subsidisation included here implies administrative cost shared between water supply schemes. An example is there could be two water scheme maintained by the one technician. In this case subsidisation is entered as a negative value. This would be equivalent to costs of the subsidised cost centred being entered as fractions of actual costs. The unit 'running' cost of the water is then calculated by dividing the costs with the water produced by the scheme.

4.1.14 Assets replacement.

Asset replacement costs are calculated as a percentage of the construction costs. This percentages are determined by the type of the asset in question. The field data collection is also used in this determination. Electro-mechanical equipment will have higher percentages than storage reservoirs.

4.1.15 System variants.

The variables used in this sheet are outlined in the previous chapter and include; Water source, energy source, pumping head, reservoirs, service level, treatment type, proximity to other systems, billing basis, revenue collection method, and reservoirs. Each variant has unique attributes in terms of scheme characteristics. This characteristics listed above in turn have costs which are specific to their nature. The variant number one describes a system with the following scheme characteristics.

Water source	- surface or bulk pumped into the system
Energy source	- electricity
Pumping head	- 1 to 50m
Reservoir size	- less than 50m^3
Service level	- Reservoir tap
Treatment type	- Gravity filter
Proximity to other systems	- shared source
Billing basis	- pre-paid meters
Revenue collection method	- House to house visits

4.2. Model Operation.

Following the guidelines given earlier in this chapter project information gathered is entered into the various spreadsheets. The information is gathered as outlined in the chapter on Methodology and Data collection using a field questionnaire. The spreadsheets are attached in **Appendix 2**. The composition of the sheets is as shown here.

1. Project description.

As indicated earlier this spreadsheet contains the general project information. This includes province of location, name of village, description of the region, capital cost, construction date, type of service provided, and the date of the survey. The output data is the capital cost, the date of construction and the date of survey.

2. Demography.

This is an input data spreadsheet of the demography of the project area. The input data includes the population, the number of households, number of non-residential consumers, and livestock. The size of the project area is also entered in this spreadsheet.
The outputs of this sheet are number of consumer units.

3. Service Level.

The data input here is the type of service delivered to the community. The number of each of the service type is entered. This data is used as an output for with the percentages of each calculated.

4. Meter Reading.

The spreadsheet on meter reading shows the monthly water consumption in water project. It is divided into bulk and consumer meter readings. This is to show the amount of losses where the readings are available. This sheet is therefore an input data spreadsheet.

5. Estimated Water Consumption.

This spreadsheet uses input data from the demography, service and meter readings data sheets. The sheet uses linked equations to calculate the kilo litres per consumer unit per month, litres per capital per day and total water consumption per month. The physical water losses component form the meter readings are also included. It application in this case is dependent of the meter readings.

6. System Description Summary.

This spreadsheet contains input data from the technical aspects of the water project. The sheet is also linked with equations to the consumption spreadsheet. The volume of water from the source of supply, pumping, treatment and transmission is therefore calculations from the estimated consumption. The distribution aspects of the water system which are storage, connector main, reticulation, and meters are entered as input data.

7. Capital Cost.

This spreadsheet extracts data from the system sheet through equations links. The average daily flow is extracted from the consumption sheets and the input data form the terminals sections is extracted form the demography sheets. The costs are data inputs from the survey.

8. Capital Cost Summary.

The Capital Cost Summary is a sheet summarising the Capital cost sheet. All its data is therefore extracted from the Capital cost sheet by equations links. The aim of this sheet is to calculate the cost of the project per consumer unit. This excludes the livestock as consumer units

9. Accounts – Rates and income in Base year.

This is one of the main spreadsheets in the model. The inputs include income of the project, rate(s) charged, amount billed, and number of payments per month. The sheet calculates and compares the amounts billed to the amounts collected. The output is the collection efficiency required to assess the managerial losses.

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10. Accounts – Expenditure.

The expenditure has two types of data input. One is a monthly total of the expenditure for the project. The other comprises the actual expenditures in their cost centres. The cost centres are then divided into administration, Bulk water, Storage, and Reticulation. The division into cost centres is required for the option of calculation of future expenditure.

11. Capital Subsidies.

This sheet records the input data on the subsidy given to the project. The subsidy is unique to the project and it is usually in the form of a lump sum amount to subsidies the total capital cost. The subsidy can be in the form of material and technical assistance. The use of the subsidy is therefore primary or secondary as shown in the spreadsheet.

12. Recurrent Costs: Asset Replacement.

The Replacement costs are developed in this spreadsheet. The source of the data is the capital costs sheets. The default percentages are input from the assessment of other existing models in outlined in the literature review.

13. Operation and Maintenance.

This is the major output data sheet which uses the data from the rest of the spread sheets. The costs calculated include Pumping, Treatment, Maintenance, Replacement, Transport, Subsidy, Staff, and Overheads costs. The option of excluding replacement costs is used in this case.

The output data is the cost of the water per litre and monthly cost water per household.

14. Scheme Variants.

The spreadsheet on scheme variants acts as a guideline for field data collection. It lists the various variations of community water supply schemes in South Africa. The common types of waters sources, energy source, pumping head, reservoirs, treatment, revenue collection, and service levels are listed.

Chapter Five

Results and Analysis of the Model's Application

The filled data collection sheets for the 16 water supply schemes were taken and the data entered into the model. The filled data sheets for a typical project (Nomponjwana) are attached in **Appendix 3**. The model gives results in terms of the following values;

1. Cost per kilolitre.
2. Cost per household per month.

The results do not consider the capital costs. The inclusion of capital costs was left as an option. The rationale behind this is that most of rural community water supplies that have been found to be sustainable have tariff structures based on operation and maintenance only (DWAF, 1998). The costs are therefore the 'running' costs of the water supply schemes i.e. operations and maintenance as well as administrative costs. This approach calculates the cost of production and delivery of a unit volume of water to the communities. It also calculates the cost per household per month. This corresponds to the 'flat rate' payable by each household every month. The costs calculation is summarised in Table 5.1.

5.1. Community Water Supplies Analysed in the Model.

5.1.1. Kwa Zulu Natal Province.

5.1.1.1.Mvunayane Water Supply

Mvunayane water supply in the province of Kwa Zulu Natal serves 528 households. The water is abstracted from boreholes by two positive displacement pumps driven by electric motors. The system produces 1050 kl per month for which the consumers pay a flat rate of R 5 per month. The scheme is managed by committee of 9 elected members who serve on full time plus 5 others on a part time basis. The scheme is managed by an Operator and a Bookkeeper. The model show by analysis that the running cost is R 2.3 per household per

Table 5.1. Summary of Cost Calculations of 11 community water supplies in KwaZuluNatal, South Africa.

Scheme	Province	Type of supply	Number of Households	Volume per month	Monthly operation cost	Monthly maintenance cost	Value of stock	Monthly staff cost	Total monthly cost	Cost per household	Unit cost/kl	Estimated total house hold cons./month	Current tariff
				kl	(R)	(R)	(R)	(R)	(R)	(R)	(R/kl)	kl	(R)
Mvunayane	KwaZuluNatal	B/hole	528	1050	43	718	2000	450	1212	**2.3**	1.15	2	5
Draylott	KwaZuluNatal	B/hole + weir	750	3375	420	580		1650	2650	**3.5**	0.79	5	5
Nhluwgwane	KwaZuluNatal	B/hole	166	3900	1400	200		400	2000	**12.0**	0.51	23	5
Kopi	KwaZuluNatal	B/hole			21			360	381	**n/a**	**n/a**	n/a	5
Zawumphilo	KwaZuluNatal	spring	45	900					0	**n/a**	**n/a**	20	5
Montebello	KwaZuluNatal	river water	250	1076	1434	30	1000	270	1734	**6.9**	1.61	4	9
Emayelisweni	KwaZuluNatal	river water	85	136	180	43	500	130	353	**4.2**	2.60	2	18
Esidumbini	KwaZuluNatal	river dam	285	2934	2636	283	2500	960	3879	**13.6**	1.32	10	20
Enzigeni	KwaZuluNatal	lake	241	1800	1537	55	100000	630	2222	**9.2**	1.2	7	10
Dicks	KwaZuluNatal	B/hole	800	7500	1750	165	0	1250	3165	**4.0**	0.4	9	10
Nomponjwana	KwaZuluNatal	river water	764	10,406	1501	750	0	10030	12281	**16.1**	1.2	14	25
Mapuye	Northern Province	B/hole	171	400	730	6	0	320	1056	**6.2**	2.64	2.3	10
Mars	Northern Province	B/hole	315	921	708	42	0	400	1150	**3.7**	1.25	2.9	5
Claremount	Northern Province	B/hole	95	108	345	25	0	320	690	**7.3**	6.39	1.1	10
Fairlite Halt	Northern Province	B/hole	380	3888	470	0	0	400	870	**2.3**	0.22	10.2	5
Makweya	Northern Province	B/hole	362	960	755	0	0	0	755	**2.1**	0.79	2.7	8

a household is taken to hold *6* *persons.* B/hole ;borehole

each person consumes an average of *25* *litres/day*

Month. This is below the R 5 per month currently charged. The presence of left over materials from the project construction phase results in a lower cost of maintenance.

5.1.1.2.Draylott Water Supply.

Draylott water supply in the province of KwaZuluNatal serves 750 households. The water is abstracted from boreholes by a positive displacement pump driven by an electric motor. Some water is also pumped from the river and chlorinated before storage. The system produces 3375 kl per month for which the consumers pay a flat rate of R 5 per month. The water is pumped to a reservoir of $212m^3$ capacity. The scheme is managed by a committee of 12 elected members who serve on full time basis. The scheme is managed by an Operator, an assistant and a Bookkeeper. The model show by analysis that the running cost for the water supply scheme is R 3.5 per household per month. This is below the R 5 per month currently charged. The relatively high personnel costs comprise the largest percentage of the monthly costs.

5.1.1.3.Nhluwgwane Water Supply Scheme.

Nhluwgwane water supply in the province of Kwa Zulu Natal serves 166 households. The water is abstracted from boreholes by a positive displacement pump driven by a diesel engine. The system produces 3900 kl per month for which the consumers pay a flat rate of R 5 per month. The water is pumped and stored in 3 reservoirs of $30m^3$ each and 1 reservoir of $40m^3$ capacity. The scheme is managed by committee of 9 elected members who serve on full time basis. The scheme is run by one Operator and Foremen. The model shows by analysis that the running cost for the water supply scheme is R 12 per household per month. This is above the R 5 per month currently charged.

5.1.1.4.Kopi Water Supply Scheme.

Kopi water supply is in the province of Kwa Zulu Natal. The water is abstracted from a borehole by a positive displacement pump driven by an electric motor with stand by diesel engine. The system is estimated at producing over 9000 kl per month for which the consumers pay a flat rate of R 5 per month. The water is pumped and stored in 11 reservoirs having a combined volume of $330m^3$ capacity. The scheme is managed by committee of 9 elected members who serve on full time basis. The scheme is run by one Operator. The model was unable to analyse the running cost for the water supply scheme due lack of information onsite of the number of consumers, cash flow and other crucial data.

5.1.1.5.Zawumphilo Water Supply Scheme.

Zawumphilo water supply in the province of Kwa Zulu Natal serves 45 households. The water is abstracted from a river weir and fed to the system by gravity. The system produces 900 kl per month for which the consumers pay a flat rate of R 5 per month. The water is stored in a reservoir of $30m^3$ capacity. The scheme is managed by committee of 10 elected members who serve on full time basis. The scheme is run by the community on a voluntary basis. The model was unable to analyse the running cost for the water supply scheme due lack of information onsite of the cash flow, cost of maintenance and other crucial data.

5.1.1.6.Montebello Water Supply Scheme.

Montebello water supply in the province of Kwa Zulu Natal serves 250 households. The water is abstracted from Mdloti river through an intake. The water is then treated with Sodium Hypochlorite. The system produces 1076 kl per month for which the consumers pay a rate of R2 per m3 via a metered system. The water is pumped and stored in 3 reservoirs of $100m^3$ capacity. The scheme is managed by committee of 7 elected members who serve on full time basis. The scheme is run by a Project plumber. The model shows by analysis that the running cost for the water supply scheme is R6.9 (R 1.6 per m^3). This is below the R 9 (R 2 per m^3) currently charged.

5.1.1.7.Emayelisweni Water Supply Scheme.

Emayelisweni water supply in the province of Kwa Zulu Natal serves 85 households. The water purchased from the Montebello water supply scheme in bulk. The water is therefore Mdloti river. The water is then treated with Sodium Hypochlorite. The system produces 136 m3 per month for which the consumers pay a rate of R2 per m3 via a metered system. The scheme is managed by committee of 10 elected members who serve on full time basis. The scheme is run by an Operator and a store man. The model shows by analysis that the running cost for the water supply scheme is R4.2 (R 3.8 per m^3). This is below the R18 (R 4 per m^3) currently charged.

5.1.1.8.Esidumbini Water Supply Scheme.

Esidumbini water supply in the province of Kwa Zulu Natal serves 285 households. The water is abstracted from a dam on Mhlali river through an intake. The water is then treated with Sodium Hypochlorite and filtered using a rapid sand filter. The system produces 2900 m3 per month for which the consumers pay a rate of R20 per household per month. The water is pumped and stored in a 100 m^3 capacity reservoir. The scheme is managed by committee of 9 elected members who serve on full time basis. The scheme is run by an Operator and a bookkeeper. The model shows by analysis that the running cost for the water supply scheme is R 13.6 per household per month. This is below the R 20 flat rate charged per month.

5.1.1.9.Ezigeni Water Supply Scheme.

Ezigeni water supply in the province of Kwa Zulu Natal serves 241 households. The water is abstracted from lake Sibayi through an intake. The water is then treated with Sodium Hypochlorite. The system produces 1500 m3 per month for which the consumers pay a rate of R10 per household per month. The water is pumped and stored in reservoirs of a combined capacity of 210 m^3. The scheme is managed by committee of 8 elected members who serve on full time basis. The scheme is run by a meter reader and a bookkeeper. The model shows by analysis that the running cost for the water supply scheme is R 9.2 per household per month. This is below the R 10 flat rate charged per month.

5.1.1.10. Dicks Water Supply.

Dicks water supply in the province of Kwa Zulu Natal serves 800 households. The water is abstracted from a borehole by a positive displacement pumps driven by an electric motor. The system produces 7500 m3 per month for which the consumers pay a flat rate of R 10 per month. The scheme is managed by committee of 5 elected members who serve full time. The scheme is run by an Operator, a Bookkeeper and two security guards. The model shows by analysis that the running cost is R 4 per household per month. This is below the R 10 per month currently charged.

5.1.1.11. Nomponjwana Water Supply.

Nomponjwana water supply in the province of Kwa Zulu Natal serves 764 households. The water is abstracted from Hlambanyati river by an electric motor driven pump. It is then treated using Alum, rapid gravity sand filtration and chlorination. The system produces 10406 m3 per month for which the consumers pay a flat rate of R 25 per month. The scheme is managed by committee of 9 elected members who serve full time. The scheme is run by a Manager, 2 Operators, a Bookkeeper, Tariff collector, Treasurer, water clerk and two security guards. The model shows by analysis that the running cost is R 16.1 per household per month. This is below the R 25 per month currently charged.

5.1.2. Northern Province.

5.1.2.1. Mapuye Water Supply.

Mapuye water supply in the Northern province serves 171 households. The project was constructed in 1996 at a cost of R 16500. The water is abstracted from 2 boreholes by positive displacement pumps driven by an a diesel motor. The system produces 400 m3 per month for which the consumers pay a flat rate of R 10 per month. The water is pumped to a reservoir of 50-m3 capacity. The scheme is managed by committee of 7 elected members who serve on a full time basis. The scheme is run by an Operator. The model show by analysis that the running cost for the water supply scheme is R 6.2 per household per month.

This is below the R 10 per month currently charged. Energy costs comprise the largest percentage of the running costs.

5.1.2.2. Mars Water Supply.

Mars water supply in the Northern province serves 315 households. The project was constructed in 1996 at a cost of R 327,846. The water is abstracted from a borehole by a positive displacement pump driven by a diesel motor. The system produces an estimated 1500 m3 per month for which the consumers pay a flat rate of R 5 per month. The water is pumped to a reservoir of 100-m3 capacity. The scheme is managed by committee of 9 elected members who serve on a full time basis. The scheme is run by an Operator. The model show by analysis that the running cost for the water supply scheme is R 3.7 per household per month. This is below the R 5 per month currently charged. Energy costs comprise the largest percentage of the running costs.

5.1.2.3. Claremount Water Supply.

Claremount water supply in the Northern province serves 95 households. The project was constructed in 1997 at a cost of R 207,754. The water is abstracted from a borehole by a positive displacement pump driven by a diesel motor. The system produces 12 m3 per month for which the consumers pay a flat rate of R 10 per month. The water is pumped to a reservoir of 160-m3 capacity. The scheme is managed by committee of 6 elected members who serve on a full time basis. The scheme is run by an Operator, Book keeper, and a Standpipe minder. The model show by analysis that the running cost for the water supply scheme is R 7.3 per household per month. This is below the R 10 per month currently charged. Personnel costs comprise the largest percentage of the running costs.

5.1.2.4. Fairlite Halt Water Supply.

Fairlite Halt water supply in the Northern province serves 380 households. The project was constructed in 1997 at a cost of R 405,350. The water is abstracted from a borehole by a positive displacement pump driven by a diesel motor. The system produces 3888 m3 per month for which the consumers pay a flat rate of R 5 per month. The water is pumped to a reservoir of 200-m3 capacity. The scheme is managed by committee of 6 elected members who serve on a full time basis. The scheme is run by an Operator, Book keeper, and a Standpipe minder. The model show by analysis that the running cost for the water supply scheme is R 2.3 per household per month. This is below the R 5 per month currently charged. Personnel costs comprise the largest percentage of the running costs.

5.1.2.5. Makweya Water Supply.

Makweya water supply in the Northern province serves 362 households. The project was constructed in 1997 at a cost of R 543,296. The water is abstracted from a borehole by a positive displacement pump driven by a diesel motor. The system produces 960 m3 per month for which the consumers pay a flat rate of R 8 per month. The water is pumped to a reservoir of 220-m3 capacity. The scheme is managed by committee of 15 elected members who serve on a full time basis. The scheme is run by an Operator paid by the Government. The model show by analysis that the running cost for the water supply scheme is R 2.1 per household per month. This is below the R 8 per month currently charged. Energy costs comprise the largest percentage of the running costs.

Chapter Six

Discussions, Conclusions and Recommendation

This Chapter discusses the extent to which the objectives of the Thesis as set in Chapter One were achieved and makes appropriate conclusions. The corresponding recommendations for each of the conclusions are made. Scope for further work in order to achieve the overall goals and objectives of the Cost Calculation of Operation and maintenance in Community Water Supplies is also set out. The following were the objectives set out for this Thesis:

- To determine the minimum factors which constitute the monthly 'running' costs of 'stand-alone' community supply schemes to ensure that the schemes are operated and maintained in a sustainable manner utilising local resources.
- To obtain empirical data for the monthly running costs from existing water supply schemes, hence
- Develop a financial framework, which provides guidelines to consultants, planners, and local authorities on the basic monthly 'running' costs of such schemes.

In order to attain the research objectives, the following activities were envisaged as necessary and were to be covered during the project period:

- Carry out a comprehensive literature review on costing of community water operation and maintenance in general.
- Benchmark the existing costing calculation techniques and models through literature search.
- Focus on water costing structures applicable to community water supplies with low-income consumers.
- Model the relevant cost calculation models.

6.1 Discussions and Conclusions.

The literature review has identified various costing of water supply services. The costing techniques reviewed included Umgemi Water Cost recovery methods, Ninham Shand model, Hildebrand's Mvula Trust manual on rural water credit, and the Palmer Water supply services model manual. The Umgemi Water cost recovery research was found to feature general approaches of cost recovery in relation to sustainability of the water supply services. It focused on techniques of water distribution and compared their performance. This research classified water scheme operating and maintenance costs. The classification and comparison of these costs in existing scheme was as far as the research covered. There were administration costs given to ensure cost recovery but the sources were not given. In addition the stated required administration cost of R 7.5 excluding maintenance and capital replacement. This research did not give sufficient guidelines for the costing of operation and maintenance.

The Ninham Shand model was unique in its shared resources perspective of administration of the water supplies. All costs were included in calculation of the monthly costs of water provision. These are capital, operation, maintenance, and administration costs. The operation and maintenance costs are high at R 11.69 for communal standpipe water distribution. This was so if the amount is compared to the average of R9.69 charged for the water supplies in the survey. When capital costs were excluded, payments of between R17 and R26 per month were required to supply and operate yard connections. Whilst the administration costs were well illustrated the source of the operation and maintenance figures were not given. The resulting monthly costs could only be taken to be indicative. The cost schedules for the reticulation system were useful in breaking down of capital costs where only lump sum system costs were available.

Hildebrand's Mvula Trust manual on rural water credit was found to analyse the operation and maintenance costs elaborately. The maintenance cost was a percentage of the construction costs like the rest of the models. The Palmer Development Group model was a manual on financial viability and sustainability of the water supply service. It was found to be useful especially when water supply is viewed as a financial investment. Running costs are required to be entered as input data. The general framework of this model was found to be useful for this research. The techniques adopted in it have therefore been used in the model on operation and maintenance costs.

Due to the assistance from Mvula Trust the data collection sheet used in the field survey yielded sufficient information to set up the model as shown in Chapter 4. The data shown in Chapter 5 gave the costs, which this research aimed for. However the data input collection did not produce the detail expected to accurately predict the maintenance component of the costs. The replacement costs were therefore worked from percentages of the magnitude indicated in the literature review. The replacement costs ware found to be high compared to the existing charges. Due to this shortcoming the replacement charges were left out of the models final costs.

The costs per household were found to be lower that the current rates charged by the committees. Apart from the exclusion of replacement costs, there are other factors contributing to this scenario. Most of the projects have stocks left over from the construction period which subsidies the maintenance costs. Since the calculations are also based on direct-recorded expenditure, the fact that the projects are relatively new (less than 5 years old) results in low operation and maintenance costs

The resulting monthly costs from the model indicate that the current charges used by the committees are sufficient to operate and maintain the systems. This is the case as long as it can be shown that the replacement costs or 'emergency fund' is 20% to 25% of the current charge. This was derived from the observation that the calculated cost were approximately 75% to 80% of the current charges.

6.2 Recommendations.

As indicated the replacement cost are high (R 48 per month) compared to the average total monthly charge of R 10. The alternative is to substitute this cost with an 'emergency fund' which would only cover the essential components of the system prone to breakdown. This alternative cost would however require accurate information specific to each project. The data survey forms would need to be adjusted to collect the information. More research also needs to be undertaken to establish accurate replacement costs. The current technique of using percentages is not backed by proof of the magnitude.

Research is also required to show the exact value of the indirect subsidies like materials and other services offered by the central government and local authorities.

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Appendix 1

Data Forms used in the Survey

Project Name:	
Province:	
Date of Field Assessment:	
Interviewers Name:	
Water Source:	
Power Supply:	
Treatment Type:	
Distance to nearest Water supply scheme	

Length of pipework and size	
Date of completion	
Capital cost of construction	
No and size of Bulk and consumer meters	
Other available infrastructure details.	
Shared O&M arrangements	

Project Information	
Households served	
Tariff being paid	
Fixed or Metered Tariff Pre-paid	
How many people paid over last six months:	
1 2 3 4 5 6	

How was the tariff determined – *Give a breakdown of the tariff*	
Has the tariff been increased since the start of the project – how often and by what amounts?	
How was the increase determined?	
Do records of monthly income and expenditure exist?	
What was the income and expenditure over the last six months? (Income / expenditure) 1 2 3 4 5 6	
Income from new connections' fees (last 6 months) including	
Does the scheme deliver water all day or is it opened at certain times.	
Is there a limit on the quantity of water that can be drawn on a daily basis by a household?	
Are funds saved for major repairs	
If so, how much.	
Is it held in a separate account	
Are there ant yard connections?	
How many are there.	
What tariff is paid for a yard connection.	
How is the amount of water used at a yard connection controlled?	

Consumer Connections categories	Number	Total (6) monthly consumption	% of Total	

Domestic Institutional Commercial Other (specify)				
Types of consumer connections Pre-paid meters –give number and tariff Metered – give number and tariff Flat rate – give number and tariff				
Service level Reservoir tap Standpipes House connections (mixed) House (tank)				
How often do you pump				
How long do you pump for.				
Record the hours of operation for a diesel engine over the past six months:				
How much water do you pump (e.g. the committee may say that they fill the reservoirs twice a week)				
Do you take a meter reading No – What is the size of the reservoir(s). Each time you start and stop pumping Once a month (If the readings are available please give				

details)	
Determine the quantity of water pumped in the month for the last six months	
How much do you pay for electricity / diesel each month	
Do you have the records for the past six months (kWh / amount or litres)	
Do you pay a fixed monthly rental to Eskom	
What is the make and model of: Pump Motor Pumping head, capacity (volume/time) (estimate in case of lack of data) & other specifications	
Type and horse power of diesel engine	
Electric motor rating (kW) & other specifications	
Bulk Supply Volume supplied in 6 months	

Cost of Bulk supply in last 6 months	
Transport Costs	
What are the transport costs associated with:	
Purchasing diesel and getting it to the engine	
Purchasing of spares	
Banking	
Filter sand replacement	
Payment of accounts	
Other costs (please specify)	
Routine Maintenance	
Engine and pump	
How much oil does the engine use	
How often is the oil filter replaced, what does it cost	
How often is the motor / pump serviced	
What does it cost	
Treatment	
What chemicals do you purchase frequency and cost?	
How often to you clean the filters	
Who does it	
How much does the sand cost?	
Reservoirs	
How often do you clean the reservoirs	
Who does it	
How much does it cost?	
Reticulation	
Have you had to repair any pipes?	
What materials did you use?	
How much did they cost?	
Who did the repairs	

How often do such repairs need to be done?	
Standpipes	
How often are these repaired	
Who does it	
How much does it cost	
Store Room	
Do you keep stock	
What type of stock	
- for routine maintenance	
- for unexpected maintenance	
Value of stock	
What method do you use to restock (minimum inventory list?)	
How often do you restock	
When do you decide that it is time to restock	
Do you pay rental for the store?	
Institutional / Management	
How many committee members are there?	
What are their qualifications	

What are their occupations:	
Who does the project pay and how much Operator / Forman Book keeper Tariff collector Standpipe minder Treasurer Committee Members Store Man	
Which of the committee members are active?	
Have peoples wages increased since the start of the project.	
If yes, by what amount?	

How was this increase determined?	
Does anybody do voluntary work	
What type of bank account is used?	
Which institution	
Does the committee receive any external support or subsidy?	
Sustainability Issues:(briefly report on the following)	
How does the committee handle breakdowns i.e. what procedure is followed.	
How are extensions to the project done?	
How does a consumer apply for a yard connection and how is it implemented.	
What is the response time to repairs?	
What allowance does the committee make for the replacement of major repairs	
What would the committee do if the water source dried up?	

Field Checks (Please ensure that the data collected is sufficient to perform the following Calculations

Item	Explanation	Field Calculation
Capital costs of construction		
Construction date		
Length and size of pipe network	Give estimates in 100m units. Size is important.	
Reservoirs	Size, material, and number is required	
No. of Consumers (households)	The population served by the system is also applicable	
Existing Tariff	Include rate charged by the official water vendors	
Ave. number of paying consumers*		
Ave. percentage of paying consumers*		
Ave. income/expenditure ratio*	use 6 months records	
Income form new connections	probably available from accounts	
Total no. of pumping hours / month*	use 6 months records ,estimate using information from operator	
Volume pumped*	use 6 months records	
Monthly cost of energy (R)	Important or get accounts no. and name and check with Eskom	

Item	Explanation	Field Calculation
Type of pumping system	Details of pump and its driving system be it diesel engine or electric motor	
Monthly Operation costs (R)	includes transport, energy, salaries, chemicals	
Monthly maintenance costs (R)	includes repairs, and small item replacements	
Value of stock (R)	estimate	
Taxes		
Salaries paid per month (R)		
	Funds set aside for operation and maintenance	
Total expenditure per month* (R)	both recorded in accounts	
Unit cost of water (Rands / m3)	divide expenditure per month by volume of water produced per month	