WATER AND SANITATION
FOR HEALTH PROJECT

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CDM and Associates

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ESTIMATING OPERATIONS AND MAINTENANCE COSTS FOR WATER SUPPLY SYSTEMS IN DEVELOPING COUNTRIES

WASH TECHNICAL REPORT NO. 48

JANUARY 1989

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Prepared for
the Office of Health,
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Prepared for the Office of Health,
Bureau for Science and Technology,
U.S. Agency for International Development
under WASH Activity No. 263

by

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and

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ACRONYMS

O&M	Operations and Maintenance
WASH	Water and Sanitation for Health Project
AID	U.S. Agency for International Development
PVO	Private Voluntary Organization
lpcd	liters per capita per day
LDC	less developed country
P	Pula (Botswana currency)
PID	Project Implementation Design
PP	Project Paper
OT	Overtime

EXECUTIVE SUMMARY

A number of factors will influence water systems project planners as they determine the type of water system they would recommend for construction in a particular situation in a developing country. The planner should consider, among others, the potential water sources, the capital cost of the system, the availability of technicians to operate and maintain the systems, and the ability and willingness of the community and regional government to support the recurrent costs associated with operating the water system.

It is this last factor which is often the most difficult to address by the planner. The need to give the community an important role in selecting the type of systems installed is generally being recognized by development agencies, and steps are being taken to include the water system works in the project development cycle. In order for the project planner to assess the ability as well as the willingness of the community to support the cost of operating and maintaining a particular type of water system, he will need to estimate this cost. However, relying on past data for this estimate or using a fixed percentage of system capital costs, as is often done by planners, will usually lead to poor estimates. If the estimate is too high, the planner and the users may conclude that the community cannot afford the system; if the estimate is low and the water system is constructed, the system is likely to fall into disuse or disrepair due to lack of funds for its operation and maintenance. Though the need for accurate cost estimates is clear, a methodology for making such estimates had not been developed.

The purpose of this report is to fill this need by presenting a step-by-step technique for estimating O&M costs for water systems prior to their construction. The technique is directed towards project planners with some technical background in water systems design and construction. The technique systematically addresses the cost components of a water system and provides forms to facilitate calculation. The cost elements are:

- Labor
- Materials
- Chemicals
- Utilities
- Transport
- Private contractors
- Others

Finally, we must caution that the task of making an accurate cost estimate of recurrent costs is a difficult one. The technique presented here will make the effort easier. Considerable work will be needed to collect the necessary data for a reasonably accurate estimate. However, the alternative of ignoring these costs until after the system is built, or of relying on highly questionable estimators, such as the percentages of capital costs, will frequently lead to the failure of the water system before its expected life is reached.

Chapter 1

INTRODUCTION

1.1 Purpose of this Report

Bilateral and multilateral agencies have funded the construction of numerous water supply systems in less developed countries in the last thirty years. These external support agencies have not, however, usually provided financial support for the cost of operating and maintaining these water systems. Such costs are considered to be the responsibility of the recipient countries and the users of the water system; hence, while design and construction costs are estimated accurately, the cost of operating and maintaining the water system after it is commissioned is estimated roughly, if at all. For example, one common method of estimating O&M costs is to use a percent of capital costs, with the percentages used ranging from 5.0 to 20.0. This approach frequently results in an underestimation of recurrent costs. The outcome of poor estimating of O&M costs often is a shortage of funds to support the operation, and particularly the maintenance, of the water system, thereby leading to inadequate O&M and, inevitably, premature failure of the water supply system.

One of the reasons for unreliable estimates of O&M costs is the lack of a systematic technique for calculating these costs as the water project is being designed. The purpose of this report is, therefore, to describe and demonstrate a technique developed by the Water and Sanitation for Health (WASH) Project to enable project planners to estimate the costs of operating and maintaining a water supply system as part of the design phase.

1.2 The Water Project Cycle

Figure 1, on the following page, shows the cycle of events that takes place from the time the need for a water system is established until the system is placed in service and requires funding for its operation and maintenance. The principal point is that an assessment of the affordability of recurrent costs by the system users must be made by the project planners <u>before</u> the project is approved. Before this step can be taken, an accurate estimate of the cost of operating and maintaining the system must also be made. As noted above, the lack of a planning tool for accurately assessing O&M costs frequently results in the discovery by the recipient government that funds to support the operation of the system are unavailable. Unfortunately, this realization is not obvious until the water system is placed in service and either the government or local community is left with a water system that it can neither operate nor maintain properly.

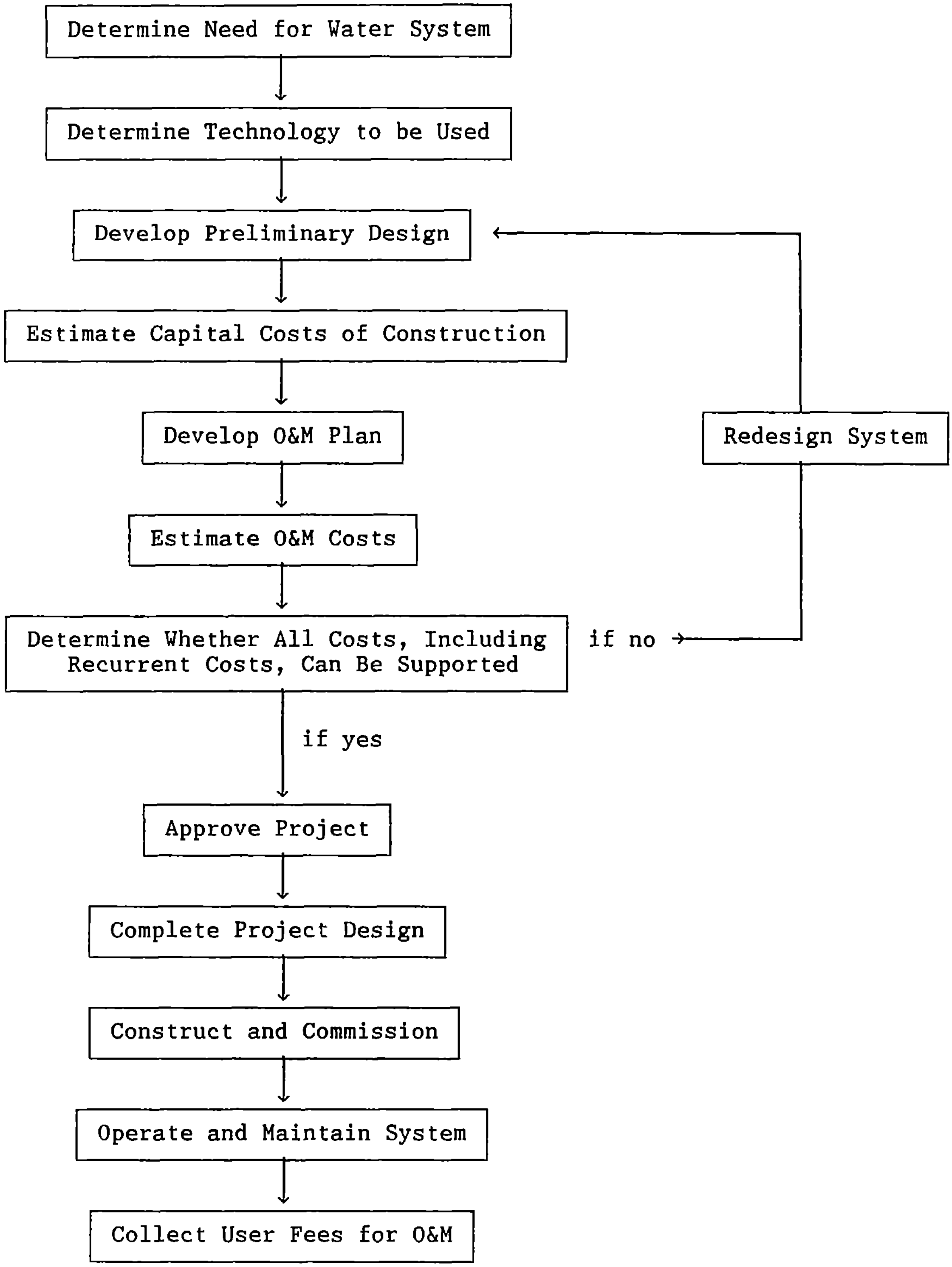


Figure 1. Water Project Cycle

1.3 Methodology

In preparing this report, the WASH team first reviewed available literature to determine whether work to develop O&M estimating procedures had previously been done, whether estimates for O&M costs were included in water project planning, and, if so, how the estimates were made.

Of those authors who discuss the need for and cost of operating and maintaining water systems, the consensus is that effective O&M is essential to sustain a system and that determining these costs is difficult. One publication (Ref. 3) refers to using fixed percentages of annualized construction costs to estimate O&M costs, but a review of several AID and PVO projects (Refs. 4-11) revealed that the majority made no attempt to estimate recurrent costs. Those projects that did provide estimates of O&M costs did not furnish detailed analyses of how the costs were calculated.

While conducting the literature search, the WASH team sent copies of a description of the activity and the preliminary report outline to interested persons in other bilateral and multilateral agencies to solicit their recommendations. These individuals indicated that the procedure that WASH proposed to develop was not currently available and would, therefore, be useful for project planning.

The next step was to develop estimating guidelines (Chapters 2 and 3) and to apply the procedure to two sample situations, one rural and one urban. The draft document was then circulated to interested parties for review. Comments were incorporated in a revised draft.

Next, a field test was conducted. These procedures were used to estimate O&M costs of two existing water systems in Ivory Coast. Results were compared to recent accounting records, with reasonable agreement. The results of this field experience were added to the manual, as a third example. Lastly, additional revisions were made and the final edition of this manual was published.

1.4 Use of the Cost Estimating Guide

1.4.1 Project Planning

Water supply systems will inevitably fail to perform as designed if they are not operated and maintained properly. Clearly, without sufficient funds to support O&M, water systems will fail prematurely, irrespective of the potential effectiveness of maintenance programs that the water board is planning to implement. While lack of knowledge of good O&M practices is a significant problem in LDCs, insufficient funds for recurrent costs of O&M is also a major problem. Although the consultants believe that the goal of a water system supported entirely by water use fees is desirable, the achievement of this goal is not essential for a water system to be constructed. Recurrent costs of a water system may, for example, be subsidized in part or entirely by local or national government. The important point is that the cost of operating and maintaining a water system must be estimated in advance and a plan developed by the water board or other responsible government agency to collect the necessary funds.

The recommended approach has three stages.

1. The project preparation team uses this guide to estimate the O&M costs for the proposed project. It should be planned or noted that a satisfactory O&M program should be in place prior to this step.

2. The responsible governmental agency (possibly with the assistance of the project team) develops a funding plan for ensuring adequate funds to support O&M. The funding plan should consider tariff revenues and any other sources of funds.

3. The project team, with assistance from the governmental agency, analyzes the proposed funding plan to ensure that it provides sufficient financial support for the O&M costs of the water project.

For a USAID project, estimation of O&M costs would take place during the preparation of the Project Implementation Design (PID). The government should prepare the funding plan prior to the Project Paper (PP) stage, while the final analysis of the practicality of the funding plan versus the O&M cost needs should be undertaken during the early stages of the PP.

For other agencies, a similar pattern is recommended, with a final decision on the affordability of the O&M component being established as early as possible in the project design phase.

1.4.2 Other Uses of the Workbook

The workbook can also serve as a useful guide for proposed and existing water supply systems in other areas, such as:

1. Preparing the O&M Budget. The guide will help O&M managers to determine line-item costs that should be included in the annual budgets for operations and maintenance.

2. Analyzing Existing Water Supply Systems. The guide will help to identify high cost areas and enable managers to assess more easily the impact of changes in system operation. It will help to pinpoint areas where savings may be realized through system modifications. For example, being aware of the method used by the electric utility to calculate power charges may suggest alternate schedules for operating water pumps.

3. Analyzing Design Alternatives. O&M cost estimates can be prepared for different engineering design alternatives or levels of service and their cost implications can be examined. That is, the O&M cost for providing water to a community in different ways can be estimated and evaluated. For example, the decision of whether to provide standposts or yard taps can be based not

only on initial investment costs but also on the recurrent costs of operations and maintenance. The affordability and consumers' willingness to pay can then be compared to a realistic estimate of recurrent costs.

4. Project Redesign. The inability of the water board or local communities to fund O&M costs for a new water project has, on occasion, forced the reconsideration of the design of the project. Unfortunately, the conclusion that the project should be modified because of lack of funds for O&M often is not reached until major capital investments have already been made. Clearly, an early estimation of O&M costs, as well as an assessment of the ability of the government and consumers to fund recurrent costs, will assist project planners in designing a sustainable project, avoiding the costly situation where a water supply project needs to be modified in midstream.

5. Tariff Design. The first step in tariff design will be an estimation of O&M costs. This information, along with willingness-to-pay data, water demand data, and other inputs, can lead to an appropriate tariff.

Chapter 2

ELEMENTS OF O&M COSTS

2.1 Introduction

This manual will focus on those elements which contribute directly to the cost of operating and maintaining a water supply system. In this section, the individual elements that constitute O&M costs will be analyzed separately, including:

- Labor
- Materials
- Chemicals
- Utilities
- Transport
- Private Contractors
- Others.

Methods for estimating costs for each of these elements will be developed, and the worksheets used to combine the elements into a single estimate will be presented in Chapter 3. Examples are shown in Chapter 4.

While performance of these procedures has no firm prerequisites, a variety of data should be collected prior to starting the estimate. First of all, the estimator must have a general orientation to the institution which will operate the system. He or she must know the basic operating procedures within the organization in order to make the estimate. Second, detailed information on the engineering design will be indispensable for estimating material, chemical, and utility costs. Third, an O&M plan for the system will greatly simplify the estimation process. It should outline the personnel required, their duties, tasks to be conducted, frequency, etc. Such planning is often not carried out, but it is very important to both good O&M performance and accurate cost estimation. Fourth, any records on costs of other systems, as well as frequency of O&M tasks (both preventive and corrective), will be very useful. Unfortunately they often are not available. Lastly, unit cost data for materials, transport, fuel, etc. will be very useful.

2.2 Labor

2.2.1 Estimating Personnel Requirements

The number of personnel required to operate and maintain a new system will, of course, vary widely. A water system which includes full treatment will require substantially more personnel for O&M than a piped system being fed from a capped spring. A more important issue that must be resolved prior to estimating staffing costs is to determine the staffing practices of the agency responsible for the water system. Each type of system requires a certain minimum number of personnel to operate and maintain it effectively. For example, Figures 2 and 3 show the minimum staff needed to operate and maintain two types of water schemes found in Sri Lanka, as recommended by a WASH team reviewing water scheme staffing patterns. These proposed organization charts were designed to achieve effective and economical scheme operation. In practice, however, the actual number of personnel that will be used by the agency responsible for water may be substantially higher because of employment policy issues. This actual number is the one that must be used to estimate staffing costs.

It is therefore recommended that the planning team request that the government report the size of the staff that will be needed to operate the new system. Alternately, the project planning team can prepare optimal staffing plans (such as those presented in Figures 2 and 3) and request that the local government approve (or revise) the proposed staffing plan. The key point is that the planning team and operators of the system (government agency/community) must agree on the size of the staff that will operate and maintain the water system. For some small water systems in rural areas, the question of whether the system operator or caretaker is to be paid or serve as a volunteer must be resolved.

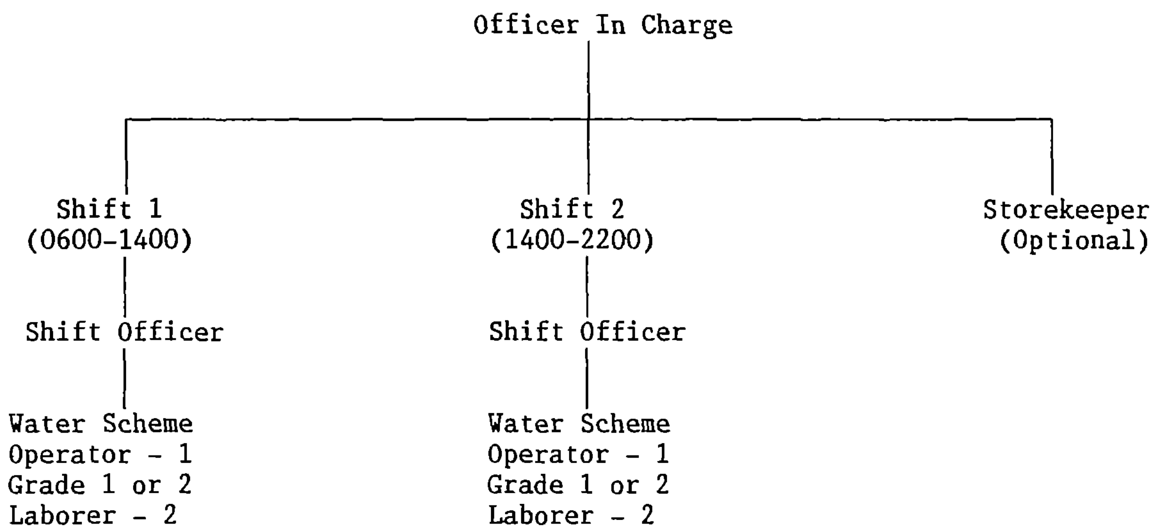
As the staff is being planned, classifications of the personnel that will operate and maintain the water system may be useful. Figure 4 furnishes examples of the types of job classifications that may be part of a water system organization. Direct personnel include those employees working in a nonsupervisory capacity. Supervisors and engineers are generally considered indirect employees. For this manual, indirect employees are not eligible for overtime compensation.

It is also important to note that many projects, particularly those in rural communities, require personnel for tasks such as health education, community development, and regional project administration. If the costs for these positions are to be provided by the government and/or community, they need to be included in the cost estimate.

The amount of overtime (OT) that the system operators may earn also needs to be estimated. Overtime is normally earned by personnel employed by a government agency that operates one or more water systems. Typically, these water systems use one or more treatment processes and electric- or diesel-powered pumps. The most accurate way to estimate OT is to review a sample of records for staff of existing water systems operated by the agency. If no records exist, interviews with water system supervisors and field personnel will provide the needed information.

2.2.2 Estimating Labor Costs

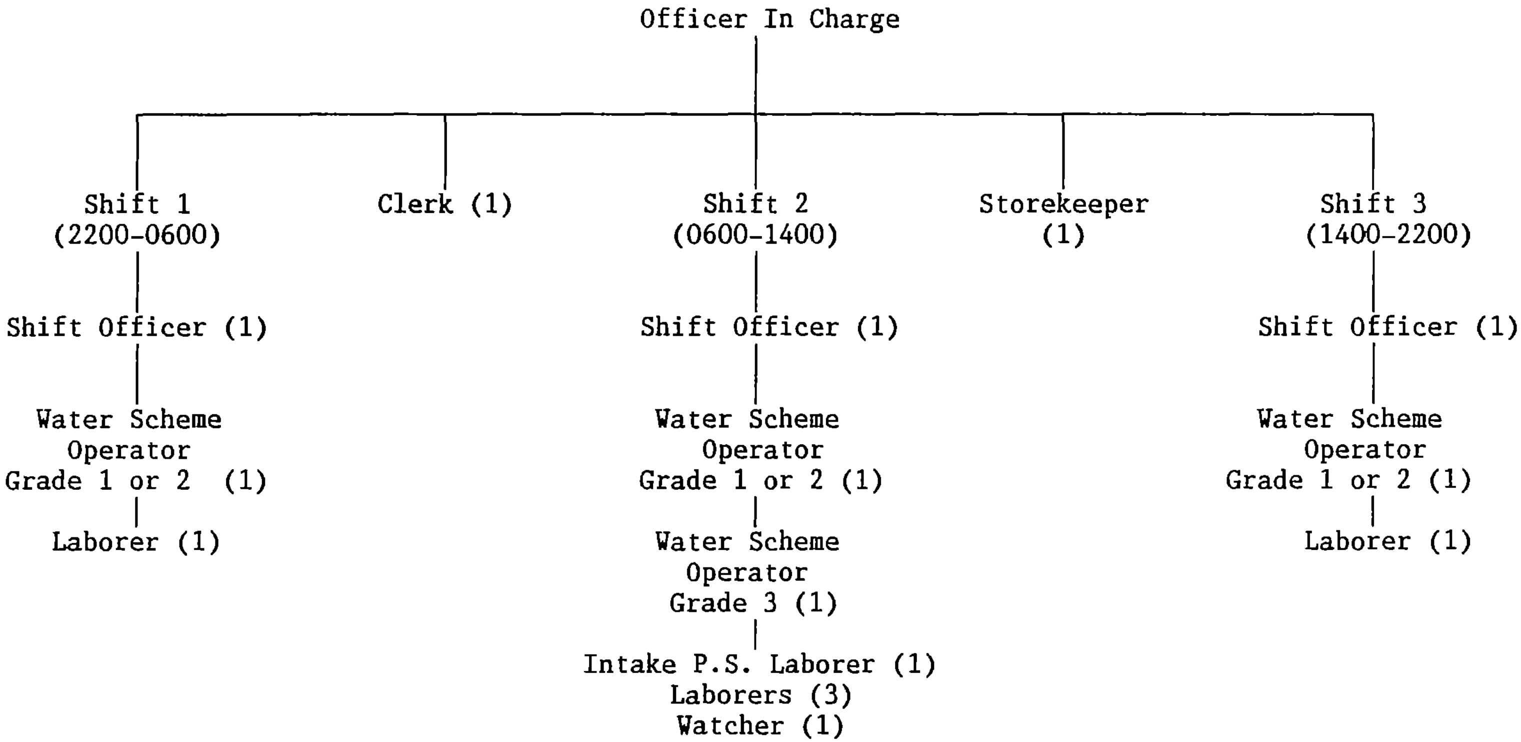
The next step in the estimating process for labor is to determine the average wage paid to personnel in each job classification that will be used in the operation and maintenance of the water system. As with OT, this determination can best be made by reviewing existing records. If records are unavailable (perhaps because the agency is new or the beneficiary of the new system is a rural community that has never had an improved water system), the planning team must work with the government or community to reach an agreement regarding the amount of wages to be paid.



Total Staffing Needed to Cover Leave and Minimize Overtime

O.I.C	-	1
Shift Officer	-	3
Operator	-	3
Laborer	-	5
		12

Figure 2. Class II Scheme Model



Total Staffing Needed to Cover Leave
and Minimize Overtime as Shown: (18)

(A) For 16 hours/day operation, two shifts only (15)

(B) For remote intake pump stations, add one Grade 2 Operator on Shift 1, one Grade 2 Operator on Shift 3, and three Grade 2 Operators on Shift 2 to cover the intake pump station.

Figure 3. Class I Scheme Model

Direct	
Plant Operator	Caretaker
Laborer	Handpump Mechanic
Equipment Operator	Shift Operator
Watchman	Storekeeper
Pipefitter	Clerk
Mechanic	Meter Reader
Electrician	Linesman
Health Worker	

Indirect	
Officer-in-Charge	Electrical Supervisor
Maintenance Foreman	Mechanical Supervisor
Water Plant Superintendent	Pipeline Maintenance Supervisor
Electrical Engineer	Mechanical Engineer
Civil Engineer	Sanitary Engineer

Figure 4. Operations and Maintenance Job Classifications

In summary, four elements of staff cost must be determined prior to estimating these costs. These are as follows:

- Job classifications;
- Number of personnel in each classification;
- Amount of overtime expected;
- Average wages, including taxes and benefits such as vacation, retirement or social security, insurance, bonuses, sick pay.

In some cases a separate tabulation may have to be made of all the cost elements that go into the average wage in a classification. Such a tabulation was made in Example 3 in Chapter 4.

With this information, personnel costs are calculated as shown in Table 1 on the following page.

Table 1

Personnel Cost Estimation

Regular Time

Classification	Number in Classification	X	Average Wages per Month[1]	=	Total
1	x		y		z
2	x		y		z
3	x		y		z
.	x		y		z
.	x		y		z
.	x		y		z
n[2]	x		y		z
			Total		

Overtime

Classification	Number	X	Average OT hours per Classification per Month	X	Average OT Rate per hour[3]	=	Total
1	x		w		y		z
2	x		w		y		z
3	x		w		y		z
.	x		w		y		z
.	x		w		y		z
.	x		w		y		z
n[2]	x		w		y		z
					Total		

Total Personnel Costs/Year = [Total Straight Time per month + Total Overtime per month] X 12 Months

[1] Average Wage = [maximum + minimum wage in classification] / 2.
[2] n = Number of classifications.
[3] OT rate must be converted to a per hour figure.

For example, if a water treatment plant is staffed by, among others, six plant operators, four laborers, and one supervisor, the calculations presented in Table 1 would be carried out as shown in Table 2 below:

Table 2

Labor Cost Estimation

Regular Time

Classification	Number in Classification	X	Average Wages per Month	=	Total
Plant Operator	6		$ 200		$ 1,200
Laborer	4		150		600
Supervisor	1		250		250
					$ 2,050

Overtime

Classification	Number	X	Average OT hours per Classification per Month	X	Average OT Rate	=	Total
Plant Operator	6		20		$1.75		$ 210
Laborer	4		10		1.25		50
							$ 260

Total Personnel Costs per Year = ($2,050 + 260) X 12 = $27,720

The calculations above are based on average wages in a classification. Precise salary or wage scale figures can be used if such a detailed determination can be made.

The calculations performed in Table 2 apply only to staff who are assigned full time to a new water system. Two other situations arise that require different approaches to estimating O&M costs for personnel.

1. Multisystem Personnel - An existing water agency, for example, may find it possible to use technicians from an existing facility to provide either electrical or mechanical maintenance for a new system. To accurately gauge O&M personnel costs, it is necessary to prorate these costs among the facilities serviced by these personnel. The best approach that can be used to

estimate this multiplier is to estimate the amount of time that the personnel in each job classification will spend operating and maintaining the new facility. The time estimate is made by using experience gained at the existing facilities and manufacturers' recommendations for operation and maintenance, particularly for preventive maintenance.

The calculations for regular and overtime would be the same as provided in Table 1 except that the cost for each classification would be multiplied by the proration factor. The calculation for percent of time at new system is as follows:

$$\text{percent of time at new system} = \frac{\text{hours per month-new system}}{\text{total hours per month}}$$

This calculation can be incorporated in Table 2 as is done in the example shown in Table 3. Note that the same job classification may appear two or more times if some of the staff in a particular classification are full time and others part time.

Table 3

Labor Cost Estimation

Regular Time

Classification	Number in Classification	x	Average Wages per Month	x	Percent of time: New System	=	Total
Electrician	2		200		100		$ 400
Mechanic	3		175		100		525
Electrician	1		200		50		100
Pipefitter	3		175		50		263
							$1,288

Overtime

Classification	Number	x	Average OT hours per Classification per Month	x	Average OT Rate per hour	x	Percent of Time: New System	=	Total
Electrician	2		25		1.75		100		$ 88
Mechanic	3		15		1.50		100		68
Electrician	1		25		1.75		50		22
Pipefitter	3		20		1.50		50		15
									$193

Total Labor Costs/Year = (1,288 + 193) x 12 = $17,772

2. Multicommunity Projects - In this case, the goals of a water project is to install a number of independent water systems with each serving one or more communities. The operation and minor maintenance is the responsibility of each community with major maintenance being performed by a central/regional water agency or by a private contractor. This type of project is generally executed in rural, rather than in urban areas, and may include the installation of two or more types of water systems. If, for example, 20 systems are built and 15 use handpumps and the balance are spring catchments feeding a piped system by gravity, the handpumps will normally require more maintenance. Hence, for communities of similar size, the cost per capita of maintaining the handpump system will generally be higher than for the gravity system.

   If the government, however, oversees major maintenance, the cost of the personnel responsible for this task is usually funded from general revenues, so that from a cost estimating standpoint, the cost of maintenance can be allocated equally to the beneficiaries of the new system, even if the systems differ. Thus, the cost procedures given in Table 1 can be used to estimate personnel costs.

   If, on the other hand, the communities must use private workshops for major maintenance, the cost of maintenance will be different for the varying types of systems.

2.3 Materials

The operation and maintenance of water systems involves the use of a variety of types of materials, usually considered in two categories - supplies and spare parts. Supplies refer to consumable items, often purchased in bulk, usually for general use, such as paint, cleaning rags, lubricating oil, bolts, and common pipe fittings. "Spare parts" refers to specific replacement components associated with particular facilities, equipment or machinery, such as bearings, gaskets, or other specific components.

Sometimes it will be difficult to label a particular item a supply or a part. Such precise definitions are not really important, however. These distinctions are merely a device for cost estimating. The main point is to recognize that some items are multipurpose items which are used regularly and some have specific uses.

The basic process for estimating material costs is to determine what items will be needed, how much of each, and the unit costs of each. Thus, information will be needed on:

- Details on all equipment, facilities, and components in the system;
- Details on the nature and frequency of O&M tasks to be performed;
- Unit costs for parts and supplies to be used.

In any water system planning effort, information on these topics will be generated. The engineering design should have complete information on the first item. An O&M plan should have information on the second. Any available records will help in estimating corrective maintenance tasks. Local cost data will have to be collected for the third topic.

Developing a complete, comprehensive list of materials should take a considerable amount of work, but, unfortunately, a detailed tabulation of material needs is the only way to an accurate cost estimate of materials. A detailed list of parts and supplies will also be very useful in project planning, project operations, and procurement planning; therefore, effort spent in planning now will pay off later.

2.3.1 Estimating Material Requirements

The starting point for the analysis would be a list of equipment, machinery, or facilities in the water system. Whether the project is a completely new system, or an expansion of an existing one, the engineering studies should provide a complete design for:

- Intake structures;

- Wells;
- Reservoirs;
- Pumping stations;
- Transmission pipelines;
- Treatment plants;
- Elevated storage tanks;
- Distribution piping;
- Water meters;
- Standpipes/house connections.

Table 4, on the following page, shows a sample list of equipment/installations for a hypothetical project involving a number of rural water schemes.

Each of these major components of a water system will have subcomponents which will require materials for maintenance and repairs. Pumping stations, treatment plants, and distribution systems are particularly complex and require special attention. The bill of materials for a project, often developed as a part of tender document preparation, will be an indispensable guide in developing a full list of equipment, hardware, and subcomponents.

Problems may arise if the cost estimate is being prepared in the early stages of project planning. If this is the case, the detailed engineering design may not have been completed, and only rough equipment and machinery lists may have been prepared. Engineering design studies, bills of materials, and other records for similar water systems will then have to be used. Once a list of the components, equipment and hardware has been made, a full list of the necessary materials and their respective quantities can be generated, component by component.

The first step in this process will be to define the operational and preventive maintenance tasks associated with each piece of equipment. These tasks should be listed in an overall O&M plan, which should be developed during the course of project planning. An example of a preventive maintenance plan for a diesel engine is shown in Table 5, which follows. It defines the timing and activities of preventive maintenance tasks as well as the materials, parts, and supplies needed.

Equipment history files are an important tool in materials estimation. These types of files may be available for other water systems, similar to the one being planned. Such files would contain detailed information on the existing equipment itself, including all subcomponents. These files should also have descriptions of operational tasks and maintenance requirements. In addition, they should contain records of repairs and maintenance performed, and hopefully, records of parts and supplies used. If these files do not exist, they should be developed.

Table 4

Form for Compilation and Classification of Installations and Equipment

Type of installation or equipment → / Location ↓	INTAKES – Well – Hand Dug – Plain	INTAKES – Well – Hand Dug – With filter	INTAKES – Well – Bored	INTAKES – Stream – Perforated pipe	INTAKES – Stream – Direct	INTAKES – Spring	INTAKES – Pipe connecting to main	Pump house	Centr. pumps	Diesel engines	Elect. motors	CHLORINATION – Gravity feeder	CHLORINATION – Test kit	TANKS – Storage	TANKS – Break pressure	Stand posts	MAIN AND DISTRIBUTION SYSTEM PIPELINES – Pipe length in meters (dia. mm) – 150	100	75	63	50	38	25	WATER METERS – Main	WATER METERS – Domestic
Group →	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q							R	S
Village A							1							1		15		4 501	1 279	351					124
Village B			1					1	2	2		1	1	1		9					4 210	1 067	381	1	80
Village C	2							1	2	2		1	1	1		13			311	1 088	253	850		1	13
Village D	3							1	2	2		3	2			8					3 752	680	259	1	8
Village E	1							1	2	2		1	1	1		11			1 362		788	930	91	1	11
Village F		1						1	2	2		1	1	1		10	140	1 131	777		204	341		1	45
Village G	1							1	2	2		1	1	1		11			1 214	371	1 067	1 043	262	1	61
Village H	1							1	2	2		1	1			3					2 454			1	3
Village I				1								1	1	1	1	16			593	1 096	1 020	680			49
Village J				1								1	1	1		25		279	948	750	900	2 402	190	1	112
Village K				1								1	1	1	2	15		1 045	1 219	305	396	731			49
Village L				1								1	1	1		15		6 663	6 379	2 073		1 236		1	124
Village M					1							1	1	1	1	21	305	1 346	803	457	2 003	1 542		1	136
Village N						1						1	1	1		7			2 077	1 829	567	1 714		1	25
Village O		1						1	2		2	1	1	1		8	274	488	174		326			1	53
Total	8	2	1	4	1	1	1	8	16	14	2	16	15	13	4	187	719	15 453	17 332	8 320	17 940	13 217	1 183	12	893

GROUP		DESCRIPTION	MAINTENANCE PERIOD	RESPONSIBILITY LEVEL	CREW	TASK TO BE PERFORMED	MATERIALS, SPARE PARTS, LUBRICANTS ETC. REQUIRED
IV TREATED WATER PUMPING	D	Diesel Engines	1 day	L	O	Check oil level and top up if necessary Lubricate all lubrications points. Record oil pressure, temperatures, speed and battery charge. Record working hours and total since last oil change/last overhaul. Clean outside parts, check nuts and bolts for tightness.	Lubricating oil
			1 week	L	O	wash and clean air filter	
			1 month	D,L	m,o	Dismantle injectors and test spray. Replace defective nozzles if necessary. Check and adjust V belt tension/ coupling alignment as applicable	Injector nozzles as necessary
			3 months	D,L	m,p,o	Clean and inspect injectors and valve clearances. Check and clean oil filters. Fit new fuel filter elements. Check starting system. Change engine oil or in accordance with manufactures manual.	Fuel filter elements, engine lubricating oil.
			1 year	D,L	m,p,o	Check and regrind valves and adjust valve clearances. Clean deposits from cylinder heads and pistons. Dismantle clutch system, if applicable.	
			2 years	R,D,L	m,p,o	Remove engine for complete overhaul in Regional workshops. Replace with spare reconditioned engine	Spare parts as required

KEY:

Level: L = Local, D = District, R = Region
Crew: e = engineer/technical officer, m - maintance team, o = plant operator, p = pump/engine mechanic

Table 5

Preventive Maintenance Checklist for Water Supply Systems
Buildings, Structures, and Equipment

A variety of other "tools" are also useful in estimating O&M material needs for a particular component or piece of equipment, such as:

- Project bill of materials (new or existing systems);
- Engineering design studies of other systems;
- Records of the use of the equipment in country;
- Records on similar equipment in country;
- Equipment manufacturer's manuals;
- Plant or system O&M manuals;
- Engineering handbooks or texts;
- Consultations with commercial suppliers of the equipment.

Although this analysis process will work well for parts needed for planned maintenance, estimating spare parts for breakdowns or repair work will require much more extensive investigation. With solid engineering knowledge and experience, it is possible to identify vulnerable parts and components. Reviewing records and equipment history files should give useful information. Discussing failure rates and breakdown experiences on similar equipment with local operators should also be useful.

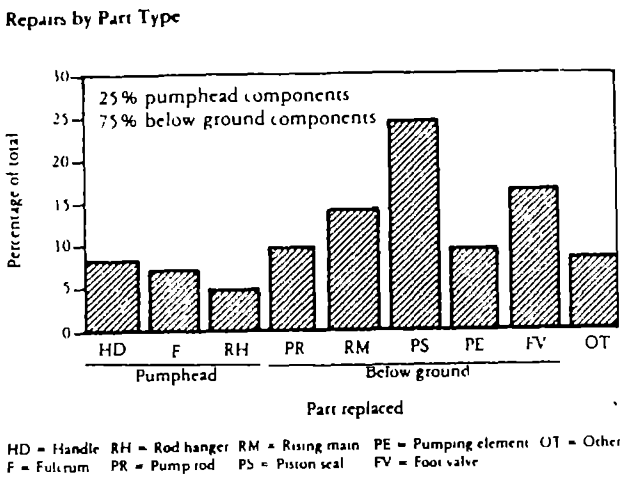
EXAMPLE

Data from U.S. cities regarding the incidence of water main breaks are another interesting example, but this information points out the difficulties in using such failure rates as predictors. A typical incidence of piping breaks is 200 water main breaks annually per 1,000 miles of distribution piping, which translates to about 12 breaks per 100 km of piping. Surveys among different U.S. cities, however, have shown a range of 36 to 1,300 breaks annually per 1,000 miles. Factors which influence this failure rate include age of the piping, type of pipe, soil type, corrosion rates, leakage rates, and even the extent to which the breaks are reported.

When considering material quantities, it is important to remember that during the cost estimating procedure we are simply concerned with materials consumption, not inventories or procurement policy. Some parts and supplies will be stocked, consumed, and reordered on a regular basis. Others will probably be purchased at the outset of a project but used only rarely. It is difficult to anticipate in advance which parts will be stocked in what quantities. Some initial stock of parts and supplies will be purchased and these should properly be considered in the capital cost of the system. The concern here is the turnover or stream of materials used and the cost stream that produces.

EXAMPLE

The World Bank has conducted field trials of many handpumps to collect data on performance and cost indicators. One particular focus is the incidence of different types of breakdowns. When considering all of the pumps tested, pump seals ("pump leathers") were the most commonly replaced components, representing 25 percent of all parts replaced. Below-ground components represented 75 percent of all repairs, while the remaining 25 percent of the repairs were on pumphead components.



Source: Community Water Supply: The Handpump Option. The World Bank, 1987.

The India Mark II handpump has been a highly successful pump in rural areas in many countries. More than 500,000 units had been installed as of 1986. World Bank field trials were conducted in six countries. Repair data are summarized below:

Country	Number of Parts Replaced per Year	Most Frequently Replaced Components
India	1.10	Piston seal, rising main
Sri Lanka	0.68	Foot valve, pumping element
Burkina Faso	0.92	Piston seal, pump rod
Niger	0.75	Pump rod, pumping element
Sudan	2.12	Piston seal, pumping element
Ghana	0.64	Rising main, pump rod

Tools are not actually what we think of as materials, i.e., they are not consumed in regular O&M tasks. But it will be wise to account for regular replacement of some tools, especially commonly used handtools. Tools often get broken, lost, or stolen, and in many locations work is delayed as a result of the lack of good, appropriate tools. A nominal tool replacement budget should be added in the cost estimate.

2.3.2 Estimating Material Costs

Once a list of the material items and quantities has been developed, the annual costs can be tabulated by multiplying annual quantity by unit price for each item and adding up these products.

Unit costs should be available from local suppliers or from records of previous purchases of these materials. It will be important to ensure that correct unit costs are used. Unit costs often vary considerably from place to place and year to year. Table 6, which follows, shows some sample unit costs for galvanized water pipe for a variety of countries. In all locations, costs increase with diameter, as expected. The costs vary widely, however, from one country to the next. In Kenya, for example, where pipe is imported, costs can be higher than in locations where pipe is produced locally or in a neighboring country.

Table 6

Prices for Galvanized Water Pipe in Selected Developing Countries

(Small Lot Quantities, 6m Lengths, Commercial Prices, Cost Per Meter)

1986 US$

Pipe Diameter	Botswana	India	Kenya	Morocco	Philippines	Philippines (Installed)
1/2"			$2.69			
3/4"		$1.30	$3.39			
1"	$2.05	$1.90			$1.45	$1.56
1 1/4"	$2.80					$2.05
1 1/2"	$3.17					$2.49
2"	$4.58		$9.48	$6.07		$3.52
2 1/2"	$5.95					$5.72
3"	$7.54	$5.70				$7.09
4"	$10.87	$7.70	$29.68			$10.07
6"		$11.07				$17.35

Note: Conversion of costs into US$ is based on exchange rate during year. Conversion to 1986 dollars is based on U.S. Producer Price Index.

In addition, unit costs vary greatly with the quantity purchased, lot size, and so forth. Table 7 below shows local costs, in Pula, for galvanized water pipe from different sources in Botswana. One column shows unit costs as specified on recent tenders to the Government water supply agency and involve the purchase of large quantities, without taxes or duty. Other columns show unit costs for the same items, from commercial suppliers, based on small lot purchases. As indicated in the following table, unit costs vary considerably.

Table 7

Cost of Galvanized Pipe, Botswana

Cost of a 3m Length, in Pula, June 1985

Diameter	Government Tender	Supplier A	Supplier B
3/4"	4.32		
1"	6.45	11.10	
1 1/4"	14.10	16.21	
1 1/2"			
2"	13.95	22.95	26.67
2 1/2"	17.67	30.15	34.32
3"	21.44	38.10	43.63
4"	33.62	56.40	61.48

Once appropriate unit costs for all materials have been collected, the annual material costs can be determined simply by multiplying the quantity by unit cost for each material and finding the sum.

EXAMPLE

For a project in Zaire, an estimate has been made of the cost of spare parts for a modified India Mark II handpump. The pumps and spare parts are to be imported from India. The exporter has recommended parts that should be purchased for use during the first five years of operation:

Name of Spare Part	Quantity	Unit Price	Total
Hexagonal bolt (M12x1.75x40mm)	16	$0.40	6.40
Hexagonal nut (M12x1.75)	32	0.12	3.84
Washer (4mm thick)	4	0.25	1.00
High Tensile Bolt (M12x1.5x490mm)	3	0.63	1.89
Nyloc Nut (M10x1.5)	5	0.64	3.20
Handle Axle, Stainless Steel	1	12.00	12.00
Bearing (6204-2z)	6	7.97	47.82
Chain with Coupling	3	11.97	35.91
Bolt for Front Cover	2	0.35	0.70
Rubber Washer	10	2.38	23.80
Leather Sealing Ring	18	0.96	17.28
Rubber Seating (big)	5	0.48	2.40
Rubber Seating (small)	5	0.48	2.40
Rubber O-ring	5	0.48	2.40
Upper Valve Guide	2	1.90	3.80
Upper Valve Seat	2	1.30	2.60
Upper Check Valve Guide with Retainer	1	7.20	7.20
Connecting Rod	4	7.18	28.72
Hexagonal Coupling	2	4.80	9.60
Total (CIF Matadi) =			$212.96
Average Annual Parts Cost =			$ 42.59

This tabulation estimates the cost of parts, CIF the Port of Matadi. The actual cost at a rural site would also include provision for import duties, transport to the distribution center, and markup, if purchased from a private distributor.

Source: WASH Field Report No. 170.

2.3.3 Replacement Costs

Most water system mechanical components such as pumps, motors, valves, water meters, etc. will have to be replaced after a period of 5, 10 or more years. Distribution piping will often be replaced after a longer period of time. In most cases, an estimate of the cost of replacement parts or smaller system components should be accounted for.

The estimator should be careful about the inclusion of replacement costs. In some cases, depending on the objective of the estimate, they should be purposely omitted. In many countries the cost of major replacements would be taken from a capital account, while frequently used minor replacements (such as engine parts or motor brushes) would come out of an operating or current budget. If the estimator is preparing an operating budget, he or she will need to conform to government policy and include the appropriate costs in the appropriate budget. The magnitude of the costs, their frequency, and general government policy will be the key factors in deciding this issue. If a major tariff study is being done and full cost recovery is the goal, then of course these costs should be included.

Some developing country governments do not concern themselves with major replacement costs because they feel they can solicit the funds from donor agencies. Inclusion of future replacement costs will be unpopular if a disgruntled public is already unhappy with high tariffs or the central government subsidies to water utilities are high. It is the general recommendation of this manual, however, that these costs be included.

The procedure for including replacement costs involves defining the items to be replaced, the year they will be replaced, and the cost of the replacement (in the year the work is performed). Collection of this data will require considerable research. The estimator should proceed from the inventory of equipment involved in the system to estimate the replacements, in the same way parts are estimated, as described above. Examination of any available records on life of equipment such as pumps, motors, etc. will be a good guide. Interviews with operators of other systems will also yield good information.

Once the above data has been collected, the equivalent annual cost of these future replacements can be found using discounting formulas. These formulas are based on the economic theory that states that future values can be translated to present values by using a discount rate. The key formula is:

$$P = F \frac{1}{(1 + i)^n}$$

where:

P = Present value of future costs, in \$
F = Future Cost, in \$
i = Discount rate
n = Year of the future cost

EXAMPLE

Calculate the present value of the cost of a pump, valued at \$2,000, replaced in year 10 of the project, assuming a discount rate of 10%.

$$P = \$2{,}000 \times \frac{1}{(1 + 0.1)^{10}}$$

$$P = \$2{,}000 \times 0.3855$$
$$P = \$771$$

The value of this factor, for different years and discount rates, is shown in the appendix.

The appropriate discount rate can be difficult to estimate. The discount rate is meant to represent the time value of money, which depends on many factors. Many financial calculations use the prevailing bank interest rate, which in developing countries may reach 20 percent. Governments often specify discount rates around 5 percent for economic studies of national policy. Ten percent is a commonly used value, in the absence of other data.

Once present values for all replacements are found, they should be added up and converted to an equivalent annual cost, using the capital recovery formula:

$$A = P \frac{i\,(1 + i)^n}{(1 + i)^n - 1}$$

where:

A = Annualized cost, in \$/yr
P = Present value, in \$
i = Discount rate
n = Project period, years

The value of this factor, for different years and discount rates, is also shown in the appendix.

EXAMPLE (continued)

Calculate the equivalent annual cost of the replacement pump cited above, assuming a 10 year project and a 10 percent discount rate.

$$A = \$771 \times \frac{0.1\ (1 + 0.1)^{10}}{(1 + 0.1)^{10} - 1}$$

$$A = \$771 \times 0.1627$$
$$A = \$125$$

Thus, to cover the future cost of $2,000 in 10 years, the agency will have to save $125 per year, with 10 percent compounded interest, to have the funds to cover that expenditure.

2.4 Chemicals

2.4.1 Background

Chemicals are used in water systems for a variety of water treatment processes. The objective of treatment is to render water acceptable for human consumption by removing solids, disinfecting, removing hardness, removing or neutralizing harmful minerals, and improving color, taste, and odor. The type of treatment required varies greatly depending on the water standards in force and the quality of the source. Some of the most common processes include coagulation, sedimentation, filtration, disinfection, and softening. The most common processes requiring chemicals are coagulation, where alum is commonly used; disinfection, where various forms of chlorine are used; and softening, where lime is commonly used.

A list of common water treatment chemicals appears in Table 8, including chemical name, use, appearance, form, and commercial strength.

Depending on the type of treatment required, chemicals can be a large portion of overall O&M costs or a very small cost. Many small water systems based on groundwater pumping use only simple chlorination, or no treatment at all. Systems using surface water resources are likely to have much more extensive treatment works, usually customized to the source water quality. Each site and system will be different. The basic approach to estimating chemical costs will be to determine chemical needs from water sample test results, records (if available, for existing systems), and engineering plans (for expansions or new water systems). Then, using local unit prices, annual chemical costs can be calculated directly.

2.4.2 Estimating Chemical Requirements

The first step in estimating chemical costs will be to determine chemical needs. The type, form, and quantities of all chemicals required must be determined. The design engineer should make these determinations for a new water project or an expansion of an existing one. It will define the treatment processes required, type and form of chemicals needed and the necessary dosages. Such information is prepared from the results of water sample tests (jar tests), which are commonly carried out in the early planning stages of a project. If the cost estimate is being prepared before such engineering plans are complete, or such data are unavailable, information on chemical needs will have to be obtained from records or interviews with operators of other nearby water systems.

From the dosages required (mg/l) and the design water flow, the annual quantity of chemical needed can be readily calculated. Allowances for loss, damage or theft must be made. Because chlorination is such a common process, a brief example has been prepared, which is shown below.

Table 8

Chemicals Commonly Used in Water Treatment

Chemical Name and Formula	Common Name	Use	Appearance and Properties	Available Forms	Shipping Containers	Commercial Strength
Aluminum Sulfate $Al_2(SO_4)*14H_2O$	Alum, filter alum	Coagulant	Light brown to grey-green, astringent	Powder, rice, lumps, blocks	Bags, drums	15%-17% Al_2O_3
Aluminum Sulfate $Al_2(SO_4)*xH_2O$	Liquid alum	Coagulant	Brown, acidic, corrosive	Solution	Tank cars, tank trucks	5.8-8.5% Al_2O_3
Calcium Hydroxide $Ca(OH)_2$	Hydrated lime, slaked lime	pH adjustment, softening	White powder, caustic	Powder	Bags, drums, or bulk	80%-95% $Ca(OH)_2$ 60%-70% CaO
Calcium Hypochlorite $Ca(OCl)_2*4H_2O$	HTH, Perchloron, Pittchlor	Disinfection, taste and odor control	White powder, corrosive	Powder, granules, pellets	Cans, drums	60%-70% available chlorine
Calcium Oxide CaO	Quick lime, burnt lime, chemical lime, unslaked lime	pH adjustment, softening	White to light grey, caustic	Powder, pebbles, lumps	Bags, drums, or bulk	70%-99%
Chlorinated Lime $CaO*2CaOCl_2*3H_2O$	Bleaching powder chloride of lime	Disinfection,	White powder, corrosive, unstable	Powder	Drums	25%-37% available chlorine (when fresh)
Chlorine Cl_2	Chlorine gas, liquid chlorine	Disinfection, taste and odor control, oxidant	Greenish-yellow gas, noxious, corrosive	Liquified gas under pressure	Cylinders	99%-99.8% available chlorine
Copper Sulphate $CuSO_4*5H_2O$	Blue vitriol, bluestone	Algicide, Molluscide	Blue crystals or powder, poisonous	Powder, crystals, lumps	Bags, drums	99%
Ferric Chloride	Chloride of iron		Corrosive, hygroscopic			
1) $FeCl_3$ sol.	Ferrichlor	Coagulant	Dark brown	Solution	Carboys, tank trucks	30%-45% $FeCl_3$ 12%-17% Fe
2) $FeCl_3*6H_2O$	Crystal	Coagulant	Yellow-brown	Crystals, lumps, granules, sticks	Drums	59%-60% $FeCl_3$ 20%-21% Fe
3) $FeCl_3$	Anhydrous	Coagulant	Green-black	Powder, crystals	Kegs	96%-98% $FeCl_3$ 34% Fe
Ferric Sulfate $Fe_2(SO_4)_3*xH_2O$	Iron sulphate, Ferrifloc, Ferrisul	Coagulant	Red-brown to red -grey, hygroscopic, corrosive	Granules, crystals, lumps	Bags, drums, or bulk	90%-94% $Fe_2(SO_4)_3$ 18%-26% Fe
Ferrous Sulfate $FeSO_4*7H_2O$	Copperas, iron sulphate, sugar sulphate, vitriol	Coagulant	Green to brown-yellow, hygroscopic, corrosive	Powder, granules, crystals, lumps	Bags, drums, or bulk	45%-55% $FeSO_4$ 20% Fe
Sodium Carbonate Na_2CO_3	Soda ash	pH adjustment, softening	White powder, caustic	Powder, crystals	Bags, drums, or bulk	98%-99% Na_2CO_3 58% Na_2O
Sodium Hydroxide NaOH	Caustic soda, lye	pH adjustment, softening, filter cleaning	White, caustic, corrosive, hygroscopic	Pellets, flakes, lumps	Drums or bulk	96%-99% NaOH
Sodium Hypochlorite NaOCl	Chlorine bleach, hypochlorite, Eau de Javalle	Disinfection	Pale yellow, corrosive, odorous	Solution	carboys, tank trucks	10%-15% available chlorine (when fresh)

EXAMPLE

A chlorination system is being planned for a small rural water system. The system is made up of a borehole, diesel pump, an elevated storage tank and a distribution system (5 km in total length). The design flow is 200 m^3/day. Calcium hypochlorite (CaOCl) compound will be dispensed into the tank. On the basis of well water quality, contact time in the tank, and the desire for a chlorine residual, a dosage of 3 mg/l is to be used. The hypochlorite is assumed to have approximately 65 percent available chlorine (See Table 8). Thus, to achieve the desired dosage 4.6 mg (3/0.65) of hypochlorite is needed. Thus, we can calculate the quantity of hypochlorite needed:

$$\text{Quantity} = \frac{4.6 \text{ mg}}{1} \times \frac{1000 \text{ l}}{1 \text{ m}^3} \times \frac{200 \text{ m}^3}{\text{day}} \times \frac{1 \text{ kg}}{1 \ (10^6 \text{ mg})} = 0.92 \text{ kg/day} = 336 \text{ kg/yr}$$

Assume approximately 350 kg/yr for estimation purposes, including a 5 percent allowance for loss.

Estimates of the required quantity of other chemicals can be made in the same way. The dosages for some chemicals, such as coagulants, can be determined only by jar test, but once such information is available, the calculation procedure will be the same as that indicated in the foregoing example.

2.4.3 Estimating Chemical Costs

Once estimates of the chemical needs have been prepared, the chemical cost can be found using unit price information for each chemical. Unit price information is best obtained in country at the time the cost estimate is being made. Chemical prices tend to vary considerably over time, and from place to place. An example of the wide variability in chemical prices is given in Table 9, where alum prices in different countries are shown. Where the chemical is imported, the unit prices can be much higher than other locations.

It is essential that correct unit prices be obtained, corresponding to the exact type of chemical required (compound), its physical form--(powder, pellets, and so forth), the packaging (sacks, bulk) and in appropriate quantities. Obviously, the required quantities will be a major factor in determining the form and packaging, and thus the unit price. Unit price for a small quantity of a chemical packaged for vehicle transport to a remote location will be different from the same chemical procured in bulk for use in a major city. Personnel at any existing water treatment plants, or chemical suppliers will be reliable sources of information on chemical unit costs.

Table 9

Unit Costs of Alum for Several Plants in Developing Countries
(1982 U.S. Dollars)

City/Country	Alum (US $/metric ton)
Cochabamba, Bolivia	140
Linhares, Brazil	94
Prudentopolis, Brazil	110
Guatemala City, Guatemala	270
San Pedro Sula, Honduras	320
Ramtek, India	120
Amman, Jordan	350
Kano, Nigeria	400
Bamako, Mali	700

Note: 1 metric ton = 2.2 U.S. tons
Source: Schulz and Okun, 1984.

Computing total cost will then be simply a multiplication of unit cost by annual quantity to yield annual chemical cost. Net cost per cubic meter of water treated is a simple but useful parameter to calculate.

EXAMPLE (continued)

Calcium hypochlorite is available in sacks of 45 kg (100 lb) capacity for a cost of $30 (based on $660/metric ton). Thus annual chlorine costs in this case are as follows:

$$\text{Annual Cost} = 350\ \text{kg/yr}\ (\$660/1000\ \text{kg}) = \$231/\text{yr}$$

$$\text{Unit Cost} = \frac{\$231/\text{yr}}{200\ \text{m}^3/\text{day} \times 365\ \text{days/yr}}$$

$$= \$0.0032/\text{m}^3$$

$$= 0.32\ \text{US cents/m}^3$$

The type of calculation shown in the example above was repeated for a variety of input values, with the results shown in Table 10.

Table 10

Cost of Chemicals, in US Cents/m^3

					AVAILABILITY =			65.0%
					WASTE/LOSS RATE =			5.0%
COST OF CHEMICAL								
US$ / Metric Ton	$100	$200	$300	$400	$500	$600	$700	$800
US$ / US Ton	$45	$91	$136	$182	$227	$273	$318	$364
DOSAGE mg/l								
1	0.016	0.032	0.049	0.065	0.081	0.097	0.113	0.130
2	0.032	0.065	0.097	0.130	0.162	0.194	0.227	0.259
3	0.049	0.097	0.146	0.194	0.243	0.291	0.340	0.389
4	0.065	0.130	0.194	0.259	0.324	0.389	0.453	0.518
5	0.081	0.162	0.243	0.324	0.405	0.486	0.567	0.648
6	0.097	0.194	0.291	0.389	0.486	0.583	0.680	0.777
7	0.113	0.227	0.340	0.453	0.567	0.680	0.794	0.907
8	0.130	0.259	0.389	0.518	0.648	0.777	0.907	1.036
9	0.146	0.291	0.437	0.583	0.729	0.874	1.020	1.166
10	0.162	0.324	0.486	0.648	0.810	0.972	1.134	1.296
11	0.178	0.356	0.534	0.713	0.891	1.069	1.247	1.425
12	0.194	0.389	0.583	0.777	0.972	1.166	1.360	1.555
13	0.211	0.421	0.632	0.842	1.053	1.263	1.474	1.684
14	0.227	0.453	0.680	0.907	1.134	1.360	1.587	1.814
15	0.243	0.486	0.729	0.972	1.215	1.457	1.700	1.943
16	0.259	0.518	0.777	1.036	1.296	1.555	1.814	2.073
17	0.275	0.551	0.826	1.101	1.377	1.652	1.927	2.202
18	0.291	0.583	0.874	1.166	1.457	1.749	2.040	2.332
19	0.308	0.615	0.923	1.231	1.538	1.846	2.154	2.462
20	0.324	0.648	0.972	1.296	1.619	1.943	2.267	2.591

2.5 Utilities

2.5.1 Background

The utilities required to support the operation and maintenance of a water supply frequently represent a significant portion of the recurrent costs of the system. Utility costs are made up of two components: 1) electrical power and/or fuel to operate pumping and peripheral equipment required for water processing and treatment and provide facility services, and 2) telephone communications.

2.5.2 Estimating Electric Power Needs

The first step will be to identify all devices needing power, i.e., an inventory must be prepared of all electrically powered devices. The equipment inventory process described in Section 2.3 (Materials) can be used to tabulate all the power-consuming devices. A list of common items includes

- raw water pump motors (from wells or surface sources);
- motors for agitators, stirrers, compressors, dosing pumps, backwash pumps, clarifiers, and other devices in treatment plants;
- finished-water pump motors and booster pump motors;
- lighting in treatment plants, offices, etc.;
- office equipment;
- workshop equipment;
- appliances such as air conditioning units, refrigerators, and laboratory equipment.

For each device, an estimate of the hours of use per day will have to be made. This type of information will have to be developed from the engineering design and the O&M plan, if one exists. For example, the design should specify pump capacity (m^3/hr), and the daily water production (m^3/day) so the hours of operation can be easily found. Interviews with operators at other water systems should provide good information on operational aspects of electrically powered devices at treatment plants.

Next, an estimate must be made of the electrical power (kw) consumed by each device. Engineering designs will also give rated power figures for major motors, expressed in kilowatts (kw) or horsepower (hp)[1]. Actual power draws can be calculated from:

$$\text{power (kw)} = \frac{\text{volts x amps}}{\text{1000 w/kw}}, \text{ for single-phase devices}$$

$$\text{power (kw)} = \frac{\text{volts x amps x 1.732 x power factor}}{\text{1000 w/kw}}, \text{ for all three-phase devices}$$

Note: For most cases, a power factor of 1 can be used.

The total power consumption, although hard to estimate, will be the sum of all power devices operating at any given moment.

The energy consumption for a given device will be:

Energy (kwh) = Power (kw) x Operating Hours

The total energy consumption over a month will be the sum over all devices, over the full month. Detailed examples of this process are shown in Sections 4.2 and 4.3.

2.5.3 Estimating Electric Power Costs

Once a full tabulation of devices, power consumption, and energy devices has been made, the estimator can begin to compute costs. The only other required data will be local electric power utility rate schedule.

Generally electric power cost calculations are made in two parts, energy costs and power costs. Energy costs will be a simple calculation:

Energy Cost ($) = Energy Consumption (kwh) x Energy Unit Costs ($/kwh)

Utilities meter energy consumption in kwh and bill customers, often with a flat unit energy cost. In some cases unit costs rise or fall as more energy is used over a month. In most places, different rates will apply to residential (low power), commercial (moderate power), and industrial (high power) rate classifications.

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[1] 1 horsepower = 0.746 kilowatt

The other part of electric power costs is power or demand charges. For low power consumption, these are very low or zero, but in commercial and higher classifications they may be the larger part of the electric power bill. The basis of power charges varies greatly. In Ivory Coast, there is a flat charge per kw "subscribed" power demand. This subscribed power demand is defined when service is established. If the consumer draws more power than his subscription, stiff penalties are imposed. In the United States, rates vary and are based on continuous reading power meters (not energy meters). In any given month, the peak is monitored and a demand charge is levied based on this peak.

EXAMPLE

In one U.S. city, power is monitored continuously. The demand charge is $5.00/kw. The basic energy charge is $0.08/kwh. In a given month the peak power was 50 kw, and the energy consumed was 18,000 kwh. Compute monthly total electric utility costs.

Power Charge:	$5.00 x 50 kw =	$ 250.00
Energy Charge:	$0.08 x 18,000 kwh =	1,440.00
	TOTAL	1,690.00

The estimator will have to investigate local metering and billing practices in order to compute electric utility costs correctly.

2.5.4 Estimating Electric Power Water Pumping Costs

For water-pumping equipment, specific formulas are often used to estimate the power and energy used. The pertinent characteristics that must be known include the amount of water supplied by the system and the system hydraulics. The appropriate equations are as follows:

$$\text{Hydraulic Power (watts)} = Q \times H \times 9.8$$

$$\text{Electric Power (kw)} = \frac{\text{Hydraulic Power}}{Em \times Ep \times 1{,}000}$$

where Q = flow in liters/sec (l/s)
H = total head in meters (m)
Em = motor efficiency
Ep = pump efficiency

EXAMPLE

If the water system as shown in Figure 5 is to provide 1,000 m^3/day* the required flow is:

$$\text{Flow} = 1{,}000\ m^3/\text{day} \times 1{,}000\ l/m^3 \times \frac{1\ \text{day}}{24\ \text{hrs}} \times \frac{1\ \text{hr}}{3{,}600\ \text{secs}} = 11.6\ l/s$$

Next we must compute the total head:

$$\text{Total head} = \text{Depth to dynamic water level} + \text{Elevation to tank top} + \text{pipe friction}$$

The first two values are shown in Figure 5. The last, pipe friction, can be found in engineering handbooks. For aged 100 m (4") pipe (C = 100) the friction is:

3.7 m/100 m of pipe length

Thus, the total head is:

$$\text{Total head} = 70\ m + 30\ m + \frac{3.7}{100} \times 150 = 105.5\ m$$

Now we can calculate the electric power required, if we assume a motor efficiency of 80 percent and a pump efficiency of 60 percent:

$$\text{Electric Power (kw)} = \frac{11.6\ l/s \times 105.5\ m \times 9.8}{0.8 \times 0.6 \times 1{,}000} = 25.0\ kw$$

$$\text{Electric Energy (kwh)} = 25\ kw \times 24\ hrs/day = 600\ kwh/day$$

Then for a rate of $0.08/kwh and a 30-day billing period, the <u>energy</u> costs will be:

600 kwh/day x $0.08 x 30 days = $1,440.00/month

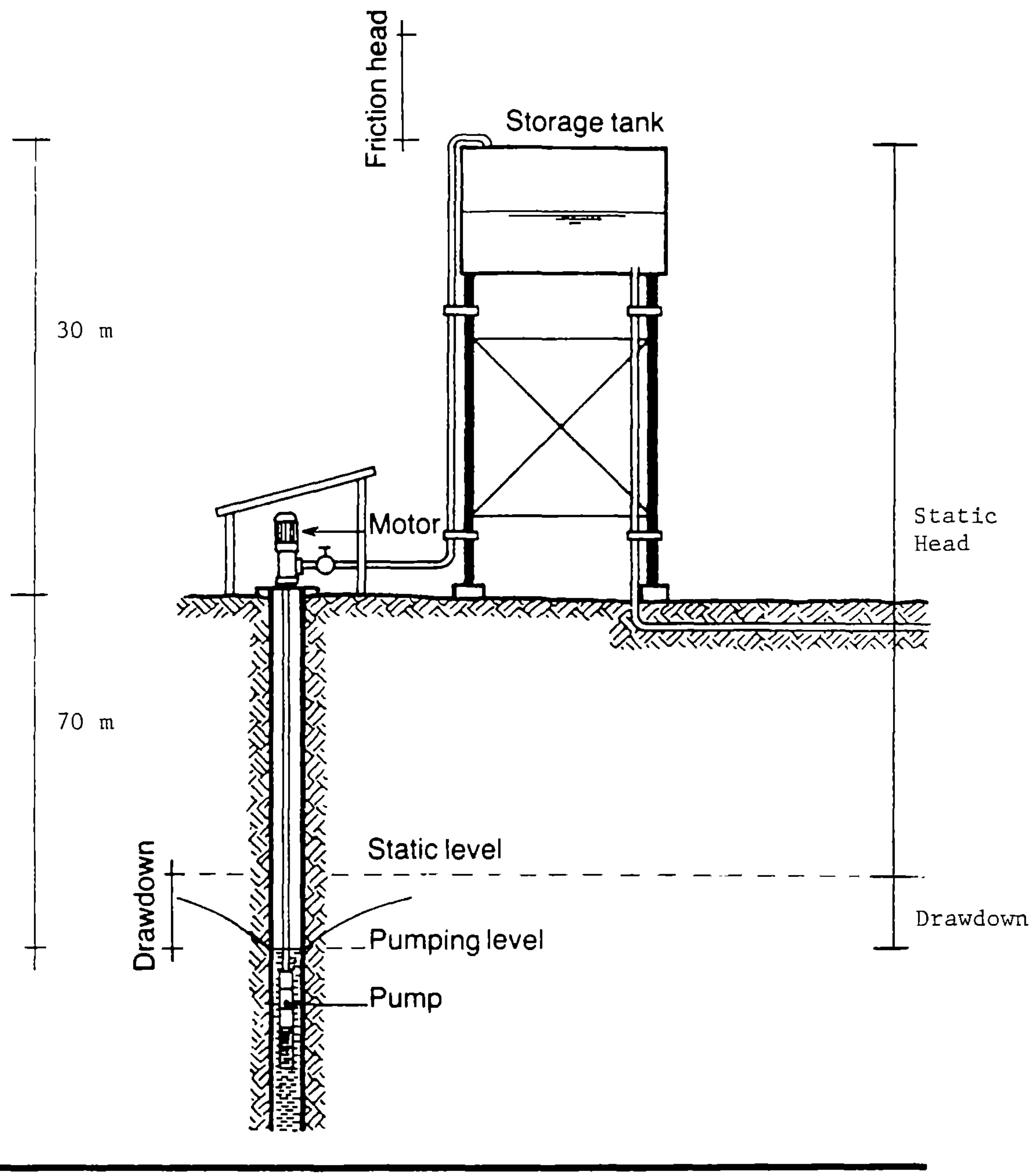
Also, the cost per cubic meter can be found:

600 kwh x $0.08/1000 m^3 = $0.048 or 4.8 cents/$m^3$

---

* 10,000 persons x 100 lpcd/1000 liters/m^3 = 1,000 m^3/day

Figure 5



Adapted from: E.H. Hofkes and J.T. Visscher, Renewable Energy Sources for Rural Water Supply. Technical Paper 23. The Hague: International Reference Centre for Community Water Supply and Sanitation, 1986, p. 48.

Table 11 shows the results of this type of calculation for other heads and energy costs.

Table 11

Cost of Electric Water Pumping, US Cents/m^3

WIRE TO WATER EFFICIENCY = 40.0%

COST OF ELECTRIC ENERGY US $/kwh		$0.04	$0.06	$0.08	$0.10	$0.12	$0.14	$0.16	$0.18	$0.20
TOTAL HEAD,m	10	0.27	0.41	0.55	0.68	0.82	0.95	1.09	1.23	1.36
	20	0.55	0.82	1.09	1.36	1.64	1.91	2.18	2.45	2.73
	30	0.82	1.23	1.64	2.04	2.45	2.86	3.27	3.68	4.09
	40	1.09	1.64	2.18	2.73	3.27	3.82	4.36	4.90	5.45
	50	1.36	2.04	2.73	3.41	4.09	4.77	5.45	6.13	6.81
	60	1.64	2.45	3.27	4.09	4.90	5.72	6.54	7.36	8.18
	70	1.91	2.86	3.82	4.77	5.72	6.68	7.63	8.58	9.54
	80	2.18	3.27	4.36	5.45	6.54	7.63	8.72	9.81	10.90
	90	2.45	3.68	4.91	6.13	7.36	8.58	9.81	11.04	12.26
	100	2.73	4.09	5.45	6.81	8.17	9.54	10.90	12.26	13.63
	110	3.00	4.50	6.00	7.49	8.99	10.49	11.99	13.49	14.99
	120	3.27	4.90	6.54	8.18	9.81	11.45	13.08	14.72	16.35
	130	3.54	5.31	7.09	8.86	10.63	12.40	14.17	15.94	17.71
	140	3.82	5.72	7.63	9.54	11.45	13.35	15.26	17.17	19.08
	150	4.09	6.13	8.18	10.22	12.26	14.31	16.35	18.39	20.44

2.5.5 Estimating Cost of Other Electric Power Uses

The cost of power to the water utility for site services and lighting does not usually represent a significant portion of the power bill, unless the new water system includes provision for a substantial office complex or service facilities, such as a maintenance workshop. Whether a one room pump house or a number of buildings are part of the water system, it is generally neither practical nor necessary to prepare a list of items which use electrical power, but rather to rely on standards based on average power used per area measure. Different standards are used for different use areas. For example, computer facilities, general office areas, laboratories, and repair shops use different area costs.

The most reliable sources of standard estimates based of cost/area are the water utility's own experience, the standards used by local architect-engineering firms, and the power company. After obtaining the standard costs for different facility types, the project planner needs to determine the area measurements for the water project that is being designed.

The final step is to estimate the power costs for each area. For example, if a maintenance workshop of 700 square meters is planned, and the standard cost is

$1.00 per square meter annually, the estimate for power costs for this building would be as follows:

700 sq. meter x $1.00 = $700.00 annually

Other area types are calculated in the same manner.

2.5.6 Estimating Fuel Costs for Pumping

This section of the guide will give the technique used to estimate the cost of the fuel used to drive water pump sets. Because a substantial majority of such units use diesel fuel, only this type of fuel will be considered. The estimating method used is similar to that used for electrically driven units. The pertinent formula to calculate the energy to pump water in kwh/day is as follows:

$$\text{Energy(kwh/day)} = \frac{Q \times H \times 9.8\text{m/sec}^2 \times 1{,}000\text{kg/m}^3}{E \times 3{,}600\text{sec/hr} \times 1{,}000\text{w/kw}}$$

where Q = output/day, m^3/day

H = total pumping head, m

E = pumping system efficiency

If E = pumping system efficiency (pump/transmission/energy), then energy is "fuel energy" required, and

$$\text{Fuel requirement(liter/day)} = \frac{\text{Energy(kwh/day)}}{\text{Fuel energy capacity (kwh/liter)}}$$

For diesel fuel, Fuel energy capacity = 10.8 kwh/liter

The system efficiency will depend of the type of diesel system (mechanical or electrical), loading factors, that is, percent of full load, and equipment characteristics. The efficiency can, however, be estimated as follows:

Mechanical Drive Diesel Systems

Component	Efficiency-%
Engine	20 - 30
Transmission	90 - 100
Pump	50 - 70

pumping system efficiency = 9* - 21

* Calculated by: (.20 x .90 x .50) x 100; other system efficiencies similarly estimated.

Electrical Diesel Systems

Engine	20 - 30
Generator	70 - 80
Transmission	90 - 100
Motor	70 - 80
Pump	50 - 70

pumping system efficiency = 4.4 - 13.4

If the type of diesel equipment that will be used in the project is known, the supplier can provide specific data. If equipment selection has not been made, a typical average figure used for overall system efficiency is 10 percent.

EXAMPLE

If the required output for the system is 240 m^3/day and the pumping head is 75 m, then

$$\text{Energy} = \frac{240m^3/day \times 75m \times 9.8m/sec^2 \times 1,000kg/m^3}{.10 \times 3600sec/hr \times 1000w/kw}$$

Energy = 490 kwh/day, and

$$\text{fuel requirement} = \frac{490kwh/day}{10.8kwh/l}$$

Fuel requirement = 45.4 liters/day

Finally, if diesel fuel sells for $.30/liter,

the daily fuel costs are 45.4 l/day x $.30/l = $13.62.

Thus, for a water project using a diesel water pumping set with an output of 240 m^3/day, the cost of fuel to operate the unit would be between $13.00 and $14.00 per day.

2.5.7 Estimating Communications Costs

In this manual, "communications" refers to the provision for telephone service. Other means of communications, such as telex, are not considered. To estimate the cost of telephone service, the planner will need to analyze the way the water board or authority uses its phone system and to obtain a rate schedule from the phone company. If, for example, the water utility makes only local calls and the telephone company charges a monthly fee for each phone and permits an unlimited number of local calls, then annual telephone costs are easily determined by:

estimated number of phones x monthly fee per phone x 12.

If, however, the water utility is likely to make numerous long-distance calls, their contribution to total annual phone costs will be quite significant. Because only larger or national water authorities are likely to have substantial phone service, the direct, and easiest approach for the planner to take is to require that the water utility estimate the number of phones they will need, and the pattern of their use with respect to long-distance calls. For an established utility, records of previous phone usage will provide useful information for making this estimate.

The form shown in Figure 6 could be used to collect the required information. The data on number of phones and long distance calls would be provided by the utility while the estimator would obtain the rate information from the phone company and calculate the total annual cost of communication.

1. Number of telephones to be installed ___

   Cost/unit/month x ___

   monthly service charge = ___

2. Long-distance calls*

From	To	Number of Minutes Per Month	Charges Per Minute	Cost
___	___	___	___	___
___	___	___	___	___
___	___	___	___	___
___	___	___	___	___

   Long Distance cost/mo = ___

   * List only if number of minutes equals or exceeds ten.

3. Total cost/yr = [service + long distance] x 12 = ___

   + 10% contingency ___

   Annual Cost of Telephone Service = ___

Figure 6. Telephone Survey Form

2.6 Transport

Estimates of transport costs are based on an assessment of transport needs and unit travel costs for vehicles.

2.6.1 Estimating Transport Needs

The first step in estimating transport costs is to identify the tasks which require transport. One must consider all aspects of operating and maintaining water systems, such as:

Transport of personnel for:

- preventive maintenance;
- repairs of pumps, motors, engines, piping, and tanks;
- notification of problems to district or regional repair crews;
- cleaning of intake structures;
- water meter reading;
- leak detection programs;
- water quality monitoring;
- attending meetings, training sessions, etc.

Transport of materials/supplies, such as

- fuel;
- chemicals;
- parts/supplies to a site for repair work;
- parts/supplies to a (regional) storage facility.

The second step will be to define the transport needs for each of these tasks, including:

- Type of vehicle required (sedan, pickup, five-ton truck, or public transport)
- Round-trip distance to be traveled (kms or miles)
- Frequency of trips (by season, if relevant).

The geography of the water systems involved will greatly influence the length and frequency of the trips. A water supply agency which is operating many rural water systems in dispersed communities will be faced with the cost of a number of long trips. Every effort should be made to minimize the number of trips as well as the total distance traveled. To minimize costs, different activities and destinations can be combined into circuit routes. An urban utility may also have many transport needs, but typically they will be shorter, more frequent trips, often for specific purposes.

Past experience, water agency records, and sound engineering judgment will be the basis for estimating the foregoing parameters. A clear and detailed O&M plan will permit reliable estimates of transport needs and will promote cost-effective operation and maintenance. Thus, task by task, the total annual travel distance for each activity can be tabulated. Then, from the same data, estimates of the total annual travel distance for each type of vehicle can be computed.

EXAMPLE

Consider the hypothetical case of a district-level rural water supply agency operating and maintaining 15 dispersed remote rural water systems. The typical system consists of a drilled well, diesel pump, an elevated storage tank, and distribution to several standpipes. A paid caretaker lives at each site, and he/she is supported by a district-level maintenance/parts/workshop facility.

The O&M plan calls for one planned visit per month by a district supervisor to each site to:

- Review operations with system caretaker;
- Inspect the caretaker's log;
- Assist the caretaker to perform minor repairs;
- Perform water quality tests;
- Deliver wages and small quantities of parts, chemicals, and supplies.

The average distance from the district-level office to the sites is 100 km. The geographical dispersal is such that, typically, the supervisor can visit three sites in a single loop trip over a two-day period. The average length of such trips is 200 km. Generally a diesel "Land Rover" type pick-up vehicle is used on rural roads in this district.

Fuel deliveries are made with a larger five-ton truck, which can carry approximately 18 barrels of diesel fuel. Each site needs, coincidentally, about 18 barrels of fuel annually. Different systems have varying fuel delivery schedules, but typically a fuel delivery trip will carry six barrels of fuel to each of three sites, and cover 200 km in one day. Thus, this same route will have to be covered three times annually. The obvious alternative is to deliver all 18 barrels to one site in one trip. Storage of a year's worth of fuel at a site is, however, undesirable.

In addition to these planned visits, additional visits for repairs will have to be planned. Experience with similar systems in other districts has shown that while these do not happen on any regular basis, the average works out to be one unscheduled visit annually. The average distance is then 200 km, and a Land Rover can be used to carry tools, tripod, pipe, and so forth.

Thus the prorated transport needs for one system may be summarized as follows:

Task	Vehicle	Trip Frequency	Trip Distance	Total Distance
System Check	Land Rover	12 per year	200 per 3	800 km
Fuel Delivery	Five-ton truck	3 per year	200 per 3	200 km
Repairs	Land Rover	1 per year	200	200 km

Thus, for each system, estimate annual transport costs on the basis of a Land Rover for 1,000 km, and a five-ton truck for 200 km.

2.6.2 Estimating Transport Costs

Once the transport needs are well defined, the transport costs per kilometer (or mile) must be estimated, so that finally, the total transport cost can be computed. The main components to be included in estimating unit transport costs are as follows:

- Fuel;
- Lubricants;
- Tires;

- Insurance, tags, fees, and tolls;
- Maintenance or repair labor;
- Maintenance or repair parts and supplies;
- Driver labor;
- Amortized capital cost of vehicles.

These parameters must be estimated for each major type of vehicle, that is, sedan, pickup, five-ton truck, and so forth.

The estimator should first determine whether there are mileage rates already being used by the water agency. It is likely that some estimates of transport costs for different types of vehicles have been made by the agency in question. As an example, some unit transport costs, developed by water supply agencies in Botswana and India are given in Table 12 on the following page. While costs generally increase with larger vehicles, considerable variability exists. Complete details of the derivation of unit transport costs for India are provided in Table 15. In some cases, available mileage rates may not include driver labor or amortized capital cost. If this is the case, these should be added into the estimate.

If unit transport costs are obtained from other local agencies, general studies or reports, the basis of the calculations should be examined, as units costs will vary greatly, depending on the anticipated use, annual distance traveled, road conditions, and other factors involved in the derivation of the rates. If recent, reliable, unit transport rates can be found then the estimation process becomes simple. The total cost will be, simply, the total distance times the unit cost. The sum of the totals for each vehicle type will yield a total transport cost.

In many cases involving rural water supply, personnel will use public transport during the course of their duties. For example, the operator of a village system, having no vehicle or bicycle, may take a public bus into district headquarters to summon repair assistance. If agency policy is that he or she should be reimbursed for such expenses then these must also be added into the tabulation.

Another potential cost item is travel allowances. Many government personnel are given a standard amount for days traveling and working away from their home base. The rate may vary depending on the location or rank of the staff member. These costs must be added into the calculation. These costs can be treated as labor costs or transport costs, as long as they are put in. The calculation of these costs will be based on an estimate of the total travel days and information on agency travel allowance policies and rates.

If recent or reliable unit transport costs are unavailable, new values can be derived, as described in Section 2.6.3, below.

Table 12

Unit Transport Costs

Country	Date	Vehicle	Unit Cost (local)	Unit Cost (US$)	Unit Cost (1986 US$)
Botswana	1986	4-wheel drive pickup	P0.47/km	$ 0.28/km	$ 0.28/km
Botswana	1984	1.5-ton truck	P0.63/km	$ 0.38/km	$ 0.37/km
Botswana	1984	5.0-ton truck	P0.92/km	$ 0.55/km	$ 0.53/km
Botswana	1986	7.0-ton truck	P1.00/km	$ 0.60/km	$ 0.60/km
Botswana	1986	10-ton truck	P1.75/km	$ 1.05/km	$ 1.05/km
India	1972	Diesel pickup	Rs 1.28/km	$ 0.17/km	$ 0.43/km
India	1972	Leyland truck	Rs 1.41/km	$ 0.19/km	$ 0.48/km

Note: Conversion of costs into US$ is based on exchange rate during year of estimate. Conversion to 1986 dollars is based on U.S. Producer Price Index (all commodities).

EXAMPLE

We can now complete the example above. A study of operating costs of local water agency vehicles has shown that unit transport costs are as follows:

Land Rover:	$0.40/km
Five-ton truck:	$0.75/km

Thus annual transport costs may be calculated as follows:

Vehicle	Total Distance	Unit Cost	Annual Cost
Land Rover	1,000 km	$0.40	$400.00
Five-ton truck	200 km	$0.75	$150.00
	Total Annual Cost =		$550.00

2.6.3 Detailed Estimates of Unit Transport Costs

A detailed estimate of transport cost per unit distance must include all the items listed in Section 2.6.2 above, which are repeated again here for convenience:

- Fuel;
- Lubricants oil;
- Tires;
- Insurance, tags, fees, tolls;
- Maintenance/repair labor;
- Maintenance/repair parts and supplies;
- Driver Labor;
- Amortized capital cost of vehicles.

Some of these costs are fixed annual costs, such as insurance, and some vary with the distance traveled, such as fuel. Thus, a complete computation must be made, using estimated values for annual distance traveled, fuel and oil consumption, tire cost and life, and initial vehicle cost. If amortized capital costs are to be included, we will have to make additional assumptions on vehicle life and discount rate.

Tables 13 and 14 show sample detailed calculation procedures and examples. Table 15 shows a slightly different approach used for one project in India.

This type of tabulation can readily give an estimate of cost per mile or kilometer. Unfortunately, these unit costs are rather sensitive to several input parameters, especially annual distance traveled, which is often hard to estimate. This calculation is also moderately sensitive to driver salary, fuel cost and vehicle cost, but these factors are often easier to estimate precisely.

In the end, these calculations should be viewed as approximate and treated with appropriate prudence.

As these estimating procedures were being finalized, the World Bank published a detailed study of vehicle operating costs, as a part of its efforts on highway design. The book, Vehicle Operating Costs: Evidence from Developing Countries, has detailed data from Kenya, Brazil, the Caribbean, and India. The effects of vehicle speed and road roughness are examined in detail. The data confirm the rough order of magnitude of vehicle costs cited here. The reader who wishes more precision in the area of vehicle operating costs will find this book very useful.

Table 13

Transport Cost Estimation - Cost per Kilometer

INPUTS		CALCULATIONS	RESULTS
Vehicle.	Sedan		
Annual distance traveled (km).	32000		
			$/km
Fuel price (US$ / liter)	$0.40	1) FUEL	
Kilometers/liter·	10	Fuel price ($/liter) / Kilometers/liter = $/km	$0 040
or, litres / 100 kilometers	10 0		
Oil change volume (liters)	5	2) OIL	
Oil price (US$ / liter)	$2.00	Oil change vol.(qt) * (Annual distance / Km / oil change) * (Oil price ($/l) / Annual distance) = $/km	$0 001
Km between oil changes	8000		
Number of tires·	4	3) TIRES	
Tire cost·	$40 00	Number of tires * (Annual distance / Km / tire change) * (Tire cost ($ ea) / Annual distance) = $/km	$0 004
Km between tire changes	40000		
Insurance, fees, tags, tolls:	$300.00	4) INSURANCE, TAGS, FEES, TOLLS	
		Annual insurance, tags, fees, tolls / Annual distance = $/km	$0 009
Annual maintenance/repair rate:	4.0%	5) MAINTENANCE AND REPAIRS	
Vehicle initial cost.	$10,000	Maintenance/repair rate * Vehicle cost / Annual distance = $/km	$0 013
		6) SUBTOTAL	$0 067
Annual driver salary.	$2,000	7) DRIVER LABOR	
		Annual driver salary / Annual distance = $/km	$0 063
Vehicle life·	10	8) AMORTIZED CAPITAL	
Discount rate:	10.0%	Initial vehicle cost * Capital recovery factor / Annual distance = $/km	$0 051
		Capital recovery factor = 0.1627	
		9) TOTAL	$0 180

Table 14

Transport Cost Estimation - Cost per Kilometer

INPUTS		CALCULATIONS	RESULTS
Vehicle·	Pickup		
Annual distance traveled (km)	32000		
Fuel price (US$ / liter)	$0.32	1) FUEL	$/km
Kilometers/liter	8		
or, litres / 100 kilometers	12.5	Fuel price ($/liter) / Kilometers/liter = $/km	$0 040
Oil change volume (liters):	5	2) OIL	
Oil price (US$ / liter)	$2 00		
Km between oil changes	8000	$\text{Oil change vol (qt)} * \frac{\text{Annual distance}}{\text{Km / oil change}} * \frac{\text{Oil price (\$/l)}}{\text{Annual distance}} = \text{\$/km}$	$0 001
Number of tires	4	3) TIRES	
Tire cost.	$50.00		
Km between tire changes·	30000	$\text{Number of tires} * \frac{\text{Annual distance}}{\text{Km / tire change}} * \frac{\text{Tire cost (\$ ea)}}{\text{Annual distance}} = \text{\$/km}$	$0 007
Insurance, fees, tags, tolls.	$300.00	4) INSURANCE, TAGS, FEES, TOLLS	
		Annual insurance, tags, fees, tolls / Annual distance = $/km	$0 009
Annual maintenance/repair rate:	5 0%	5) MAINTENANCE AND REPAIRS	
Vehicle initial cost	$15,000		
		Maintenance/repair rate * Vehicle cost / Annual distance = $/km	$0 023
		6) SUBTOTAL	$0 080
Annual driver salary	$2,000	7) DRIVER LABOR	
		Annual driver salary / Annual distance = $/km	$0 063
Vehicle life	8	8) AMORTIZED CAPITAL	
Discount rate	10.0%		
		Initial vehicle cost * Capital recovery factor / Annual distance = $/km	$0 088
		Capital recovery factor = 0.1874	
		9) TOTAL	$0 231

Table 15

Running Costs for Vehicles in India (Rupees), 1972

VEHICLE TYPE =	BEDFORD DIESEL PICKUP	LEYLAND TRUCK
INITIAL VEHICLE COST =	27465	53107
VEHICLE LIFE =	125000	250000
ANNUAL DISTANCE (km) =	25000	20830
	12 MONTHS / YEAR	10 MONTHS / YEAR

COST ITEM	USE RATE	UNIT COST	MONTHLY COST	ANNUAL COST	COST / KM	USE RATE	UNIT COST	MONTHLY COST	ANNUAL COST	COST / KM
1) LABOR										
2 Drivers @		252.52	505.04				306.00	612 00		
Leave reserve @ 25%	25.0%	63.13	126.26			25.0%	76.50	153.00		
Travel allowance		30.00	60.00				30.00	60.00		
Labor subtotal			691.30	8295.60	0.332			825.00	8250.00	0 396
2) FUEL & LUBRICANTS										
Fuel km/l =	3	0.92		7666.67		3	0.92	638 79	6387 87	
Mobil oil km/l =	150	1.74		290.00		100	1.74	36.24	362.44	
Gear oil km/l =	200	1.31		163.75		400	1.31	6 82	68 22	
Brake oil km/l =	1500	6.95		115.83		2000	6.95	7.24	72 38	
Grease kg/week =	0 5	2.05		53.30		0.9	2.05		95 94	
Fuel & Lube subtotal				8289.55	0.332				6986 85	0 335
3) TIRE REPLACEMENT										
Tire set every 40000 km	40000	3032.00			0.076	30000	3496.00			0 117
4) DEPRECIATION										
Initial cost/life					0.220					0 212
5) RUNNING REPAIRS										
Repairs @ 60% of depreciation	60.0%				0.132	70.0%				0.149
6) MAJOR REPAIRS AND OVERHAULS										
Repairs @ 80% of depreciation	80.0%				0.176	80.0%				0 170
7) MISCELLANEOUS SUPPLIES / FEES				330.00	0.013			62.50	625 00	0 030
TOTAL					1.280					1 409

SOURCE. COST ESTIMATION OF WATER RESOURCE PROJECTS, UN-ESCAP, 1972

NOTE: Exchange rate approximately 7 5 Rs per US$

2.7 Private Contractors

2.7.1 Background

Private contractors are frequently used to service the equipment and structures that compromise a water system. They may be employed to repair or replace damaged pipe for a gravity-fed village water system, replace the below-ground components of a handpump or for a large urban system, repair an electric motor or rebuild a water pump. Types of private contractors range from village artisans who are paid directly by a community for repair service to private workshops which perform maintenance work under contract to a water agency. For purposes of this manual, any individual or firm that is reimbursed for providing specific O&M services for a water system is considered a private contractor.

2.7.2 Estimating the Use of Private Contractors

The first step taken to estimate the cost of using contractors to service water systems is to establish which (if any) maintenance tasks will be performed by private contractors.

For small community water systems involving handpumps or spring catchments, the number of tasks that can be contracted to the private sector is limited. For systems using handpumps, the repair or replacement of below-ground parts such as leathers or valves is frequently performed by the private sector. For gravity fed systems, maintenance tasks for private contractors include repairing major damage to the spring catchment or dam and replacing main distribution line pipe.

For larger water systems, contractors are commonly used for:

- supplementary labor for emergencies, repairs, etc.;
- scheduled or unscheduled repairs or maintenance;
- grounds-keeping and janitorial services;
- laboratory services, including water quality testing;
- legal or accounting services;
- maintenance of office equipment, copiers, computers, etc.

Some or all of these costs should be included in the estimate depending on the case and the type of estimate being performed.

As contract tasks are identified, the frequency of occurrence must also be determined. It is helpful to differentiate between those maintenance tasks which occur on a regular basis and those which are unforeseen. Examples of the former are changing the leathers on a handpump or the brushes on an electric motor. Examples of the latter include the repair of damaged water pipes or motor rewindings. A better estimate can be made of the cost of the regularly occurring tasks than for the unforeseen ones. A rule of thumb often used is to account for the occurrence of one major repair job by contract, considering the type of water system involved, and use this for unforeseen repair work.

2.7.3 Estimating the Cost of Private Contractors

The tabulation of cost of contractors is found by multiplying the cost of each task (scheduled or not) by the frequency and adding up all the products. The cost per task will have to be based on local research.

EXAMPLE

For a typical handpump, maintained by a local contractor, the cost could be estimated at:

Task	Annual Frequency	Unit Cost	Total
Replace leather cups	2	$30	$60
Repair pump handle	1	10	10
Unforeseen repair	1	30	30
			$100

2.8 Other Costs

There are several additional costs that the estimator may wish to include.

One additional "cost" that is often included in O&M estimates is contingency. No estimate can be considered perfectly accurate, so many estimators put an additional amount to cover unforeseen costs, inflation, or other unexpected cost items. This is common in budgeting, to ensure that enough funds are allocated. Typically, estimators add 5 or 10 percent of the total estimated O&M costs. This is often a good idea, especially in budgeting. It is always difficult to estimate costs accurately, and contingency ensures that the estimate is not too low. There could be cases, however, when an estimator may wish to leave contingency out. For example, if detailed O&M cost estimates are being prepared for two engineering designs being compared, contingency is unnecessary.

The second additional cost is administrative personnel. In some cases administrative personnel are clearly linked to the operation of a system, and sometimes not. For instance, in a village water supply situation, there may be no administrative personnel at the site of a water system whose costs are being estimated, but at a district office there may be supervisors or managers who spend part of their time dealing with the system at hand. The cost of these personnel should be included in the estimate using the pro-rating method described in Section 2.2.2. In addition the examples in Chapter 4 examine various methods of pro-rating administrative costs.

Overheads are another cost, similar to administrative costs, which can be included. Many government agencies will have standard overhead rates on labor or direct expenses, to account for indirect costs such as administration, employee benefits, etc. If definite overhead figures are in use by the agency involved they should probably be included in the estimate. However, the estimator should be aware of what costs are included in these overheads, so no duplication occurs.

The inclusion of administrative or overhead costs must be decided on a case-by-case basis, depending on the objective of the cost estimation procedure. If tabulations are being made to design tariffs and full cost recovery is the goal, then of course they must be included. If, on the other hand, a sample calculation is being made to see if villagers can support routine maintenance costs at the site, then probably they are not necessary. Also, if cost estimates are being prepared to compare two or more water systems or engineering designs and these costs are identical, then there is no reason to include them.

Depreciation is another item sometimes seen in O&M cost estimates. Depreciation is an accounting method to allow for the "cost" of deteriorating equipment and facilities. However, no real cash flow is associated with depreciation. The authors do not recommend the use of depreciation allowances in these procedures. They prefer that the cost of maintenance and replacements be estimated and included.

Chapter 3

COST ESTIMATING WORKSHEETS

The following forms have been prepared for project planners to use, as a reminder of the elements that need to be included in an estimate of O&M costs, and as a convenient way of recording and manipulating cost data.

They are based on the methodology developed in Chapter 2 and have been used in the examples in Chapter 4 and in the field test work. The authors recognize that no form is perfect for all situations. In some cases, a much smaller, more compact form will be needed; in other cases, the forms do not allow enough room to put in all the data. No one form can be correct for use all over the world, given the wide range of water systems. If necessary, estimators can perform preliminary calculations on separate sheets and insert the results into these forms. This approach was needed in Ivory Coast. Nonetheless, we feel these forms are comprehensive and will aid in the performance of a complete estimate. As always, the authors invite feedback from readers on the use of these forms.

The forms displayed in Figures 7 to 13 are designed to record the data and perform the necessary calculations for each individual cost item. They correspond to the elements discussed in sections 2.2 through 2.8. Figure 14 is the form for summarizing the cost data for each of the elements.

WASH O&M COST ESTIMATING HANDBOOK	PAGE 1 LABOR ESTIMATE
SITE: ______	AGENCY: ______
POPULATION: ______	PREPARED BY: ______
ANNUAL WATER PRODUCTION, m3: ______	DATE: ______

1) DIRECT LABOR - REGULAR TIME

A) MANAGEMENT/SUPERVISION

Classification	No. in Class	Average Monthly Wage	% Time	Total

B) SKILLED LABOR

Classification	No. in Class	Average Monthly Wage	% Time	Total

C) UNSKILLED LABOR

Classification	No. in Class	Average Monthly Wage	% Time	Total

MONTHLY SUBTOTAL ______

ANNUAL SUBTOTAL ______

Figure 7. Labor Estimate Form

WASH O&M COST ESTIMATING HANDBOOK	PAGE 3	MATERIALS ESTIMATE

SITE: ______________________ AGENCY: ______________________

POPULATION: ______________________ PREPARED BY: ______________________

ANNUAL WATER PRODUCTION, m3: ______________________ DATE: ______________________

1) SUPPLIES

Item	Unit	Annual Quantity	Unit Cost	Total
			SUBTOTAL	

2) PARTS

Item	Unit	Annual Quantity	Unit Cost	Total
			SUBTOTAL	

3) TOOLS

Item	Unit	Annual Quantity	Unit Cost	Total
			SUBTOTAL	

TOTAL MATERIALS ESTIMATE = ______

Figure 8. Labor Estimate Form, page 2

WASH O&M COST ESTIMATING HANDBOOK	PAGE 5 UTILITIES ESTIMATE

SITE: ______________________ AGENCY: ______________

POPULATION: ______________________ PREPARED BY: ______________

ANNUAL WATER PRODUCTION, m3: ______________ DATE: ______________

1) ELECTRIC POWER

A) DEMAND CHARGE

Peak Power (KW)	Demand Charge / KW	Annual Demand Charge

B) ENERGY CHARGE

Equipment	# of units	Rated Power (Hp)	Power Draw (kw)	Daily Operating Period (hr)	Average Daily Energy Consumption (kwh)	Days Use per Year	Energy Cost/kwh	Total Cost
	a		b	c	d=b*c	e	f	g=a*d*e*f

ELECTRIC ENERGY SUBTOTAL ______

2) FUEL

Equipment	# of units	Power (Hp)	Type of Fuel Used	Daily Operating Period (hr)	Average Hourly Fuel Consumption	Days Use per Year	Unit Fuel Cost	Total Cost
	a			b	c	d	e	f=a*b*c*d*e

FUEL SUBTOTAL ______

TOTAL UTILITIES ESTIMATE = ______

Figure 9. Materials Estimate Form

SITE: ______________________ AGENCY: ______________________

POPULATION: ______________________ PREPARED BY: ______________________

ANNUAL WATER PRODUCTION, m3: ______________________ DATE: ______________________

1) PRIVATE CONTRACTORS

A) SCHEDULED

Task / Service Performed	Annual Frequency of Service/Contract	Service / Contract Cost	Total
		ANNUAL SUBTOTAL	

B) UNSCHEDULED

Task / Service Performed	Frequency of Service	Service / Contract Cost	Total
		ANNUAL SUBTOTAL	

TOTAL PRIVATE CONTRACTOR ESTIMATE = __________

2) OTHER COSTS

TOTAL OTHER COSTS ESTIMATE = __________

Figure 10. Chemicals Estimate Form

WASH O&M COST ESTIMATING HANDBOOK	PAGE 2 LABOR ESTIMATE
SITE: ______	AGENCY: ______
POPULATION: ______	PREPARED BY: ______
ANNUAL WATER PRODUCTION, m3: ______	DATE: ______

2) DIRECT LABOR - OVERTIME

Classification	No. in Class.	Average Overtime Hrs.	Hourly Rate	% Time	Total
				MONTHLY SUBTOTAL	
				ANNUAL SUBTOTAL	

3) ADMINISTRATION

Classification	No. in Class.	Average Monthly Wage	% Time	Total
			MONTHLY SUBTOTAL	
			ANNUAL SUBTOTAL	

TOTAL LABOR ESTIMATE (1+2+3) = ______

Figure 11. Utilities Estimate Form

WASH O&M COST ESTIMATING HANDBOOK	PAGE 4 CHEMICALS ESTIMATE
SITE:	AGENCY:
POPULATION:	PREPARED BY:
ANNUAL WATER PRODUCTION, m3:	DATE:

CHEMICAL CONSUMPTION

Chemical Used	Desired Dosage (mg/l)	Commercial Strength, %	Required Dosage (mg/l)	Water Production (m3/day)	Net Consumption (kg/day)
	a	b	c=a/b	d	e=c*d/1000

CHEMICAL COST

Chemical Used	Net Consumption, kg/day	Chemical Unit	No. of Units/yr	Unit Cost	Total Cost
				ANNUAL SUBTOTAL	

TOTAL CHEMICALS ESTIMATE = ____________

Figure 12. Transport Estimate Form

SITE: ______________________ AGENCY: ______________

POPULATION: ______________________ PREPARED BY: ______________

ANNUAL WATER PRODUCTION, m3: ______________ DATE: ______________

1) PRIVATE CONTRACTORS

A) SCHEDULED

Task / Service Performed	Annual Frequency of Service/Contract	Service / Contract Cost	Total
		ANNUAL SUBTOTAL	

B) UNSCHEDULED

Task / Service Performed	Frequency of Service	Service / Contract Cost	Total
		ANNUAL SUBTOTAL	

TOTAL PRIVATE CONTRACTOR ESTIMATE = ________

2) OTHER COSTS

TOTAL OTHER COSTS ESTIMATE = ________

Figure 13. Contractors/Other Costs

WASH O&M COST ESTIMATING HANDBOOK — SUMMARY SHEET

SITE: ____________________ AGENCY: ____________________

POPULATION: ____________________ PREPARED BY: ____________________

ANNUAL WATER PRODUCTION, m3: ____________________ DATE: ____________________

SUMMARY OF ANNUAL OPERATIONS AND MAINTENANCE COST

		Annual O&M Cost	Percent of Total
1) LABOR			
- Regular	____		
- Overtime	____		
- Administration	____		
SUBTOTAL	____	____	____
2) MATERIALS			
- Supplies	____		
- Parts	____		
- Tools	____		
SUBTOTAL	____	____	____
3) CHEMICALS		____	____
4) UTILITIES			
- Electric Power	____		
- Fuel	____		
SUBTOTAL	____	____	____
5) TRANSPORT		____	____
6) PRIVATE CONTRACTORS		____	____
7) OTHER		____	____
TOTAL O&M COST		____	____
TOTAL O&M COST PER CAPITA		____	
TOTAL O&M COST PER m3		____	

Figure 14. Summary Sheet

Chapter 4

EXAMPLES

4.1 Rural Water Project Example

4.1.1 The Setting

In Botswana, many small rural water supply systems serve small villages with 300 to 2,000 people. Most systems include a borehole (well), diesel engine/pump, elevated water tank and a small reticulation system serving several standpipes. Our example will consider three "model" water systems, described in Table 16. This example assumes that new systems are being installed in a district without such systems, but that costs in the new region will be similar to costs in other districts.

Table 16

General Information on Small Water Systems
(Botswana, 1984)

Village		A	B	C
Population		300	1,000	1,800
Per Capita Consumption	(lpcd)	20	20	20
Consumption				
Total Household Use	(m^3/d)	6	20	36
School	"	2	5	7
Clinic	"	-	5	7
Total	"	8	30	50
Number of Boreholes	(nos)	1	1	2
Reticulation System	(km)	-	6	9
Storage Capacity	(m^3)	9	45	65
Standpipes	(nos)	1	5	9
Yield of Each Borehole	(m^3/h)	3	8	8
Total Pump Capacity	"	2	5	10
Water Table (below ground)	(m)	60	60	60
Level Different Borehole-Tank	"	8	20	20
Friction Losses	"	2	20	20
Total Pumping Head	"	70	100	100

A variety of personnel and agencies are involved in the O&M of these systems. An on-site operator runs the engine, keeps logs and does simple maintenance on the engine/pump and civil works. A district-level office of the Water Department supports these systems and their operators. An Officer-in-Charge, based at the District Office, supervises the operators through regular visits. "Mechanical crews" operate out of District Headquarters and undertake major service on the engine twice a year and on the pump once a year. These same crews respond to problems or breakdowns with the pumping system. "Civil crews", also operating out of District Headquarters, perform repairs on tanks, piping, and standpipes. The District Headquarters houses a workshop, store of spare parts, and administrative offices.

The calculations are based on water supply planning reports from Botswana, for 1984. The values have been extracted from the report "Operation and Maintenance of Village Water Supplies in Botswana--Recommendations for Improvement" by R. White and G. Melchert, a report to SIDA, the Swedish Donor Agency, which has been working on water supply projects with the Government of Botswana for many years. In a couple of instances we have had to "fill in the gaps" in their presentation of the estimation procedure. For instance, in one case, they included the total cost and the unit cost of an item but not the quantity. By calculation, we have surmised the quantity and presented it as a part of the estimate calculation.

It should also be pointed out that field work by WASH in Botswana, since 1984, has collected more data on the actual water system maintenance performed, and actual engine breakdown rates, and so forth. Such data are not in a form to be included here, but, the data does show a lower incidence of engine repair, and different vehicle unit transport costs than those estimated by White and Melchert. We have elected to present the original estimate by White and Melchert, in its entirety, because it provides a good, complete example of the cost estimation procedure. The following pages present a discussion of the costs involved in the estimate. We have also written these costs onto the forms developed in Chapter 3, and the completed forms are included here.

The objective of the cost estimation exercise below is to arrive at a typical O&M cost for the three systems. Estimates of the "normal" or "typical" operating costs of the three types of systems are desired for budget purposes. Major replacement costs are not to be included in this calculation as such capital expenses, like initial construction costs, are funded out of a different government budget from O&M costs. However, in Section 4.1.10 all three types of costs—initial capital, replacement, and O&M cost—will be reviewed.

4.1.2 Labor

For each system, there is a regular operator who works full time, five days per week and a relief operator to cover weekends, vacation and sick periods for the regular operator. The daily wage is P6 (P1 = US $0.60). Experience has shown that accounting for 400 days of wages annually will be sufficient for labor costs for both operators. Thus, the total is P2400 annually. It is important to note that operator cost is completely independent of system size.

Labor performed by the mechanical and civil crews must also be accounted for. Some records are available for the cost of labor and parts for various maintenance/repair jobs. These records combine these two line items into one cost figure, but these data are used because they are the most reliable available. Because the elements of labor and parts are combined, and to illustrate the form for contract/labor services, the work of the mechanical and civil crews will be treated as if it were performed by contract. See Section 4.1.7 and Table 20. Note that repair crew transport costs are not included; but this will be added in later, in the discussion of transport costs.

Headquarters costs must be spread out among the systems in a district. If a given district had, for example, 40 identical systems of the Type "B" that has been discussed (one borehole each) headquarters costs could be prorated across these 40 systems equally, assigning a cost of P1,750 per system. It is unlikely, however, that all systems will be the same size. Larger systems deserve a bigger share of the administrative costs and smaller systems a lesser share. One method of proration is by population, i.e., determining headquarters-cost-per-person as a basis for estimating individual system costs.

A better approach would be to divide the costs according to the magnitude of other recurrent costs. This approach may seem confusing at first, but it is logical that systems which experience low direct O&M costs, should have a small portion of the administrative and management costs. Conversely, systems with high recurrent costs should have a large prorated share of the total headquarters costs.

Note also that these headquarters costs, which are mostly supervisory labor, can be considered a labor cost, or "other cost." Their place in the calculation does not matter, as long as they are included.

4.1.3 Materials

1. Spare Parts

The cost of parts used in repair/maintenance work has been included in the list of the cost of various repair/maintenance tasks (see Table 20).

2. Supplies

Several consumable items are used in O&M of engine based pumping systems. The main consumable item is oil and oil filters, see Table 17. Oil consumption is derived from the assumed operating plan that oil is changed once a month, for engines run four to six hours per day. The total oil consumed per year is found from the engine crankcase volume multiplied by the number of changes per year plus an additional 10 percent to 20 percent for waste and spillage.

3. Replacements

Future replacement costs per se have not been included here, as the objective of this calculation is to estimate "normal" annual costs.

Table 17

Annual Material Costs

Village	A	B	C
Lubricating Oil			
- Crankcase volume (liters)	1.25	5	5 x 2
- Volume consumed (liters/yr)	20	70	140
- Oil price (P/liter)	P4	P4	P4
- Net cost	P80	P280	P560
Oil Filters			
- Number of filters used/yr	12	12	24
- Price of filters	P5	P5	P5
- Net cost	P60	P60	P120
Engine/Pump Belts			
- Annual belt change cost (P)	P50	P50	P100
Total Material Costs	P190	P390	P780

4.1.4 Chemicals

No water treatment is currently used on these small systems which pump directly from groundwater. Thus, there are no direct chemical costs.

4.1.5 Utilities

The single "utility" expense in these systems is the diesel fuel for the engines. Table 18 shows calculations for the fuel consumption and cost at the three different size villages.

Table 18

Fuel Cost Calculation

Village	A	B	C
Total Pumping Head (m)	70	100	100
Pump Capacity (m^3/hr)	2	5	10
Net Power Required (kW) (based on pump eff. = 50%)	1.02	3.65	7.31
Engine (Lister Model #)	LT 1 (4 hp)	8/1 (6 hp)	8/1 x 2 (6 hp) x 2
Fuel Consumption (liters/hr)	0.36	1.14	1.14 x 2
Water Output (m^3/day)	8	30	50
Operating Hours/day	4	6	5
Fuel Consumption (liters/month)	43.2	205.2	342.0
(liters/yr)	518.4	2,462	4,104
Fuel Consumption, with allowance for spillage & pilfering (10%) (liters/yr)	570	2,700	4,500
Fuel Price (ex depo) (P/liter)	0.6	0.6	0.6
Total Fuel Cost	P350	P1,620	P2,700
Total Fuel Cost (P/m^3)	P0.12	P0.15	P0.15
Total Fuel Cost (t/m^3/m head*)	P0.17	P0.15	P0.15
Total Fuel Cost P/Person	P1.2	P1.6	P1.5

* 100 t = 1 Pula

4.1.6 Transport Costs

Transport costs are relatively large in this case of a number of small dispersed water systems. Three major transport needs have been identified including:

- Fuel distribution/system checks;
- Maintenance and repairs;
- General purpose.

The frequency of trips, vehicles to be used, and distances have been determined from records of previously installed water systems. For visits to the "A" type systems for fuel distribution/system checks, the distance traveled annually is expected to be less than larger systems because several small systems can be visited in a single trip. These data and unit cost of transport for different trucks is displayed in Table 19.

Table 19

Transport Costs

Village	A	B	C
Fuel Distribution/System Check			
- Trip frequency	12/yr	12/yr	12/yr
- Distance per year (km)	1200	2400	2400
- Vehicle used	5 ton	5 ton	5 ton
- Cost per km	P0.92	P0.92	P0.92
- Total cost	P1,100	P2,200	P2,200
Maintenance and Repairs			
- Trip frequency	5/yr	10/yr	15/yr
- Distance per year (km)	1000	2000	3000
- Vehicle used	1.5 ton	1.5 ton	1.5 ton
- Cost per km	P0.63	P0.63	P0.63
- Total cost	P630	P1260	P1890
General Purpose			
- Distance per year (km)	500	1000	1500
- Vehicle used	1.5 ton	1.5 ton	1.5 ton
- Cost per km	P0.63	P0.63	P0.63
- Total cost	P315	P630	P945
Total	P2,045	P4,090	P5,035

Note: Based on 100 km separation between site and District Headquarters.

4.1.7 Private Contractors

As noted in Section 4.1.2, the maintenance work performed by the mechanical and civil crews is most easily handled by treating these personnel as private contract workers. Table 20 contains the labor and parts costs for these crews.

Table 20

Annual Maintenance and Repair Costs

Labor and Parts

Village	A	B	C
Engine Decarbonization	P160	P160	P300
Engine Overhaul	P400	P500	P800
Miscellaneous Repairs			
- Engine and pump	P150	P200	P350
- Pipes and tanks	P50	P200	P350
Total	P760	P1,060	P1,800

4.1.8 Other Costs

There are additional labor costs for management and administrative personnel based at the district headquarters. Records in other districts show that these costs depend on the number of systems served by District Headquarters, as indicated below:

	Total Cost	Average Cost Per Borehole
Up to 20 Boreholes	P40,000	P2000
30 to 50 Boreholes	P70,000	P1750
> 60 Boreholes	P90,000	< P1500

4.1.9 Total O&M Costs

At this juncture, all of the estimated O&M costs may be added, as shown in Table 21. Then, labor costs for the District Headquarters can be divided. It is assumed that a moderate size system "B" has an average headquarters cost of P1,750 and headquarters costs for other systems are proportional to the total of all other recurrent costs.

Table 21

Preliminary Cost Tabulation

Village	A	B	C
Labor cost			
- Operator	P2,400	P2,400	P2,400
- Maintenance & repair	760	1060	1800
Materials	190	390	780
Chemicals	0	0	0
Utilities	350	1,620	2,700
Transport	2,045	4,090	5,035
Subtotal	P5,745	P9,560	P12,715
Prorated Headquarters Costs	P1,050	P1,750	P2,330
TOTAL	P6,795	P11,310	P15,045

Table 22 shows a complete tabulation of all the annual O&M costs for the three model village sizes. In addition the table shows the percentage breakdown of the costs, the cost per person served, and per m^3 of water delivered.

As indicated in the previous calculations, labor and transport are the main cost items. Given the relatively large separation of the villages, and the variety of transport requirements, the total transport cost will be high. A significant portion of the labor cost is the operator. As noted previously, this cost is the same regardless of size of the system. In a small water system, the operators' time might not be fully used, but still the person must be fully retained to provide reliable service. This type of cost is often called a fixed cost. Other costs, called variable costs, are directly proportional to the water pumped. Fuel, in this case, is a good example of variable cost.

The breakdown of the costs changes as the scale changes. For example, the fuel costs change from 5 percent of the total for a small system to 18 percent in the largest system. As more and more water is pumped, for a given fixed cost, fuel cost becomes a larger share. In general, in larger systems, variable costs tend to become a larger portion of the total and fixed costs less important.

Table 22

Total O&M Costs
(Botswana, 1984)

Village	A	B	C	A	B	C
Population	300	1,000	1,800	300	1,000	1,800
Water Use (m^3/day)	8	30	50	8	30	50
Labor Cost						
- operators	P2,400	P2,400	P2,400	35.5%	21.2%	16.0%
- headquarters costs	1,050	1,750	2,330	15.5%	15.5%	15.5%
- maintenance and repair	760	1,060	1,800	11.2%	9.4%	12.0%
- Subtotal	P4,210	P5,210	P6,530	62.0%	46.1%	43.4%
Materials Cost	190	390	780	2.8%	3.4%	5.2%
Chemicals Cost	0	0	0	0.0%	0.0%	0.0%
Utilities Cost	350	1,620	2,700	5.2%	14.3%	17.9%
Transport Cost	2,045	4,090	5,035	30.1%	36.2%	33.5%
Total O&M Cost	P6,795	P11,310	P15,045	100.0%	100.0%	100.0%
Total O&M Cost Per Person	P22.65	P11.31	P8.36			
Total O&M Cost Per m^3	P2.33	P1.03	P0.82			

It is clear that as village size increases, O&M costs also increase, but not proportionally. In essence, there are economies of scale in operations and maintenance of these small water systems. Comparing village "C" to village "A", we are pumping approximately six times the water volume, but costs have increased only by a factor of approximately 2.2. This is also illustrated by the fact that cost per unit of water declines from 2.33 to 0.82 P/m^3 as scale increases. The cost per person declines by approximately the same magnitude.

This aspect of economics of scale has important implications. It means that running small water systems is expensive, but large ones less so. Thus in allocating scarce financial resources in the water sector, large projects may be favored over small ones if other factors, such as social impact, do not intervene.

4.1.10 Use of O&M Cost Estimating Forms

The following pages show the use of the O&M cost estimating forms, (developed in Chapter 3) for the case of village "B."

WASH O&M COST ESTIMATING HANDBOOK	PAGE 1 LABOR ESTIMATE
SITE: Botswana "B" Village	AGENCY: Water Affairs
POPULATION: 1000	PREPARED BY: Dist. Engineer
ANNUAL WATER PRODUCTION, m3: 10950 ($30 m^3$/day)	DATE: 9/9/84

1) DIRECT LABOR - REGULAR TIME

A) MANAGEMENT/SUPERVISION

Classification	No. in Class	Average Monthly Wage	% Time	Total
Operator	1	30days x P6 = P180	100%	P 180

B) SKILLED LABOR

Classification	No. in Class	Average Monthly Wage	% Time	Total

C) UNSKILLED LABOR

Classification	No. in Class	Average Monthly Wage	% Time	Total

MONTHLY SUBTOTAL P 180

ANNUAL SUBTOTAL P 2160

Figure 15. Labor Estimate Form

SITE: BOTSWANA "B" VILLAGE AGENCY: WATER AFFAIRS

POPULATION: 1000 PREPARED BY: DIST. ENGINEER

ANNUAL WATER PRODUCTION, m3: 10950 (30m³/day) DATE: 9/9/84

2) DIRECT LABOR - OVERTIME

Classification	No. in Class.	Average ~~Hrs.~~ Days Overtime	~~Hourly~~ Daily Rate	% Time	Total
Operator	1	40/year	P 6	100%	P 240
				MONTHLY SUBTOTAL	
				ANNUAL SUBTOTAL	P 240

3) ADMINISTRATION

Classification	No. in Class.	Average Monthly Wage	% Time	Total
			MONTHLY SUBTOTAL	
			ANNUAL SUBTOTAL	

TOTAL LABOR ESTIMATE (1+2+3) = P 2400

Figure 16. Labor Estimate Form (p. 2)

WASH O&M COST ESTIMATING HANDBOOK — PAGE 3 — MATERIALS ESTIMATE

SITE: BOTSWANA "B" VILLAGE — AGENCY: WATER AFFAIRS

POPULATION: 1000 — PREPARED BY: DIST ENGINEER

ANNUAL WATER PRODUCTION, m3: 10950 (30m³/day) — DATE: 9/9/84

1) SUPPLIES

Item	Unit	Annual Quantity	Unit Cost	Total
Engine Oil	liters	70	P 4.00	P 280
			SUBTOTAL	P 280

2) PARTS

Item	Unit	Annual Quantity	Unit Cost	Total
Oil Filters		12	P 5.00	P 60
Belts		1	P 50.00	P 50
			SUBTOTAL	P 110

3) TOOLS

Item	Unit	Annual Quantity	Unit Cost	Total
			SUBTOTAL	

TOTAL MATERIALS ESTIMATE = P 390

Figure 17. Materials Estimate Form

WASH O&M COST ESTIMATING HANDBOOK	PAGE 4 CHEMICALS ESTIMATE
SITE: BOTSWANA "B" VILLAGE	AGENCY: WATER AFFAIRS
POPULATION: 1000	PREPARED BY: DIST. ENGINEER
ANNUAL WATER PRODUCTION, m3: 10950 (30m³/day)	DATE: 9/9/84

CHEMICAL CONSUMPTION

Chemical Used	Desired Dosage (mg/l)	Commercial Strength, %	Required Dosage (mg/l)	Water Production (m3/day)	Net Consumption (kg/day)
None					
	a	b	c=a/b	d	e=c*d/1000

CHEMICAL COST

Chemical Used	Net Consumption, kg/day	Chemical Unit	No. of Units/yr	Unit Cost	Total Cost
				ANNUAL SUBTOTAL	
				TOTAL CHEMICALS ESTIMATE =	0

Figure 18. Chemicals Estimate Form

SITE: BOTSWANA "B" VILLAGE AGENCY: WATER AFFAIRS

POPULATION: 1000 PREPARED BY: DIST. ENGINEER

ANNUAL WATER PRODUCTION, m3: 10950 (30m³/day) DATE: 9/9/84

1) ELECTRIC POWER

A) DEMAND CHARGE

Peak Power (KW)	Demand Charge / KW	Annual Demand Charge

B) ENERGY CHARGE

Equipment	# of units	Rated Power (Hp)	Power Draw (kw)	Daily Operating Period (hr)	Average Daily Energy Consumption (kwh)	Days Use per Year	Energy Cost/kwh	Total Cost
	a		b	c	d=b*c	e	f	g=a*d*e*f

ELECTRIC ENERGY SUBTOTAL ____

2) FUEL

Equipment	# of units	Power (Hp)	Type of Fuel Used	Daily Operating Period (hr)	Average Hourly Fuel Consumption	Days Use per Year	Unit Fuel Cost	Total Cost
Engine	1	6	Diesel	6	1.142+10%≈1.25	365	0.6	P1620
	a			b	c	d	e	f=a*b*c*d*e

FUEL SUBTOTAL P1620

TOTAL UTILITIES ESTIMATE = P1620

Figure 19. Utilities Estimate Form

SITE: BOTSWANA "B" VILLAGE AGENCY: WATER AFFAIRS

POPULATION: 1000 PREPARED BY: DIST. ENGINEER

ANNUAL WATER PRODUCTION, m3: 10950 (30m³/day) DATE: 9/9/84

TRANSPORT NEEDS

Transport Purpose	Vehicle Type	Annual Trip Frequency	Average Trip Distance	Total Distance
Fuel Distribution/ System check	5 ton truck	12	200 km	2400 km
Maintenance/Repairs	1.5 ton truck	10	200 km	2000 km
General	1.5 ton truck		1000 km	1000 km

TRANSPORT COSTS

Vehicle Type	Total Distance for Vehicle Type	Unit Travel Cost	Total Cost
5 ton truck	2400 km	P 0.92	P 2200
1.5 ton truck	2000 + 1000 = 3000 km	P 0.63	P 1890

TOTAL TRANSPORT COST P 4090

TOTAL TRANSPORT ESTIMATE = P 4090

Figure 20. Transport Estimate Form

SITE: BOTSWANA "B" VILLAGE AGENCY: WATER AFFAIRS

POPULATION: 1000 PREPARED BY: DIST. ENGINEER

ANNUAL WATER PRODUCTION, m3: 10950 (30m³/day) DATE: 9/9/84

1) PRIVATE CONTRACTORS

A) SCHEDULED

Task / Service Performed	Annual Frequency of Service/Contract	Service / Contract Cost	Total
Engine Overhaul	1/year	P 500	P 500
Engine Decarbonisation	1/year	P 160	P 160
		ANNUAL SUBTOTAL	P 660

B) UNSCHEDULED

Task / Service Performed	Frequency of Service	Service / Contract Cost	Total
Engine Repair	1/year	P 200	P200
Piping Repair	1/year	P 200	P 200
		ANNUAL SUBTOTAL	P 400

TOTAL PRIVATE CONTRACTOR ESTIMATE = P 1060

2) OTHER COSTS

Prorated Headquarters Cost (Annual) P1750

TOTAL OTHER COSTS ESTIMATE = P 1750

Figure 21. Contractors/Other Costs

WASH O&M COST ESTIMATING HANDBOOK		SUMMARY SHEET
SITE: BOTSWANA "B" VILLAGE		AGENCY: WATER AFFAIRS
POPULATION: 1000		PREPARED BY: DIST. ENGINEER
ANNUAL WATER PRODUCTION, m3: 10950 (30m³/day)		DATE: 9/9/84

SUMMARY OF ANNUAL OPERATIONS AND MAINTENANCE COST

		Annual O&M Cost		Percent of Total
1) LABOR				
- Regular		P2160		
- Overtime		P 240		
- Administration				
	SUBTOTAL	P 2400	P 2400	21.2%
2) MATERIALS				
- Supplies		P 280		
- Parts		P 110		
- Tools				
	SUBTOTAL	P 390	P 390	3.5%
3) CHEMICALS			0	0%
4) UTILITIES				
- Electric Power				
- Fuel		P 1620		
	SUBTOTAL	P 1620	P 1620	14.3%
5) TRANSPORT			P 4090	36.2%
6) PRIVATE CONTRACTORS			P 1060	9.4%
7) OTHER			P 1750	15.5%
	TOTAL O&M COST		P 11 310	100.0%
	TOTAL O&M COST PER CAPITA		P 11.3	
	TOTAL O&M COST PER m3		P 1.03	

Figure 22. Summary Sheet

/

4.1.11 O&M Costs Compared with Capital Costs

Estimates of the capital costs of these three systems have also been made. The capital costs consist of initial costs (Table 23), and the costs of replacements after 10 years and 20 years (Table 24). A total present value over the life of the system (assumed to be 25 years) can be found by adding the initial cost and discounted values for the future replacement values.

The annual O&M costs of water systems are sometimes estimated as a simple percentage of capital cost. People sometimes simply assume these O&M costs will be approximately 2 percent or 5 percent of initial capital cost. This method is inexact and quite misleading. For this case in Botswana, there are reliable estimates of both capital and annual O&M cost, so one can calculate this percentage, and evaluate the results. As shown in Table 235 annual O&M costs range from 20 percent of capital cost for the smallest system, to about 10 percent for the largest. Thus, this percentage varies greatly depending on the size of the system.

Table 23

Estimate of Water System Initial Capital Costs (Pula)
Botswana, 1984

Village	A	B	C	A	B	C
Population	300	1,000	1,800	300	1,000	1,800
Water Use (m^3/day)	8	30	50	8	30	50
Initial Costs						
Boreholes						
- boreholes drilled	2	3	4			
- boreholes successful	1	1	2			
- siting and drilling	P15,000	P2,0000	P25,000	44.1%	22.2%	17.6%
- casing @P5,000 ea.	5,000	5,000	10,000	14.7%	5.6%	7.0%
- testing @P2,000 ea.	2,000	2,000	4,000	5.9%	2.2%	2.8%
Subtotal	P22,000	P27,000	P39,000	64.7%	30.0%	27.5%
Pumping Equipment	P8,000	P10,000	P20,000	23.5%	11.1%	14.1%
Distribution System						
- tanks, tank stands	3,000	12,000	20,000	8.8%	13.3%	14.1%
- piping @ 6 P/km (installed)	0	36,000	54,000	0.0%	40.0%	38.0%
- standpipes @ P1,000 ea.	1,000	5,000	9,000	2.9%	5.6%	6.3%
Subtotal	P4,000	P53,000	P83,000	11.8%	58.9%	58.5%
Total Initial Construction Cost	P34,000	P90,000	P142,000	100.0%	100.0%	100.0%
Initial Capital Cost per person	P113	P90	P79			
Initial Capital Cost per m^3	P11.6	P8.2	P7.8			

Table 24

Present Value of Replacements
(6% discount rate)

Village	A	B	C
Year 10			
- Pumping equipment	P4,467	P5,584	P11,168
- tanks, tank stands	1,675	6,701	11,168
- standpipes @ P1,000 each	558	2,792	5,026
Year 20			
- Pumping equipment	2,494	3,118	6,236
- tanks, tank stands	935	3,742	6,236
- standpipes @ P1,000 each	312	1,559	2,806
Total Present Value of Replacements	P10,442	P23,495	P42,640
Total Initial Construction Cost (from Table 23)	P34,000	P90,000	P142,000
Total Present Value of Construction Cost	P44,442	P113,495	P184,640

Table 25

O&M Cost in Relation to Capital Cost

Village	A	B	C
Population	300	1,000	1,800
Water Use (m^3/day)	8	30	50
Annual O&M Cost (P)	6,795	11,310	15,045
Initial Construction Cost (P)	34,000	90,000	142,000
Annual O&M/Initial Construction	20.0%	12.6%	10.6%
Annual O&M Cost (P)	6,795	11,310	15,045
Total PV Construction Cost (P)	44,442	113,495	184,640
Annual O&M/Total PV Construction	15.3%	10.0%	8.1%

The various O&M line item costs were also calculated as a percentage of initial capital cost. The results, shown in Table 26, indicate that the percentage varies for most line items. Labor costs vary from 12 percent to 5 percent depending on scale. Overall, it appears that the ratio of O&M costs to capital costs is quite variable and thus will be a poor estimator.

Table 26

O&M Line Item Costs in Relation to Initial Construction Cost

Village	A	B	C
Population	300	1,000	1,800
Water Use (m^3/day)	8	30	50
Labor Cost/Construction Cost			
-- Operators	7.1%	2.7%	1.7%
-- Headquarters costs	3.1%	1.9%	1.6%
-- Maintenance & repair	2.2%	1.2%	1.3%
-- Subtotal	12.4%	5.8%	4.6%
Materials Cost/Construction Cost	0.6%	0.4%	0.5%
Chemicals Cost/Construction Cost	0.0%	0.0%	0.0%
Utilities Cost/Construction Cost	1.0%	1.8%	1.9%
Total O&M Cost/Construction Cost	20.0%	12.6%	10.6%

4.1.12 Regression Analysis of O&M Costs

Regression analysis of O&M costs will provide a clearer indication of economies of scale. In the water supply field costs are often modeled using a cost function in the form of a power function:

$$C = aQ^b$$

where: C = Annual (O&M) cost (Pula/yr)
Q = Water flow (m^3/yr)
a,b = constants determined by regression analysis

A computer regression analysis has given the following results for the case example in Botswana:

$$C = 228 \times Q^{0.424}$$

The coefficient of correlation is 0.99, indicating an excellent fit to the data.

The exponent value, 0.424, is important to examine. If the value of this exponent were 1, the O&M costs would be directly proportional to flow. Because the exponent is much lower than one, costs climb slowly as flow increases. Thus, there are significant economies of scale.

The regression formula is also useful for calculating average and marginal costs of operation and maintenance. Table 27 shows formulas and results of calculations of these unit costs. Average costs are equal to the "cost per m^3" calculated previously in Table 22. Marginal costs, indicating the cost of the "last" m^3 pumped, are far less, due to economies of scale. Interestingly, if one multiplies the average costs by the exponent (0.424), the result is the value of the marginal cost. Although well beyond the scope of this paper, marginal costs are interesting in that they show the cost of an additional unit of water.

Table 27

Analysis of O&M Costs

Village	A	B	C
Population	300	1,000	1,800
Water Use, Q (m^3/yr)	2,920	10,950	18,250
Annual O&M Cost, C (P/yr)	P6,795	P11,310	P15,045
Regression Function Cost (P/yr)	P6,720	P11,771	P14,618
Marginal Cost (P/m^3)			
Marginal Cost = $ba^{Q(b-1)}$	P0.98	P0.46	P0.34
Average Cost (P/m^3)			
Average Cost = $aQ^{(b-1)}$	P2.30	P1.07	P0.80

4.2 Urban Water Project Example

4.2.1 The Setting

The City of Portola is a city in a hypothetical developing country. The current population is 50,000, but, due to rural to urban migration, the population has recently been growing at a 5 percent annual rate. Approximately 40,000 residents are currently served by a water system built in the early 1960s. A major expansion is now being planned, to cover the unserved and growing population. Current and projected future demand and supply figures are given in Table 28 below. A design period of 10 years has been used.

Table 28

Portola Demand and Supply Data

	Current	Future
Population	50,000	82,000
Population Served	40,000	82,000
Water Production (m^3/day)	4,500	13,340
Water Losses	1,000	2,000
Water Supplied	3,500	11,340
Water Supplied To:		
- Residential*	3,000	9,840
- Industrial	500	1,500
- Total	3,500	11,340

* Based on 75 lpcd currently, 120 in the future.

The current system is illustrated in Figure 23. Water from the North River is treated, at least partially, at a treatment plant located near the river. A 12 km gravity transmission main carries water to a distribution network, whose total piping length is 175 km. Two elevated storage tanks in town are connected to the network on a "floating" basis.

The water system is owned and operated by the Portola Water Authority, a semiautonomous municipal agency. The Portola Water Authority receives some support from the City of Portola, in terms general financial support, the use of the Municipal motor garage, and other services. It also receives financial support and technical assistance from the National Water Authority, a national government agency. The Portola Water Authority has a Headquarters office in central Portola, with offices, vehicle yard, maintenance workshop, materials storage, and so forth.

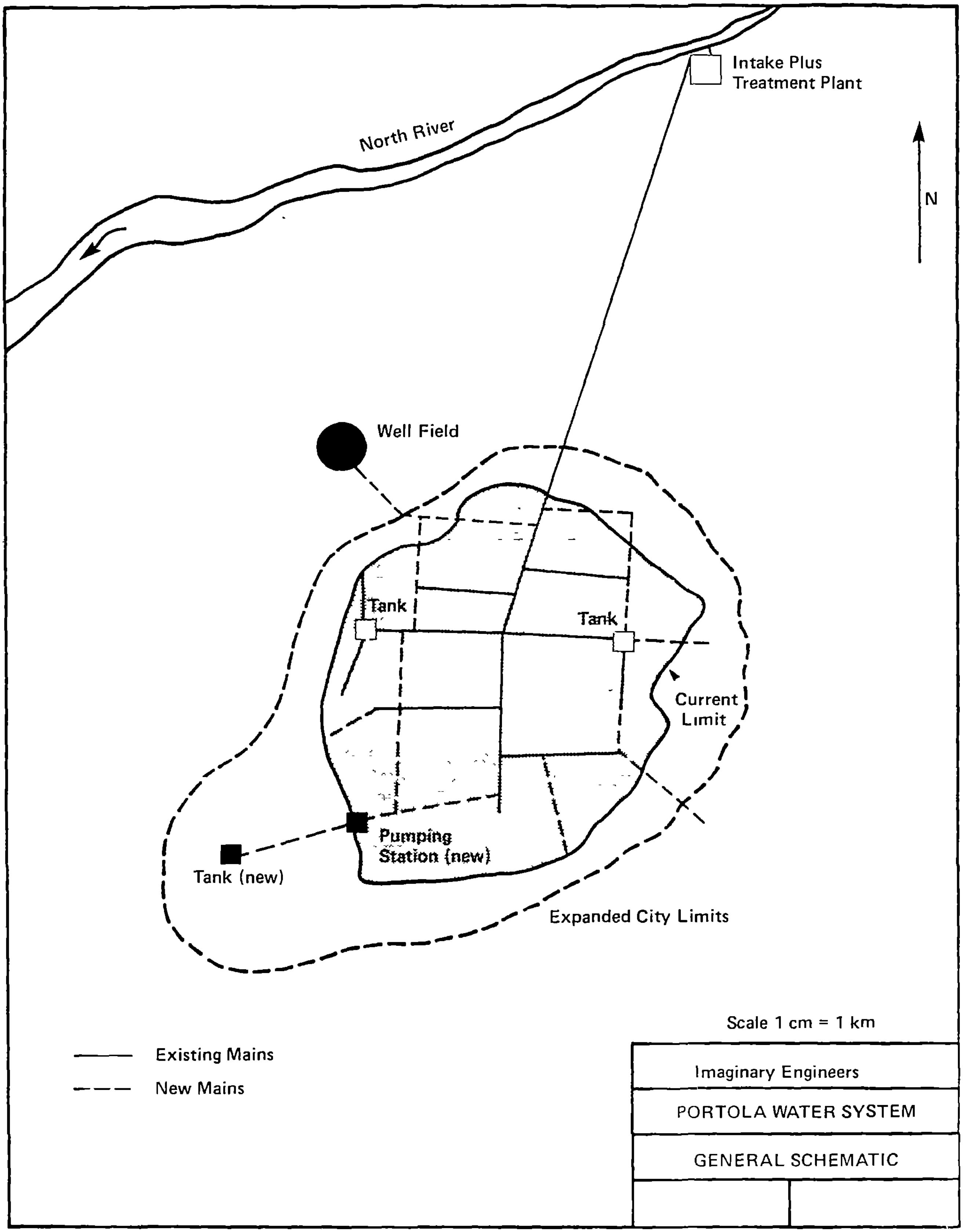


Figure 23. Portola Water System

Under the project that is being planned a number of improvement/expansions are to be made. First, some renovation and expansion to the treatment plant will allow it to increase its capacity from the current value of 4,500 m^3/day, up to 5,000 m^3/day. A new well field is to be developed, closer to town. Pilot wells have shown the existence of a good resource (up to 10,000 m^3/day), with excellent water quality (only chlorination needed). In addition, a small pumping station will be added, to serve a rapidly growing sector of town, up on a hill, which has not had piped water to date. The goal is to be able to serve the existing population of 50,000 right away and to expand the network incrementally as the city population expands.

The timing of these improvements will follow demand. At the end of the initial construction phase, the demand should be 5,000 m^3/day (50,000 * 100 lpd) in residential, 500 m^3/day in industrial, and 1,000 m^3/day in losses, thereby creating a total of 6,500 m^3/day. Two wells of 750 m^3/day each will be constructed initially, and with the improved treatment plant capacity of 5,000 m^3/day a supply of 6,500 m^3/day will be reached. Additional wells will be added as demand grows. Studies indicate the wisdom of installing the full 1,000 m^3/day of pumping station capacity now. In addition, the installation of most of the new mains will be part of the initial work. A full list of equipment for the new system is given in Table 29, showing equipment in place at the end of the initial construction phase, and at the end of the ten year design period.

Table 29

City of Portola Water Supply System

Component	Initial Phase	Future
Treatment Plant	5,000 m^3/day	5,000 m^3/day
Wells	2 @ 750 m^3/day	9 @ 750 m^3/day
Transmission Main	12 km @ 300mm	12 km @ 300mm
Elevated Storage Tanks	3 * 1,000m^3	3 * 1,000m^3
Pumping Station	1,000 m^3/day (dual pump)	1,000 m^3/day (dual pump)
Distribution		
200 mm	20 km	20 km
150 mm	20	30
100 mm	40	60
50 mm	60	100
25 mm	100	100
Total	240 km	310 km
House Connections	10,000	16,400
Water Meters		
1/2"	8,000	11,400
3/4"	2,000	5,000

In the following pages, an estimate of all O&M costs will be made, for the year immediately following completion of the initial phase. Similar estimates could also be made for the tenth year, but that is left to the reader. The purpose of these estimates is to study the recurrent costs associated with the engineering design choices, that have been made, as outlined above. Similar estimates are being made for use of another, more distant surface water resource (with different treatment needs), instead of the renovated treatment plant and new well field. The estimate does not include labor for management, consumer accounts, and some administrative functions, which would be the same for both alternatives.

4.2.2 Labor

As a part of the engineering plan, a staffing plan has been developed for operations, maintenance, and administrative personnel. Staff at management, supervisory, skilled labor, and unskilled labor grades have been planned for the initial stage of use of the "new" system and at the ten-year point. The required staff are listed in Figures 24 and 25 on the following pages. Also included are monthly wages and overtime allowances to reach a total direct labor estimate. An estimate of maintenance related clerical staff is also accounted for.

4.2.3 Materials

The list of equipment outlined in Table 29 will be the starting point for estimating O&M materials cost. Basic supplies for O&M will include pipe, paint, rags, lubricating oil, and so forth. Page 3 of the estimating form shows tabulations of each of these. Quantities for pipe were based on an estimate from previous Portola Water Authority experience of 16 breaks per 100 km in distribution piping. Thus, the following incidence of pipe breaks may be anticipated:

Pipe Size	Pipe Length	Expected Breaks per year
25 mm	100 km	16.0
50 mm	60 km	9.6
100 mm	40 km	6.4
150 mm	20 km	3.2
200 mm	20 km	3.2

An estimate has also been made for spare parts, particularly motors. A worse case approach has been used. That is it is expected that the well pumps could, under worse case conditions, last only two years. A nominal allowance for miscellaneous tools has been made.

4.2.4 Chemicals

A variety of chemicals will be needed for the surface water used, but only chlorine for the well water. Tests on the river water indicate that full treatment, including coagulation and sedimentation, filtration, pH adjustment, and disinfection is needed. The coagulant used is alum, which is available in powder form, in 100 kg drums. From jar tests, the desired dose is 4 mg/l of Al_2O_3. Because the available alum has a strength of 15 percent, the dose of powder is 26.67 mg/l. For pH adjustment, a dose of 7.5 mg/l of locally available slaked lime will be used. Chlorine doses in both locations will be 5 mg/l. A summary of these chemical needs is shown in Figure 27.

Unit costs for chemicals has been obtained from local suppliers. The locally produced lime is available in Portola, at a cost of $10 per 50 kg bag. The alum and chlorine (calcium hypochlorite) are imported into the country, and trucked from the capital. Quotations indicate a cost for each of $33 per 50 kg bag of $Ca(OCl)_2$ (delivered) and $35 per 100 kg drum for the alum. From these data the annual chemical cost is found, as shown in Figure 27.

4.2.5 Utilities

Electric power will be needed for well pumps, pumping station pumps, treatment plant motors, lighting for the plant, offices, and so forth. No fuel costs are expected, other than those for vehicle fuel which is included in transport costs. A nominal allowance for telephone costs will be made.

To estimate electricity cost, energy cost and power demand charges must be tabulated. For energy costs, power draw (kw), operating schedule, and unit energy cost must be determined. Table 30 and Figure 28 show such details.

The power draw of the well pumps can be estimated from the daily production. Each well can produce 10 liters/sec (36 m^3/hr), which on a continuous pumping basis would produce 864 m^3/day. We need only 750 m^3/day, so each well need only produce 8.68 l/s. Thus the pump flow will be close to 8.68 l/s. The power draw of the pump, given a head of 110 m, and a pump/motor efficiency of 45 percent, will be as follows:

$$\text{Power draw (kw)} = 8.68 \text{ l/s} * 110 \text{ m} * 9.8 \;/\; 0.45$$
$$= 20.8 \text{ kw}$$

Similar calculations can be made for the pumping station, where the head is 50 m.

Table 30

Electrical Energy Requirements

Device	Rated Power (hp)	Power Draw (kw)	Operating Schedule (hr/day)
Well Pump #1	50	21	24
Well Pump #2	50	21	24
Pumping Station Pump #1	50	19	8
Pumping Station Pump #2	50	19	8
Treatment Plant Motors (6)	10	5 ea	12
Office Lighting, etc.		5	8

4.2.6 Transport

Transport is needed for the following purposes:

- Water meter reading
- Water quality monitoring
- Distribution network repairs
- General transport - headquarters to treatment plant
- General transport - headquarters to well field
- Miscellaneous/unforeseen.

It should be noted that the chemical supplier delivers the chemicals to the treatment plant directly from the capital city. The transport costs are built into the delivered chemical price and are not borne directly by the Portola Water Authority.

The Portola Water Authority has several pickup trucks and a five-ton truck, for transport of personnel, supplies and materials. Estimated vehicle use is shown in the completed estimation form (Figure 29). The Portola Water Authority has estimated that the running and capital cost of vehicles, not including driver labor, is as follows:

Pickup	$0.40/km
Five-ton truck	$0.75/km

With this information a complete transport cost estimate can be made, as shown on the form in Figure 29.

4.2.7 Contractors

The Portola Water Authority conducts its own preventive and corrective maintenance and retains operators on its staff. The current plans do not call for any outside contracts for the operation and maintenance of this system (Figure 30).

4.2.8 Total O&M Costs

The total O&M costs are tabulated on the summary sheet of the estimating forms (Figure 31.) Clearly, labor and utilities are the main costs, followed by chemicals, transport, and materials. The total annual O&M is close to $200,000, or approximately $4.00 per capita annually, which yields a cost of approximately $0.085 per m^3.

The choice of wells clearly leads to high utility costs. As time goes on, and more wells are added, this will lead to higher and higher costs. Investigation of another surface water source may be warranted. The treatment cost associated with it would have to be estimated during such a study. The overall choice of technology will depend on considerations of both capital and O&M costs, and other factors which are beyond the scope of this manual. Still, with a reliable estimate of O&M costs, one part of the decision will be made on firm ground.

WASH O&M COST ESTIMATING HANDBOOK PAGE 1 LABOR ESTIMATE

SITE: PORTOLA AGENCY: PWA

POPULATION: 50,000 (Initial phase) PREPARED BY: Maint. Engr.

ANNUAL WATER PRODUCTION, m3: 24x10^6 m3/yr or 6500 m3/day DATE: 10/10/87

1) DIRECT LABOR - REGULAR TIME

A) MANAGEMENT/SUPERVISION

Classification	No. in Class	Average Monthly Wage	% Time	Total
Maintenance Engineer	2	$ 350	100%	$ 700
Plant Superintendant	2	$ 300	"	$ 600
Vehicle Manager	1	$ 200	"	$ 200

B) SKILLED LABOR

Classification	No. in Class	Average Monthly Wage	% Time	Total
Plant Operator	5	$ 250	100%	$ 1250
Pipe Fitter	2	$ 200	"	$ 400
Electrician	1	$ 250	"	$ 250
Lab Technician	1	$ 200	"	$ 200

C) UNSKILLED LABOR

Classification	No. in Class	Average Monthly Wage	% Time	Total
Storekeeper	1	$ 150	100%	$ 150
Meter Reader	2	$ 150	"	$ 300
Driver	4	$ 100	"	$ 400
Laborer	5	$ 75	"	$ 375
Watchman	2	$ 100	"	$ 200

MONTHLY SUBTOTAL $ 5025

ANNUAL SUBTOTAL $ 60300

Figure 24. Labor Estimate Form

WASH O&M COST ESTIMATING HANDBOOK	PAGE 2	LABOR ESTIMATE

SITE: PORTOLA AGENCY: PWA

POPULATION: 50,000 (Initial phase) PREPARED BY: Maint Engr

ANNUAL WATER PRODUCTION, m3: $24 \times 10^6 m^3/yr$, $6500 m^3/day$ DATE: 10/10/87

2) DIRECT LABOR - OVERTIME

Classification	No. in Class.	Average Overtime Hrs.	Hourly Rate	% Time	Total
Operator	4	40	$ 2.50	100%	$ 400
Superintendent	1	10	$ 3.00	"	$ 30
Pipe Fitter	2	20	$ 2.00	"	$ 80
Electrician	1	10	$ 2.50	"	$ 25
Driver	2	20	$ 1.00	"	$ 40
Laborer	2	20	$ 0.75	"	$ 30

MONTHLY SUBTOTAL $ 605

ANNUAL SUBTOTAL $ 7260

3) ADMINISTRATION

Classification	No. in Class.	Average Monthly Wage	% Time	Total
Clerical	2	$ 150	75%	$ 225

MONTHLY SUBTOTAL $ 225

ANNUAL SUBTOTAL $ 2700

TOTAL LABOR ESTIMATE (1+2+3) = $ 70260

Figure 25. Labor Estimate Form (p. 2)

WASH O&M COST ESTIMATING HANDBOOK	PAGE 3	MATERIALS ESTIMATE

SITE: PORTOLA AGENCY: PWA

POPULATION: 50,000 (Initial phase) PREPARED BY: Maint Engr

ANNUAL WATER PRODUCTION, m3: 2.4x10⁶ m³/yr or 6500m³/day DATE: 10/10/87

1) SUPPLIES

Item	Unit	Annual Quantity	Unit Cost	Total
PIPE 25mm	6m length	16breaks x ½ length = 8	$3/m x 6m = $24	$ 192
50	"	4.8	$5/m x 6m = $30	$ 144
100	"	3.2	~~$8/m x 6m = $48~~	$ 154
150	"	1.6	$15/m x 6m = $90	$ 144
200	"	1.6	$25/m x 6m = $150	$ 240
Valves 25mm	each	20	$ 5	$ 100
50mm	each	20	$ 10	$ 200
Water Meters	each	20	$ 30	$ 600
Paint	5l	20	$ 20	$ 400
Rags	bales	2	$ 10	$ 20
Unforseen				$ 500
			SUBTOTAL	$2694

2) PARTS

Item	Unit	Annual Quantity	Unit Cost	Total
Well Pump		0.5	$ 8000	$ 4,000
Motor - 10hp		1.0	$ 500	$ 500
Miscellaneous			$ 500	$ 500
			SUBTOTAL	$5,000

3) TOOLS

Item	Unit	Annual Quantity	Unit Cost	Total
Miscellaneous			$ 500	$ 500
			SUBTOTAL	$ 500

TOTAL MATERIALS ESTIMATE = $ 8194

Figure 26. Materials Estimate Form

WASH O&M COST ESTIMATING HANDBOOK	PAGE 4 CHEMICALS ESTIMATE
SITE: PORTOLA	AGENCY: PWA
POPULATION: 59000 (Initial phase)	PREPARED BY: Maint Engr
ANNUAL WATER PRODUCTION, m3: 2.4x10^6 m^3/yr or 6500m^3/day	DATE: 10/10/87

CHEMICAL CONSUMPTION

Chemical Used	Desired Dosage (mg/l)	Commercial Strength, %	Required Dosage (mg/l)	Water Production (m3/day)	Net Consumption (kg/day)
Wells					
Chlorine	5	60%	8.3	1,500	12.5
Plant					
Alum	4	15%	26.6	5,000	133
Lime	6	80%	7.5	"	37.5
Chlorine	5	60%	8.3	"	41.5
	a	b	c=a/b	d	e=c*d/1000

CHEMICAL COST

Chemical Used	Net Consumption, kg/day	Chemical Unit	No. of Units/yr	Unit Cost	Total Cost
Chlorine	54+10% ~ 60	50 kg bag	438 bags	$ 33	$14,454
Lime	37.5+10% ~ 42	50 kg bag	307 bags	$ 10	$ 3,070
Alum	133+10% ~ 150	100kg drum	548 drums	$ 35	$ 19,180
				ANNUAL SUBTOTAL	$36,704

TOTAL CHEMICALS ESTIMATE = $36,704

Figure 27. Chemicals Estimate Form

WASH O&M COST ESTIMATING HANDBOOK — PAGE 5 UTILITIES ESTIMATE

SITE: PORTOLA — AGENCY: PWA

POPULATION: 50,000 (Initial Phase) — PREPARED BY: Maint. Engr

ANNUAL WATER PRODUCTION, m3: 2.4x10⁶ m³/yr or 6500 m³/day — DATE: 10/10/87

1) ELECTRIC POWER

A) DEMAND CHARGE

Peak Power (KW)	Demand Charge / KW	Annual Demand Charge
85	$10/month/KW	$10,200

B) ENERGY CHARGE

Equipment	# of units	Rated Power (Hp)	Power Draw (kw)	Daily Operating Period (hr)	Average Daily Energy Consumption (kwh)	Days Use per Year	Energy Cost/kwh	Total Cost
Well pumps	2	50	21 each	24	504	365	$0.08	$29,434
Pumping station	2	50	19 each	8	152	365	$0.08	$8,877
Treatment Plant Motors	6	10	5 each	12	60	365	$0.08	$10,512
Lighting			5	8	40	260	$0.08	$832
	a		b	c	d=b*c	e	f	g=a*d*e*f

ELECTRIC ENERGY SUBTOTAL $49,655

2) FUEL

Equipment	# of units	Power (Hp)	Type of Fuel Used	Daily Operating Period (hr)	Average Hourly Fuel Consumption	Days Use per Year	Unit Fuel Cost	Total Cost
	a			b	c	d	e	f=a*b*c*d*e

FUEL SUBTOTAL ______

TOTAL UTILITIES ESTIMATE = 59,855

Figure 28. Utilities Estimate Form

WASH O&M COST ESTIMATING HANDBOOK	PAGE 6 TRANSPORT ESTIMATE
SITE: PORTOLA	AGENCY: PWA
POPULATION: 50,000 (Initial phase)	PREPARED BY: Maint. Engr.
ANNUAL WATER PRODUCTION, m3: 2.4x10⁶ m³/yr or 6500m³/day	DATE: 10/10/87

TRANSPORT NEEDS

Transport Purpose	Vehicle Type	Annual Trip Frequency	Average Trip Distance	Total Distance
Meter Reading	Pickup	24	50	1200
Water Quality Check	Pickup	12	20	240
Repairs	Pickup	40	100	4000
Repairs	5 ton truck	40	50	2000
Hqrts ↔ Plant	Pickup	200	25	5000
Hqrts ↔ Wells	Pickup	50	15	750
Misc	Pickup			2000
Misc.	5 ton truck			400

TRANSPORT COSTS

Vehicle Type	Total Distance for Vehicle Type	Unit Travel Cost	Total Cost
Pickup	13190	0.40	$ 5276
5 ton truck	2400	0.75	$ 1800
		TOTAL TRANSPORT COST	$ 7076

TOTAL TRANSPORT ESTIMATE = $ 7076

Figure 29. Transport Estimate Form

WASH O&M COST ESTIMATING HANDBOOK	PAGE 7 CONTRACTORS / OTHER COSTS
SITE: PORTOLA	AGENCY: PWA
POPULATION: 50,000 (Initial phase)	PREPARED BY: Maint. Engr.
ANNUAL WATER PRODUCTION, m3: $2.4 \times 10^6 m^3/yr$ or $6500 m^3/day$	DATE: 10/10/87

1) PRIVATE CONTRACTORS

A) SCHEDULED

Task / Service Performed	Annual Frequency of Service/Contract	Service / Contract Cost	Total
none			

ANNUAL SUBTOTAL ________

B) UNSCHEDULED

Task / Service Performed	Frequency of Service	Service / Contract Cost	Total
none			

ANNUAL SUBTOTAL ________

TOTAL PRIVATE CONTRACTOR ESTIMATE = 0

2) OTHER COSTS

none

TOTAL OTHER COSTS ESTIMATE = 0

Figure 30. Contractors/Other Costs

WASH O&M COST ESTIMATING HANDBOOK — SUMMARY SHEET

SITE: PORTOLA — AGENCY: PWA

POPULATION: 50,000 (Initial Phase) — PREPARED BY: Maint. Engr.

ANNUAL WATER PRODUCTION, m3: 2.4×10^6 m³/yr or 6500 m³/day — DATE: 10/10/87

SUMMARY OF ANNUAL OPERATIONS AND MAINTENANCE COST

		Annual O&M Cost	Percent of Total
1) LABOR			
- Regular	$60,300		
- Overtime	$ 7,260		
- Administration	$ 2,700		
SUBTOTAL	$ 70,260	$70,260	38.6%
2) MATERIALS			
- Supplies	$ 2,694		
- Parts	$ 5,000		
- Tools	$ 500		
SUBTOTAL	$ 8,194	$ 8,194	4.5%
3) CHEMICALS		$ 36,704	20.1%
4) UTILITIES			
- Electric Power	$59,855		
- Fuel			
SUBTOTAL	$59,855	$59,855	32.9%
5) TRANSPORT		$ 7,076	3.9%
6) PRIVATE CONTRACTORS		0	0.0%
7) OTHER		0	0.0%
TOTAL O&M COST		$182,089	100.0%
TOTAL O&M COST PER CAPITA		$ 3.64	
TOTAL O&M COST PER m3		$ 0.077	

Figure 31. Summary Sheet

4.3 Field Test Example

4.3.1 Introduction

A field test of these cost O&M estimating procedures was performed in Ivory Coast. With the assistance of SODECI, a private national water utility, detailed cost estimates were prepared on two water systems. One was a small village system with a well and simple treatment, while the other was a larger system involving surface water and full treatment. Results of the cost estimates were compared to cost records, showing reasonably close agreement. A number of potential improvements to the manual were identified. The current edition of this manual includes these improvements. In addition, O&M cost data were analyzed for 13 additional water systems in the same region. These calculations showed interesting trends in O&M costs and confirmed that the two sites studied were reasonably typical.

4.3.2 Basic information on SODECI

The Société de Distribution d'Eau de la Côte d'Ivoire (SODECI) is a private firm which was founded in 1960 by the French company SAUR to operate the Abidjan water system. At the end of 1986, SODECI operated over 200 water systems throughout Ivory Coast and many thousand village handpump systems. Currently, the ownership is approximately 53 percent Ivoirian and 47 percent French. SODECI is free to hire, fire, and compensate its staff as it chooses, but water standards and tariffs are regulated.

Over the past 15 years SODECI has operated under an "affermage" type contract[1]. A department of the Ministry of Public Works is responsible for planning and implementing new investments in the water sector, supervising SODECI, and negotiating contracts. SODECI collects tariffs, retains a portion for its operating costs, overhead, and nominal profit, and passes a portion back to the State for debt service and reinvestment. The SODECI fee is directly related to the volume of water sold (not water produced). The tariff is said to be one of the highest in Africa, but water quality and supply pressure are quite reliable and among the best in Africa.

In the past, SODECI had little role in the selection and engineering design of sites. Thus their own O&M cost considerations, in their opinion, could receive a lower emphasis compared to investment considerations in the development of system designs. In October 1987 the new contract modified the arrangement such that SODECI will retain an additional part of the tariff for new investments, but will continue to pass funds to the State to service the old debt. Under this new arrangement SODECI will have a larger role in selecting and planning new systems and expansions, in keeping with investment

[1] This and other private contracting arrangements are described well in The Private Provision of Public Services in Developing Countries, Roth, G., World Bank, 1987.

goals established by the State. It should also be noted that in the contract negotiations, the fee that SODECI retains was reduced to 159F CFA to 134F CFA[2].

The management of SODECI is an interesting mix of centralized control and decentralized operations. On the lowest level, water system operators run the systems, track local costs, hire and manage daily labor, read meters and collect fees, bank fees at the end of the month, perform minor repairs, etc. These local operators have full local operational authority and budgetary responsibility. Local cost savings will improve their chances for a year end bonus or improved salary adjustment. Regional offices support the local operators with technical services as needed (i.e., major repairs), logistic support and fiscal control. The national office retains final fiscal control including billing and accounting, bulk procurement, specialized engineering support, planning, overall management, and relations with the State.

Ivory Coast is blessed with ample surface water resources and groundwater resources. Small SODECI systems tend to be based on drilled wells, while larger systems tend to have a major surface water component. In general, surface water sources are more abundant in the south; the north is much more arid and dependent on groundwater. An important exception is Abidjan where about 70 percent of the city's supply comes from wells. This water requires little treatment and is found at modest well depths.

The SODECI systems are classified according to size and treatment used, as described in the table below. These classifications are not rigid; for example, some of the larger systems may have more staff depending on the nature of the treatment works or other factors.

Class	C1	C2	C3	C4	C5	C6	CD
No. of connections	0-200	0-200	200-500	200-500	500-1500	500-1500	>1500
Treatment used	Simple	Full	Simple	Full	Simple	Full	Full
No. of staff	1	1	1	2	3	4	>=5
No. of motorbikes	1	1	1	1			
No. of vehicles					1	1	>=2

A typical C1 or C3 system consists of a drilled well, with electric pump, simple chlorination, an elevated concrete storage tank, PVC distribution network, and direct house connections with individual metering[3]. In urban

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[2] Average Exchange Rates CFA Francs/US Dollar:

CY 1985	449	FY 1986	362
CY 1986	346	FY 1987	305
Jan 1988	266 (spot value)		

[3] SODECI owns the one firm in Ivory Coast which makes water meters.

areas, SODECI had used public standposts in the past but has phased them out. They do use coin-operated standposts in urban areas (at a rate of 400 F/m^3, and acknowledge that water vendors (who charge about 1500 F/m^3) are common in some urban neighborhoods.

SODECI employed 1670 people as of the end of FY 86[4]. Operators are trained at a special SODECI training institute for a period of one year prior to assuming operational responsibility. SODECI uses considerably less staff than many public water utilities in Africa, but pay rates are probably higher than in other countries. SODECI makes ample use of daily labor which can be obtained quite cheaply.

Chemicals are purchased in bulk on the international market. SODECI shops for the best price, depending on market forces and exchange rates and pays import duty and taxes. The net costs are still far lower than prices charged by other importers selling in Abidjan. All systems use chlorination, and most of the larger ones (with surface water) use alum and lime.

Electric power is a major cost factor, due to high electric energy costs (approximately $0.20 per kwh). SODECI pays the normal electric rates, according to low voltage tariff for smaller stations, and medium voltage for larger ones. In 1982, SODECI initiated a major cost reduction program, focused on electric power costs. For medium voltage installations, major savings have been made by shifting pumping to off-peak hours as much as possible and by adjusting power demand to minimize demand charges.

Transport costs are high because fuel costs are very high ("super" gasoline was approximately $4.75 per gallon). Operators of small water systems are allocated a motorbike and given a fuel allowance and repair allowance. Actual expenses and bike use are left to the discretion of the user. Depending on the region, these bikes are amortized over two to four years. To keep vehicle and motorbike use down SODECI makes use of public transport for inter-city travel as much as possible. In larger systems, service vehicles (for meter readers or repair crews) are operated and maintained by the system staff. The allocation/allowance system is used for transport of senior staff.

Material costs are relatively low as most networks are relatively new and constructed primarily out of PVC. However, the frequency of repairs seems to be high. Electric motors for pumps or treatment plant equipment appear to be particularly susceptible. SODECI initiated a preventive maintenance program several years ago, with the support of a local engineering firm. This private consulting group established preventive maintenance procedures and schedules for a pilot water system in each province. SODECI was to replicate these procedures in other systems. Regional personnel now are completely convinced of the benefits of preventive maintenance.

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[4] SODECI uses a fiscal year from October to September. For example, FY 86 is from October 1985 to September 1986.

The national (uniform) water tariff is an increasing block rate structure, as indicated in the table below:

BLOCK	CONSUMPTION	PRICE PER M^3 Before 10/87	PRICE PER M^3 After 10/87	NOTES
Social	0-30 m^3/quarter	2000 F/quarter +99 F/m^3	159 F	Minimum billing of 15 m^3 for new tariff
Domestic	30-90 m^3/quarter	261 F	209 F	
Normal	90-300 m^3/quarter	330 F	307 F	
Government		261 F	261 F	
Industrial		458 F	412 F	Also used for consumption > 300 m^3/quarter
Fee retained by SODECI		159 F	134 F	

The O&M costs incurred by SODECI are discussed in much more detail in subsequent sections of this report. However, some quick figures to compare to the tariff above may be instructive. According to SODECI accounting records, the direct O&M costs[5] for both Abidjan and Bouaké were 70 F CFA per m^3 for FY 86, while smaller systems are typically 100 F to 200 F. Costs can even reach as high as 400 F for very small systems. Thus, given the tariff outlined above, it is clear that SODECI runs a surplus in the two cities and a deficit in the small systems. In essence, the big systems support the small systems.

4.3.3 Cost Estimates

With the Bouaké regional staff it was decided to visit a C1, a C4 and, if time allowed, a C6 site. Cost estimates were prepared for two sites, Beoumi (a C4), and Boniere (a C1). The first is a moderate-sized rural town and the other a smaller village. The first uses surface water (from a lake) and has a full water treatment plant, while the second has a drilled well and only simple chlorination. Engineering details of the two systems are outlined in Table 31. There was not adequate time to do a comparable survey of the C6 site.

[5] The indirect cost of the regional office in Bouaké and the prorated indirect cost of the national headquarters are not included in these figures. Such costs can be easily added in. The do not change the main point of a major surplus on these systems and a deficit on small ones.

Table 31

Engineering Details of the Beoumi and Boniere Systems

	Beoumi	Boniere
SODECI Class	C4	C1
Water Source	Dam next to a lake	Drilled well
Water Production (FY87)	133,000m^3/yr 365m^3/day aver	8864m^3/yr 24m^3/day aver.
Treatment	Aeration Flocculation Sedimentation Filtration pH adjustment Chlorination	Chlorination
Storage	Elevated tank 600m^3	Elevated tank 50m^3
Distribution Network		
PVC		
63mm	17620m	2000m
75mm	870m	
90mm	12825m	2000m
110mm	3060m	
Cast Iron		
60mm	60m	
100mm	80m	
200mm	4095m	
Total	38610m	4000m
Connections	642	71
SODECI personnel	2	1
Buildings	Treatment plant Office/house	Pump house Office/house
Motorbikes	2	1
Vehicles	0	0

The basic approach to estimating costs was to go to the site, interview the operator and, with his assistance and the guidance of the regional personnel, go through the steps outlined in the manual. The interview with the operator would begin with an explanation of the objectives—to estimate annual costs for the previous year and compare to real costs. Next, data would be collected on the system engineering design and configuration, and then the operational and maintenance tasks typically performed were reviewed.

A thorough discussion revealed all the tasks that require daily labor, the frequency of tasks, the time needed to complete these tasks, and typical wage rates.

In this way, step by step, estimates for most O&M cost components could be compiled. Labor, chemicals, power, and transport were relatively easy to estimate. Some topics such as operators' salary components and the details of the electric tariff, were best discussed with the regional staff after the interview. Estimates for materials/repair costs were more difficult. The operators didn't keep detailed records of material consumed or breakdown frequency. Operators didn't have much sense of the unit cost of repairs because they were done by outside shops. On several occasions the calculation procedures needed did not match the form of worksheets in this manual. To compute full labor costs or estimate pumping costs preliminary calculations were made on separate sheets, and the results entered in the worksheets.

The time needed to complete an estimate was about one day, with travel to the site, a tour of the system, interviewing, lunch, discussions, and return travel. Lengthy discussions were also held with regional and even national SODECI personnel before and after the estimates, for orientation to SODECI general procedures and to refine the estimates. Because of this learning requirement, initial estimates in any country or region will be slow but subsequent ones will go faster and faster.

Results of the cost estimates are given at the end of this section. Summaries for each site are given in Tables 32 and 33[6]. While the SODECI cost reports are tabulated differently from this manual, comparisons of estimates and real costs could also be made. A reasonably close estimate was prepared in both cases. Quite precise values were found for labor, chemicals, and electric power. Reasonable values could be found for contractors and other costs, with some use of cost records. However, without extensive use of cost records, only rather poor estimates of materials/repair costs were possible. Estimates tended to underestimate these material costs, but since power or transport were often often overestimated, the net result was not far off.

[6] These tables do not include depreciation expenses and non-water-related expenses which are normally found in SODECI accounting records.

TABLE 32

ESTIMATED AND REAL O&M COSTS - BONIERE

	ESTIMATED	REAL FY 87	ESTIMATED /REAL
LABOR	1,564,483F	1,567,000F	99.8%
MATERIALS			
Supplies	42,500F	12,000F	
Parts	60,000F	285,000F	
Repairs		11,000F	
Total	102,500F	308,000F	33.3%
CHEMICALS	818F	1,250F	65.4%
ELECTRIC POWER			
Pumps/plant	397,481F	436,320F	
Office/house	101,428F	77,180F	
Total	498,909F	513,500F	97.2%
TRANSPORT			
Travel/Allowances	327,800F	226,000F	
Fuel	297,000F	262,500F	
Total	624,800F	488,500F	127.9%
CONTRACTORS /SERVICES	68,500F	52,220F	131.2%
OTHER	160,000F	175,000F	91.4%
TOTAL DIRECT O&M COST	3,020,010F	3,105,470F	97.2%
COST PER CONNECTION	42,535F	43,739F	
COST PER m3	341F	350F	
TOTAL DIRECT O&M COST WITH 10% CONTINGENCY	3,322,011F	(Real) 3,105,470F	107.0%

TABLE 33

ESTIMATED AND REAL O&M COSTS - BEOUMI

	ESTIMATED	REAL FY 87	ESTIMATED /REAL
LABOR	3,305,203F	3,623,000F	91.2%
MATERIALS			
Supplies	130,000F	143,000F	
Parts	480,000F	682,000F	
Repairs	600,000F	1,387,000F	
Total	1,210,000F	2,212,000F	54.7%
CHEMICALS	4,998,672F	4,912,000F	101.8%
ELECTRIC POWER			
Pumps/plant	2,596,220F	2,742,500F	
Office/house	493,209F	188,500F	
Total	3,089,429F	2,931,000F	105.4%
TRANSPORT			
Travel/Allowances	391,600F	339,400F	
Fuel	528,000F	408,000F	
Total	919,600F	747,400F	123.0%
CONTRACTORS /SERVICES	338,600F	384,794F	88.0%
OTHER	440,000F	707,000F	62.2%
TOTAL DIRECT O&M COST	14,301,504F	15,517,194F	92.2%
COST PER CONNECTION	22,276F	24,170F	
COST PER m3	107F	116F	
TOTAL DIRECT O&M COST WITH 10% CONTINGENCY	15,731,654F	(Real) 15,517,194F	101.4%

Calculations were also made for the cost of regional/national offices. Derivations are given in Tables 34 and 35. These costs were added onto the direct costs for these systems, on a prorated basis, in Table 36. Various methods of applying these indirect costs were used. The "overhead" method applies these costs in proportion to the direct costs themselves. The other two prorate these costs per m^3, or per connection. Prorating costs per m^3 allows economies of scale to be passed to the the small systems, but the opposite is true with the overhead basis. The connection approach runs down the middle. No matter the method, these "overheads" are substantial. Calculations to assess financial viability of water systems accurately must include these costs. However, for a simple engineering study comparing different technical systems, these overheads are less important.

4.3.4 Analysis of O&M Costs

Additional data on the O&M costs of the other water systems in the Bouaké region were collected and analyzed. This exercise was performed to evaluate the "representativeness" of the sites where the cost estimates were performed, and to investigate trends in O&M costs.

An examination was made of costs for 15 systems, from very small to very large, including systems with simple and full treatment. In general, the systems with simple treatment are the smaller systems, and full treatment systems are the larger ones. The simple systems are found over a narrow range, but full systems over a broad range. Data for FY 86 and FY 87 were obtained from large computer printouts, showing line-item costs for every SODECI water system in the country. Depreciation expense is included here, in keeping with SODECI accounting records. However, regional and national office costs are not included.

Tables 37 and 38 show a summary of the results, including cost breakdowns, cost per cubic meter, and labor analysis for the two years. For the simple systems, labor and power are the dominant costs. In the larger, full treatment systems, costs per m^3 fall, with a more even split of costs between labor, power, and chemicals.

In Figures 32 and 33, direct O&M costs per m^3 are shown as a function of annual water volume produced. There are very clear economies of scale with the small simple systems. In fact, using regression analysis a cost function was fit to the data. The results showed an economy-of-scale factor of 0.43 and 0.47 for FY 86 and FY 87, indicating substantial economies of scale[7]. With the full treatment systems, economies of scale are less evident. Regression analysis showed an economies-of-scale factor of 0.83 in both years, indicating less effect of scale[8].

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[7] The regression correlation coefficient, r^2, was 0.88 and 0.85, respectively, for the two years, which indicates a good curve fit.

[8] For the full treatment systems the correlations were not as good, with r^2 values of 0.58 and 0.52 in the two years.

TABLE 34

REGIONAL OVERHEAD/ADMINISTRATIVE COSTS FOR THE BOUAKE REGION

	FY 1986	FY 1987
TOTAL CONNECTIONS	17,717	17,970
REGIONAL VOLUME BILLED, m3		
REGIONAL VOLUME PRODUCED, m3	5,727,131	6,174,937
VOLUME PRODUCED/CONNECTION m3/yr	323	344
REGIONAL DIRECT WATER COSTS	469,292,000F	507,548,000F
REGIONAL ADMINISTRATION COSTS	166,031,000F	170,419,000F
TOTAL REGIONAL WATER COSTS	635,323,000F	677,967,000F
REGIONAL ADMINSTRATIVE RATE	35.4%	33.6%
REGIONAL ADMIN. per m3 PRODUCED	28.99F	27.60F
REGIONAL ADMIN per CONNECTION	9,371F	9,484F

TABLE 35

NATIONAL HEADQUARTERS ADMINISTRATIVE/OVERHEAD COSTS AT SODECI

	FY 1986	FY 1987	NOTES
TOTAL CONNECTIONS	185,602	193,288	FY 87 Estimated
NATIONAL VOLUME BILLED, m3	76,576,000	80,098,496	FY 87 Estimated
NATIONAL VOLUME PRODUCED, m3	87,018,182	91,021,018	Assumes 88% billed/prod
VOLUME PRODUCED/CONNECTION m3/yr	469	471	
DIRECT WATER COSTS	7,983,422F	8,086,909F	In thousands of F CFA
INDIRECT WATER COSTS (Headqrtrs)	1,561,569F	1,291,910F	In thousands of F CFA
TOTAL NATIONAL WATER COSTS	9,544,991F	9,378,819F	In thousands of F CFA
TOTAL ADMINISTRATIVE COST	4,716,760F	6,234,438F	In thousands of F CFA
PRORATED (WATER) ADMIN COSTS	3,348,283F	4,517,067F	In thousands of F CFA
GRAND TOTAL WATER COSTS	12,893,274F	13,895,886F	In thousands of F CFA
per connection	69,467F	71,892F	
per m3 billed	168F	173F	
per m3 produced	148F	153F	
INDIRECT WATER RATE	19.56%	15.98%	
WATER ADMINISTRATIVE RATE	35.08%	48 16%	
NET NATIONAL SURCHARGE	61.50%	71.83%	
INDIRECT WATER COSTS per m3 prod	17.95F	14 19F	
WATER ADMIN COSTS per m3 produced	38.48F	49.63F	
SUM	56.42F	63 82F	
INDIRECT WATER COSTS per m3 bill	20.39F	16 13F	
WATER ADMIN COSTS per m3 billed	43 72F	56 39F	
SUM	64.12F	72.52F	
INDIRECT WATER COSTS per connect.	8,414F	6,684F	
WATER ADMIN COSTS per connection	18,040F	23,370F	
SUM	26,454F	30,054F	

TABLE 36

APPLICATION OF PRORATED REGIONAL AND NATIONAL SURCHARGES

OVERHEAD APPROACH	BONIERE	BEOUMI
TOTAL DIRECT O&M COST	3,020,010F	14,301,504F
REGIONAL OVERHEAD @ 33.6%	1,014,723F	4,805,305F
SUBTOTAL	4,034,733F	19,106,809F
NATIONAL OVERHEAD @ 71.83%	2,898,149F	13,724,421F
DERIVED GRAND TOTAL O&M COST	6,932,882F	32,831,230F
per connection	97,646F	51,139F
per m3	782F	246F

WATER PRORATED APPROACH	BONIERE	BEOUMI
TOTAL DIRECT O&M COST	3,020,010F	14,301,504F
per m3 produced	341F	107F
REGIONAL ADMIN. per m3	28F	28F
INDIRECT WATER COSTS per m3	18F	18F
WATER ADMIN. COST per m3	38F	38F
TOTAL WATER COST per m3	425F	191F
DERIVED GRAND TOTAL O&M COST	3,764,852F	25,497,577F
per connection	53,026F	39,716F
per m3	425F	191F

CONNECTION PRORATED APPROACH	BONIERE	BEOUMI
TOTAL DIRECT O&M COST	3,020,010F	14,301,504F
per conn.	42,535F	22,276F
REGIONAL ADMIN. per connect.	9,484F	9,484F
INDIRECT WATER COSTS per conn	6,684F	6,684F
WATER ADMIN. COST per conn.	23,370F	23,370F
TOTAL WATER COST per connect.	82,073F	61,814F
DERIVED GRAND TOTAL O&M COST	5,827,208F	39,684,900F
per connection	82,073F	61,814F
per m3	657F	298F

Table 37

SODECI Water O&M Costs

(FY 86)

SODECI
WATER O&M COSTS FY86
BOUAKE REGION

SITE	SOURCE	TREATMENT	NUMBER OF CONNECTIONS	NUMBER OF PERMAN. STAFF	ANNUAL WATER PRODUCTION (m3/yr)	m3/day PER STAFF	TOTAL EXPENSES (Thous. of F)	EXPENSES PER m3 PRODUCED (F CFA)	DIRECT EXPENSE PER m3 PRODUCED: LABOR	MATER.	CHEMS	ELECTR.	TRANS.	SERVICES	DEPR.	OTHERS
N'Guessan	(from Bouake)		586	1			8095									
Niakara	Dam	Full	239	1	35,643	98	7119	200F	63.3F	16.9F	24.0F	58.9F	11.6F	2.3F	5.8F	16.8F
Botro	Dam	Full	190	1	42,285	116	7248	171F	60.5F	11.2F	21.3F	50.3F	6.6F	3.0F	5.4F	13.1F
Dabakala	Dam	Full	386	2	75,062	103	10240	136F	53.1F	5.0F	18.4F	28.5F	7.2F	11.1F	4.4F	8.8F
Tortiya	River	Full	235	1	82,131	225	6907	84F	27.3F	3.4F	7.7F	29.7F	4.8F	3.0F	3.0F	5.1F
Beoumi	Dam	Full	645	2	117,764	161	15810	134F	39.6F	7.4F	35.0F	26.5F	5.1F	8.0F	5.6F	7.0F
Katiola	Dam + Wells	Full	1502	6	314,488	144	42679	136F	38.1F	6.3F	24.0F	41.3F	13.7F	2.0F	3.7F	6.5F
Bouake	Dam + Wells	Full	12215	36	4,850,517	369	335499	69F	19.0F	3.4F	12.1F	23.6F	3.1F	1.0F	3.1F	4.0F
Boniere	Well	Chlor.	56	1	6,640	18	2790	420F	269.3F	13.9F	0.3F	56.7F	42.3F	5.7F	16.4F	15.7F
Brobo	Well	Chlor.+Neutr	149	1	17,810	49	4602	258F	94.6F	8.2F	0.3F	106.7F	13.5F	10.1F	7.3F	17.6F
Fronan	Well	Chlor.	194	1	16,246	45	4221	260F	118.5F	16.2F	0.8F	88.6F	19.1F	0.6F	9.2F	6.9F
Prikro	Well	Chlor.	248	1	25,628	70	5010	195F	86.5F	13.3F	7.5F	43.7F	16.0F	6.5F	8.3F	13.6F
Tafire	Well	Chlor.	190	1	32,522	89	3902	120F	50.3F	2.2F	0.2F	41.6F	7.8F	1.0F	9.9F	7.0F
Sakassou	Well	Chlor.	604	2	49,849	68	6722	135F	52.5F	7.4F	4.0F	25.4F	10.7F	13.8F	14.7F	6.4F
M'Baiakro	Well	Chlor.	278	1	60,546	166	8348	138F	45.9F	2.8F	3.7F	61.0F	8.7F	1.0F	7.6F	7.2F
REGIONAL TOTAL			17717	58	5,727,131	271	469192	82F	23.9F	3.9F	13.1F	26.3F	5.1F	1.6F	3.5F	4.6F
COUNT	15	14	15	15	14	14	15	14F	14	14	14	14	14	14	14	14
MEAN			1181	4	409,081	123	31279	176F	72.7F	8.4F	11.4F	48.7F	12.2F	4.9F	7.5F	9.7F
STD DEV			2969	9	1,234,080	87	81845	87F	60.3F	4.9F	10.9F	23.7F	9.5F	4.2F	3.9F	4.5F
SD/MEAN			2.51	2.24	3.02	0.71	2.62	0.49	0.83	0.58	0.95	0.49	0.78	0.85	0.53	0.46
MINIMUM			56	1	6,640	18	2790	69F	19.0F	2.2F	0.2F	23.6F	3.1F	0.6F	3.0F	4.0F
MAXIMUM			12215	36	4,850,517	369	335499	420F	269.3F	16.9F	35.0F	106.7F	42.3F	13.8F	16.4F	17.6F

Table 38

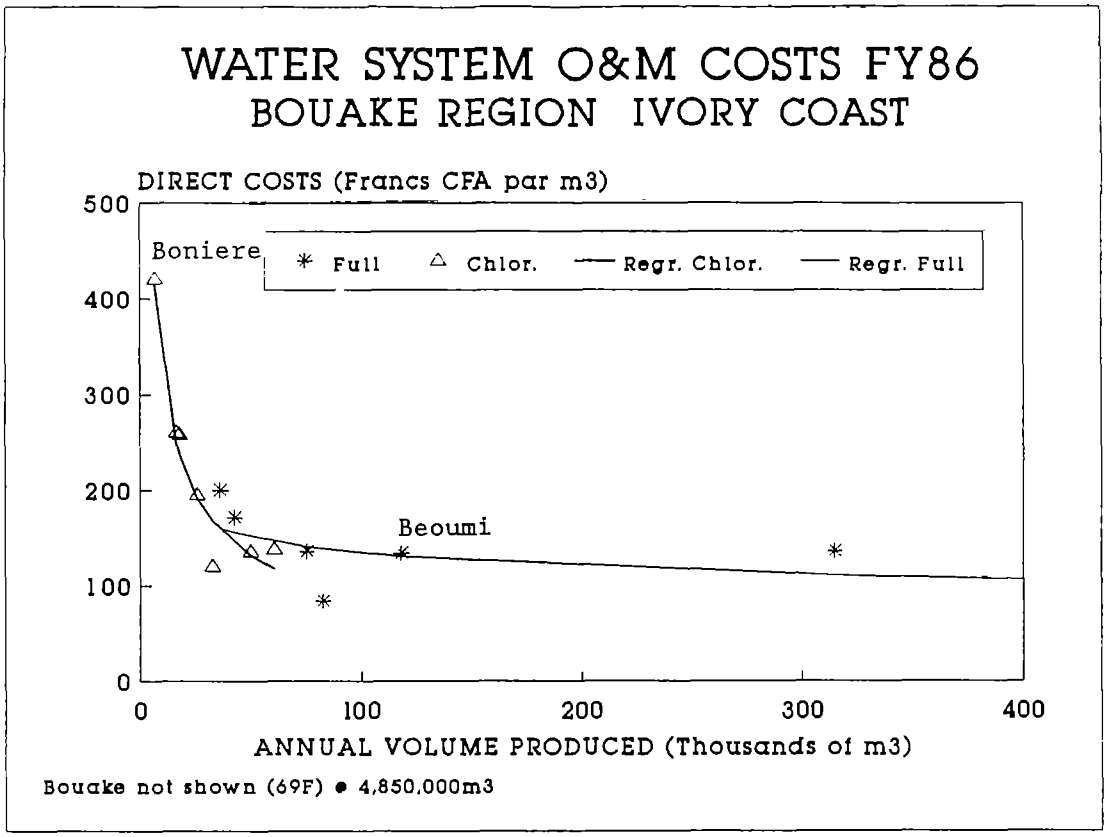
SODECI Water O&M Costs

(FY 87)

SODECI
WATER O&M COSTS FY87
BOUAKE REGION

SITE	SOURCE	TREATMENT	NUMBER OF CON-NECTIONS	NUMBER OF PERMAN. STAFF	ANNUAL WATER PRODUCTION (m3/yr)	m3/day PROD. PER STAFF	TOTAL EXPENSES (Thous. of F)	EXPENSES PER m3 PRODUCED (F CFA)	DIRECT EXPENSE PER m3 PRODUCED LABOR	MATER.	CHEMS	ELECTR.	TRANS.	SERV.	DEPR.	OTHERS
N'Guessan	(from Bouake)			1			6692									
Niakara	Dam	Full	241	1	39,570	108	8395	212F	60.1F	23.7F	18.1F	66.8F	11.9F	3.1F	10.2F	18.1F
Botro	Dam	Full	309	1	40,753	112	6677	164F	40.2F	14.8F	37.2F	43.1F	8.0F	1.2F	14.4F	4.9F
Dabakala	Dam	Full	411	2	83,960	115	11655	139F	39.9F	11.8F	20.2F	29.5F	7.5F	11.6F	6.2F	12.0F
Tortiya	River	Full	249	1	85,008	233	7353	86F	23.2F	8.6F	7.1F	23.1F	11.3F	1.3F	2.4F	9.5F
Beoumi	Dam	Full	622	2	133,293	183	16593	124F	30.1F	6.2F	36.9F	22.0F	5.3F	10.4F	8.4F	5.3F
Katiola	Dam + Wells	Full	1715	6	324,055	148	43284	134F	43.9F	2.5F	18.2F	39.1F	13.9F	0.8F	5.6F	9.4F
Bouake	Dam + Wells	Full	12760	36	5,195,199	395	366679	71F	17.8F	3.0F	15.3F	22.0F	3.0F	0.9F	3.5F	5.0F
Boniere	Well	Chlor.	79	1	8,864	24	3555	401F	199.7F	33.4F	0.1F	58.0F	55.1F	1.2F	33.8F	19.7F
Brobo	Well	Chlor.+Neut	152	1	22,662	62	4886	216F	66.1F	7.2F	4.3F	97.1F	10.9F	2.9F	15.4F	11.7F
Fronan	Well	Chlor.	219	1	23,200	64	4475	193F	91.6F	8.5F	0.3F	51.9F	17.6F	2.8F	16.8F	3.4F
Prikro	Well	Chlor.	151	1	25,240	69	3618	143F	63.6F	9.1F	0.3F	33.0F	14.2F	2.4F	12.3F	8.5F
Tafire	Well	Chlor.	200	1	33,029	90	5001	151F	46.7F	24.8F	0.4F	41.3F	12.5F	3.6F	11.7F	10.3F
Sakassou	Well	Chlor.	511	2	64,894	89	9310	143F	50.0F	10.3F	0.0F	27.5F	9.6F	24.6F	14.8F	6.7F
M'Baiakro	Well	Chlor.	351	1	95,210	261	9375	98F	36.8F	3.4F	1.0F	42.0F	5.7F	0.6F	4.2F	4.7F
REGIONAL TOTAL			17970	58	6,174,937	292	507548	82F	22.3F	3.8F	15.4F	24.4F	4.9F	1.5F	4.3F	5.6F
COUNT	15	14	14	15	14	14	15	14F	14	14	14	14	14	14	14	14
MEAN			1284	4	441,067	140	33837	163F	57.8F	11.9F	11.4F	42.6F	13.3F	4.8F	11.4F	9.2F
STD DEV			3207	9	1,320,794	96	89460	78F	43.4F	8.9F	12.8F	20.0F	12.2F	6.4F	7.7F	4.8F
SD/MEAN			2.50	2.24	2.99	0.69	2.64	0.48	0.75	0.74	1.12	0.47	0.91	1.33	0.68	0.52
MINIMUM			79	1	8,864	24	3555	71F	17.8F	2.5F	0.0F	22.0F	3.0F	0.6F	2.4F	3.4F
MAXIMUM			12760	36	5,195,199	395	366679	401F	199.7F	33.4F	37.2F	97.1F	55.1F	24.6F	33.8F	19.7F

Figure 32



Cost Functions FY 86:

Chlorinated Systems: Cost per m^3 = 61768 $Q^{-0.5685}$ ($r^2 = 0.88$)

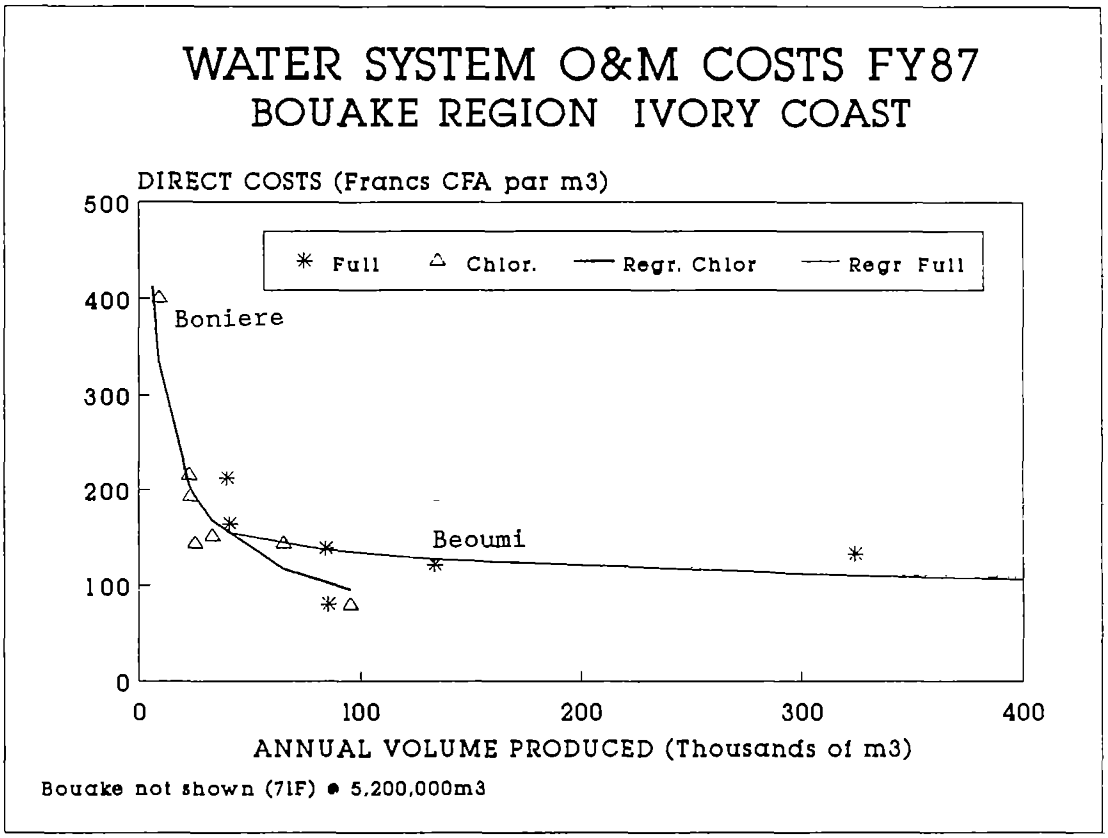
Full Treatment Systems: Cost per m^3 = 942 $Q^{-0.1691}$ ($r^2 = 0.58$)

Economy of Scale Factor:

Chlorinated Systems: 1 - 0.5685 = 0.4315

Full Treatment Systems: 1 - 0.1691 = 0.8309

Figure 33



Cost Functions FY 87:

Chlorinated Systems: Cost per m^3 = 41157 $Q^{-0.5289}$ (r^2 = 0.85)

Full Treatment Systems: Cost per m^3 = 886 $Q^{-0\ 1643}$ (r^2 = 0.52)

Economy of Scale Factor:

Chlorinated Systems: 1 - 0.5289 = 0 4711

Full Treatment Systems: 1 - 0 1643 = 0.8357

These effects can be logically explained by looking at cost components. The small systems have a large fixed cost component (labor), and a lesser variable cost component (power, chemicals), so economies of scale should be pronounced. With the larger full treatment systems, labor costs will be more closely linked to size, and the variable costs (power and chemicals) will be more significant, making economies of scale less pronounced. The greater variability of costs with full treatment systems can be attributed to greater site variability in raw water quality, producing greater cost variability.

From the tables and figures we can conclude the Beoumi and Boniere represent a reasonable sampling of regional costs. That is, they don't appear to be extraordinary systems in any way.

The variation of costs from year to year is also an interesting point. Table 39 shows aggregate regional figures for direct O&M costs. The total unit cost changed little from one year to the next. However, as shown in Figure 34, the breakdown of costs shows some shifts. Labor and power costs per m^3 actually declined, while chemical costs rose markedly (up 17 percent). Careful examination of records shows that chemical consumption, not prices, rose, presumably due to declining water quality. The decline in unit power costs can be attributed to SODECI's electricity cost reduction efforts. It is also worth noting that gross revenues rose, but not as fast as the production of water, causing a net decline in the unit revenues.

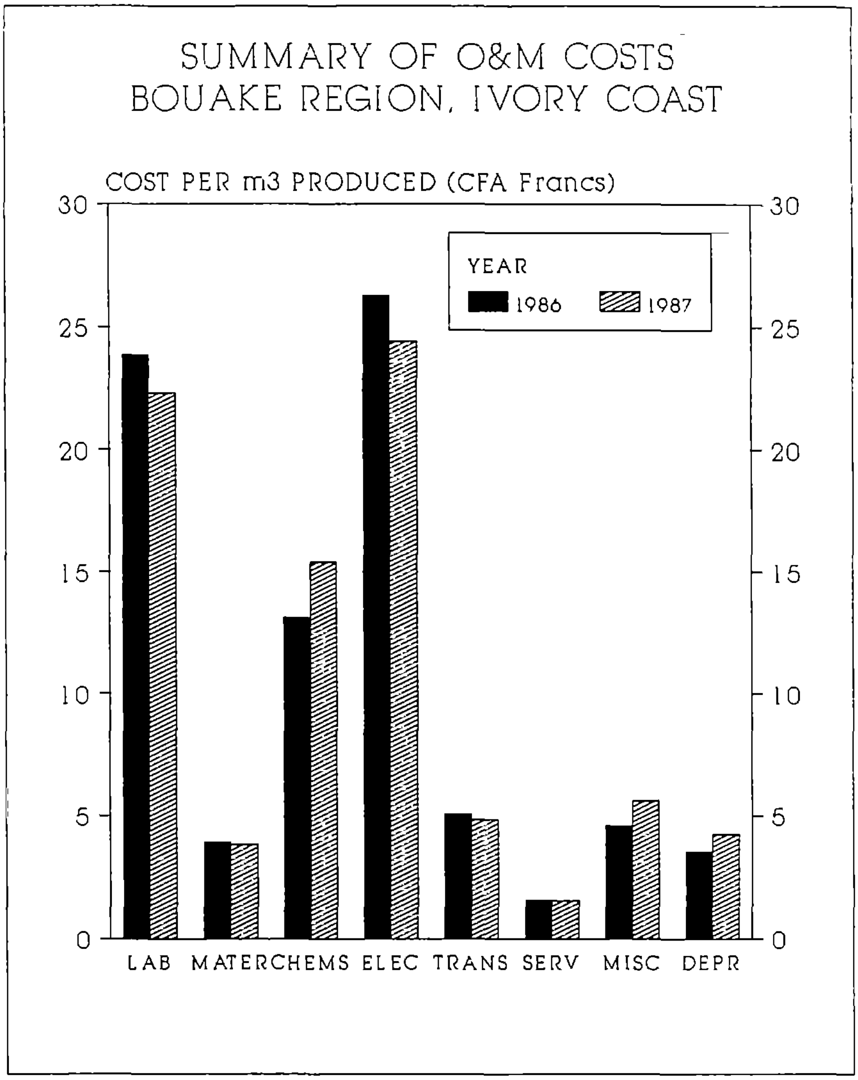
Overall, analyses of O&M costs such as those presented above are a useful complement to the direct cost estimation procedure, but they depend entirely on the availability of reliable and complete cost records.

Table 39

Summary of Costs for Bouaké Region

YEAR	1986	1987	% DIFF
# OF CONNECTIONS	17,717	17,970	1 4%
VOLUME PRODUCED (m3)	5,727,131	6,174,937	7 8%
VOL PROD/CONNECTION	323	344	6 3%
GROSS REVENUE	891,835,000F	905,991,000F	1 6%
REVENUE/CONNECTION	50,338F	50,417F	0 2%
REVENUE/m3 PRODUCED	156F	147F	-5.8%
EXPENSES			
LABOR	136,631,000F	137,634,000F	0 7%
MATERIALS	22,385,000F	23,570,000F	5 3%
CHEMICALS	75,217,000F	95,207,000F	26 6%
ELECTRICITY	150,469,000F	150,789,000F	0 2%
TRANSPORT	29,105,000F	29,957,000F	2 9%
SERVICES	9,013,000F	9,544,000F	5 9%
MISC	26,282,000F	34,573,000F	31 5%
SUBTOTAL	449,102,000F	481,274,000F	7 2%
DEPRECIATION	20,190,000F	26,274,000F	30 1%
TOTAL EXPENSES	469,292,000F	507,548,000F	8 2%
TOTAL EXPENSES/CONNECTION	26,488F	28,244F	6 6%
TOTAL EXPENSES/m3 PRODUCED	82F	82F	0 3%
GROSS MARGIN	422,543,000F	398,443,000F	-5 7%
EXPENSE PER m3 PRODUCED			
LABOR	23.9F	22.3F	-6 6%
MATERIALS	3.9F	3 8F	-2 3%
CHEMICALS	13 1F	15.4F	17 4%
ELECTRICITY	26.3F	24 4F	-7 1%
TRANSPORT	5.1F	4 9F	-4 5%
SERVICES	1.6F	1 5F	-1.8%
MISC	4 6F	5.6F	22 0%
SUBTOTAL	78 4F	77.9F	-0 6%
DEPRECIATION	3.5F	4.3F	20 7%
TOTAL EXPENSES	81 9F	82 2F	0 3%
EXPENSE PER CONNECTION			
LABOR	7,712F	7,659F	-0 7%
MATERIALS	1,263F	1,312F	3 8%
CHEMICALS	4,245F	5,298F	24 8%
ELECTRICITY	8,493F	8,391F	-1 2%
TRANSPORT	1,643F	1,667F	1 5%
SERVICES	509F	531F	4 4%
MISC	1,483F	1,924F	29 7%
SUBTOTAL	25,349F	26,782F	5 7%
DEPRECIATION	1,140F	1,462F	28 3%
TOTAL EXPENSES	26,488F	28,244F	6 6%
COST BREAKDOWN			
LABOR	29.1%	27 1%	-6 9%
MATERIALS	4.8%	4 6%	-2 6%
CHEMICALS	16 0%	18.8%	17 0%
ELECTRICITY	32 1%	29.7%	-7 3%
TRANSPORT	6.2%	5.9%	-4 8%
SERVICES	1.9%	1.9%	-2 1%
MISC	5.6%	6 8%	21 6%
SUBTOTAL	95.7%	94 8%	-0 9%
DEPRECIATION	4 3%	5.2%	20 3%
TOTAL EXPENSES	100.0%	100 0%	0 0%
LABOR ANALYSIS			
# OF PERM STAFF	58	58	0 0%
COST/PERM. STAFF	2,355,707F	2,373,000F	0 7%
CONNECTIONS/PERM. STAFF	305	310	1 4%
m3/day / PERM. STAFF	271	292	7 8%

Figure 34


SUMMARY OF O&M COSTS
BOUAKE REGION, IVORY COAST
COST PER m3 PRODUCED (CFA Francs)
YEAR
1986
1987
30
25
20
15
10
5
0
LAB
MATER
CHEMS
ELEC
TRANS
SERV
MISC
DEPR

WASH O&M COST ESTIMATING HANDBOOK — PAGE 1 — LABOR ESTIMATE

SITE: BEOUMI AGENCY: SODECI

POPULATION: 642 Connections PREPARED BY: A Wyatt

ANNUAL WATER PRODUCTION, m3: FY87 133,239 m³/yr DATE: 1/25/88

1) DIRECT LABOR - REGULAR TIME

A) MANAGEMENT/SUPERVISION

Classification	No. in Class	Average Monthly Wage	% Time	Total
Chef de Centre	1			2,055,006 F

B) SKILLED LABOR

Classification	No. in Class	Average Monthly Wage	% Time	Total
Agent de Station	1			1,250,197 F

C) UNSKILLED LABOR

Classification	No. in Class	Average Monthly Wage	% Time	Total
Daily Labor – See Contractors Sheet				

~~MONTHLY SUBTOTAL~~

ANNUAL SUBTOTAL 3,305,203 F

Figure 35. Labor Estimate Form

LABOR - BEOUMI

	Chef de Centre	Agent de Station
1) SALARY		
Base Salary	86,622F	53,502 F
Supplementary Salary	12,314F	0 F
Subtotal	98 936 F	53,502 F
Seniority Bonus	8904F	2140 F
TOTAL MONTHLY SALARY	107,840	55,642 F
2) ALLOWANCES		
Motor bike	3000 F	3000 F
Cash box management (10% of Monthly)	9894 F	0 F
3) TOTAL MONTHLY PAY	120,734F	58,642
4) TOTAL ANNUAL (Monthly x 11)	1,328,074F	645,062F
5) SOCIAL SECURITY, HEALTH BENEFITS, RETIREMENT, ETC 55%	652,432F	336,634 F
5b) LODGING ALLOWANCE (17000 F/month x 12)		204,000 F
6) YEAR END BONUS	74,500 F	64,500 F
7) GRAND TOTAL ANNUAL LABOR COST	2,055,006F	1,250,197F

SITE: BEOUMI AGENCY:

POPULATION: PREPARED BY:

ANNUAL WATER PRODUCTION, m3: DATE:

2) DIRECT LABOR - OVERTIME

Classification	No. in Class.	Average Overtime Hrs.	Hourly Rate	% Time	Total

MONTHLY SUBTOTAL

ANNUAL SUBTOTAL 0

3) ADMINISTRATION

Classification	No. in Class.	Average Monthly Wage	% Time	Total
Direct Costs	Only!			

MONTHLY SUBTOTAL

ANNUAL SUBTOTAL 0

TOTAL LABOR ESTIMATE (1+2+3) = 3,305,203F

Figure 36. Labor Estimate Form (p. 2)

WASH O&M COST ESTIMATING HANDBOOK PAGE 3 MATERIALS ESTIMATE

SITE. BEOUMI
AGENCY:
POPULATION:
PREPARED BY:
ANNUAL WATER PRODUCTION, m3:
DATE:

1) SUPPLIES

Item	Unit	Annual Quantity	Unit Cost	Total
SMALL REPAIRS SUPPLIES (PIPE BREAKS)		58	1000 F	58,000
OTHER SUPPLIES		12 (monthly)	1000 F	12,000
FORMS, PAPER, MISC SUPPLIES				60,000
			SUBTOTAL	130,000

2) PARTS

Item	Unit	Annual Quantity	Unit Cost	Total
ELECTRICAL PARTS		12 (monthly)	20,000 F	240,000
MECHANICAL PARTS		12 (monthly)	20,000 F	240 000
LARGE REPAIR		1	600,000 F	600,000 F
			SUBTOTAL	1,080 000 F

3) TOOLS

Item	Unit	Annual Quantity	Unit Cost	Total
			SUBTOTAL	0

TOTAL MATERIALS ESTIMATE = 1,210,000 F

Figure 37. Materials Estimate Form

SITE: BEOLMI AGENCY:

POPULATION: PREPARED BY:

ANNUAL WATER PRODUCTION, m3: 133,239 m³/yr DATE:

CHEMICAL CONSUMPTION

Chemical Used	Desired Dosage (mg/l)	Commercial Strength, %	Required Dosage (mg/l)	Water Production (m3/day)	Net Consumption ~~(kg/day)~~ M tons/yr
Alum			130 g/m³	133,239	17.321
LIME			10.69 g/m³	133,239	1.424
CALCIUM HYPOCHLORITE			29.27 g/m³	133,239	3 900
	a	b	c=a/b	d	e=c*d/1000

CHEMICAL COST

Chemical Used	Net Consumption, ~~kg/day~~ M tons/yr	Chemical Unit	No. of Units/yr	Unit Cost	Total Cost
Alum	17.321	50 kg		127F/kg	2,199,767F
LIME	1.424	25 kg		114 F/kg	162,373
CALCIUM HYPOCHLORITE	3 900	50 kg		615 F/kg	2,398,500
					4,760,640
			ADD	5% FOR WASTE	238,032
				ANNUAL SUBTOTAL	4,998,672

TOTAL CHEMICALS ESTIMATE = 4,998,672

Figure 38. Chemicals Estimate Form

WASH O&M COST ESTIMATING HANDBOOK	PAGE 5 UTILITIES ESTIMATE
SITE: BEOUMI	AGENCY:
POPULATION:	PREPARED BY:
ANNUAL WATER PRODUCTION, m3:	DATE:

1) ELECTRIC POWER

A) DEMAND CHARGE

Peak Power (KW)	Demand Charge / KW	Annual Demand Charge
Trtmt Plant (MV) 28kw	14080/KW/YEAR	394,240 F
Office/House (LV) 9.8kw	1200 F/KW every 2 months	143,160 F
		537,400 F

B) ENERGY CHARGE

	Equipment	# of units	Rated Power (Hp)	Power Draw (kw)	Daily Operating Period (hr)	Average Daily Energy Consumption (kwh)	Days Use per Year	Energy Cost/kwh	Total Cost
PLANT	RAW WATER PUMP			4.6kw	8.69	46.00	365	33.84F	494064F
	FINISHED WATER PUMP			13.2kw	9.01	118.90	365	33.84F	1,468,605F
	COMPRESSOR			15.0kw	0.25	3.75	365/2	"	23,159
	BACK WASH PUMP			7.5kw	0.50	3.75	365/2	"	23,159
	DOSING PUMPS	5	0.25	1.25kw	8.00	10.00	365	"	123,516
	AGITATORS	5	0.15	0.75kw	2.00	1.50	365	"	18,527
	LIGHTING	11		W25each	15.00	4.125	365	"	50,950
OFFICE HOUSE	LIGHTING	10		W25each	8.00	2.00	"	59.20F	43216
	AIR COND	1		1	12.00	12.00	"	59.20F	259296
	RADIO	1		50W	8.00	0.40	"	59.20F	8643
	FRIDGE	1		150W	12.00	1.80	"	59.20F	38894
		a		b	c	d=b*c	e	f	g=a*d*e*f

ELECTRIC ENERGY SUBTOTAL 2,552,029

2) FUEL

Equipment	# of units	Power (Hp)	Type of Fuel Used	Daily Operating Period (hr)	Average Hourly Fuel Consumption	Days Use per Year	Unit Fuel Cost	Total Cost
	a			b	c	d	e	f=a*b*c*d*e

FUEL SUBTOTAL 0

TOTAL UTILITIES ESTIMATE = 3,089,429

Figure 39. Utilities Estimate Form

PUMP CALCULATIONS

RAW WATER PUMPING

HEAD = 25 m

	Q, m³/hr	Q l/s	P electric
Pump A	36	10	4.0
Pump B	48	13.3	5.2

> AVERAGE 4.6 kW

Hours/Day = 133,239 ÷ 365 = 365 ÷ 42 m³/hr = 8.69 hrs/day

FINISHED WATER PUMPING

HEAD = 54 m

	Q, m³/hr	Q l/s	P electric
Pump A	38	10.6	12.4 kw
Pump B	43	11.9	14.0 kw
	Ave = 40.5		

> AVERAGE = 13.2 kW

Hours/Day = 133,239 ÷ 365 = 365 ÷ 40.5 = 9.01 hrs/day

DEMAND CHARGES

1) Tr Plant Power Subscription (MV) = 28 kW
@ MV rate 14080 F/kw/YEAR

2) Office/House Power Subscription (LV) = 19.8 kW
@ LV Rate 19.8 X 1200 F every 2 months + 100 F every 2 months
= 143160 F

ENERGY CHARGE

LV ⇒ 59.2 F/kwhr

MV			
	Day	38.00	30%
	Peak	58.80	10%
	Night	27.30	60%

⟶ 33.84 F/kwhr

SITE: BEOUMI AGENCY:

POPULATION: PREPARED BY:

ANNUAL WATER PRODUCTION, m3: DATE:

TRANSPORT NEEDS

Transport Purpose	Vehicle Type	Annual Trip Frequency	Average Trip Distance	Total Distance
ATTEND MEETINGS IN BOUAKE	PUBLIC BUS	2/month = 24		
ATTEND OPERATORS SPECIAL MEETINGS IN BOUAKE	PUBLIC BUS	4/YEAR		
OTHER TRIPS TO BOUAKE (CHEF DE CENTRE)		4/YEAR		
SUMMON REPAIR CREW (AGENT)	PUBLIC BUS	4/YEAR		
OTHER TRIPS TO BOUAKE (AGENT)	PUBLIC BUS	8/YEAR		
TRANSPORT OF MAIL TO BOUAKE		2/month = 48		
MISC TRANSPORT AT SITE	MOTORBIKE (2)			

TRANSPORT COSTS

Vehicle Type	Total Distance for Vehicle Type	Unit Travel Cost	Total Cost
PUBLIC BUS TO BOUAKE	32 TRIPS (Chef)	3000F	96,000 F
	12 TRIPS (Agent)	3000F	36,000 F
TRAVEL EXPENSES			
MEALS	24 MEALS (Agent)	1100 F	26,400 F
MEALS	76 MEALS (Chef)	1300 F	98,800 F
HOTEL	36 NIGHTS (Chef)	2400 F	86,400 F
MAIL CARRIER	48 TRIPS	1000 F	48,000 F
MOTORBIKE	2 X 60 l/mon X 11 months	400F/litre	528,000 F

TOTAL TRANSPORT COST 919,600

TOTAL TRANSPORT ESTIMATE = 919,600 F

Figure 40. Transport Estimate Form

SITE: BECUMI AGENCY:

POPULATION: PREPARED BY:

ANNUAL WATER PRODUCTION, m3: DATE:

1) PRIVATE CONTRACTORS

A) SCHEDULED

Task / Service Performed	Annual Frequency of Service/Contract	Service / Contract Cost	Total
CLEAN INTAKE AT DAM	24	3000 F	72 000
CLEAN STORAGE TANK	2	2000 F	4000F
GROUNDSKEEPING	12	2300 F	27 600 F
MISC PLANT TASKS	12	3000 F	36 000 F
ELECTRO/MECH MAINTENANCE	8	1200 F	9600F
DISTRIBUTION MAINTENANCE	2	3000 F	6000 F
UNLOADING CHEMICALS	44 SACKS/MONTH X12	10 F	5280F
	DAILY LABOR SURCHARGE	(25%)	40120F
		ANNUAL SUBTOTAL	200,600F

B) UNSCHEDULED

Task / Service Performed	Frequency of Service	Service / Contract Cost	Total
PIPE BREAK REPAIRS	34 on mains	2400	81,600
	24 on connections	1200	28,800
			110,400
	DAILY LABOR SURCHARGE	(25%)	27,600
		TOTAL	138 000
		ANNUAL SUBTOTAL	138,000

TOTAL PRIVATE CONTRACTOR ESTIMATE = 338,600F

2) OTHER COSTS

TELEPHONE	12,000 F/month	140,000
ANALYSES	5 samples x 6/year x 10,000F	300,000

TOTAL OTHER COSTS ESTIMATE = 440,000

Figure 41. Contractors/Other Costs

WASH O&M COST ESTIMATING HANDBOOK		SUMMARY SHEET
SITE: BEOUMI		AGENCY:
POPULATION:		PREPARED BY:
ANNUAL WATER PRODUCTION, m3:		DATE:

SUMMARY OF ANNUAL OPERATIONS AND MAINTENANCE COST

		Annual O&M Cost		Percent of Total
1) LABOR				
- Regular		3,305,203		
- Overtime				
- Administration				
	SUBTOTAL	3,305,203	3,305,203 F	23.1%
2) MATERIALS				
- Supplies		130,000		
- Parts		480,000		
- ~~Tools~~	Repairs	600,000		
	SUBTOTAL	1,210,000F	1,210,000F	8.5%
3) CHEMICALS			4,998,672 F	35.0%
4) UTILITIES				
- Electric Power		3,089,429		
- Fuel				
	SUBTOTAL	3,089,429	3,089,429 F	21.6%
5) TRANSPORT			919,600F	6.4%
6) PRIVATE CONTRACTORS			338,600F	2.4%
7) OTHER			440,000F	3.1%
	TOTAL O&M COST		14,301,504F	100.0%
	TOTAL O&M COST PER ~~CAPITA~~ CONNECTION		22,276F	
	TOTAL O&M COST PER m3		107 F	

Figure 42. Summary Sheet

WASH O&M COST ESTIMATING HANDBOOK — PAGE 1 — LABOR ESTIMATE

SITE: BONIERE — AGENCY: SODECI

POPULATION: 71 connections — PREPARED BY: A WYATT

ANNUAL WATER PRODUCTION, m3: 8864 m^3 - F487 — DATE: 1/26/88

1) DIRECT LABOR - REGULAR TIME

A) MANAGEMENT/SUPERVISION

Classification	No. in Class	Average Monthly Wage	% Time	Total
Chef de Centre	1	See attached Sheet		

B) SKILLED LABOR

Classification	No. in Class	Average Monthly Wage	% Time	Total

C) UNSKILLED LABOR

Classification	No. in Class	Average Monthly Wage	% Time	Total
Daily Labor -	~~See Contractors Sheet~~			

~~MONTHLY SUBTOTAL~~

ANNUAL SUBTOTAL 1,564,483 F

Figure 43. Labor Estimate Form

LABOR BONIEZE

M. TICALY – Chef de Centre

1) SALARY

Base Salary	73034 F/month
Seniority Bonus (1% per year)	7303 F/month
TOTAL MONTHLY SALARY	80337 F/month

2) ALLOWANCES

Motor bike	3000 F/month
Tools	2400 F/month
Cash box management (10% of base)	7303 F/month

3) TOTAL MONTHLY PAY = 93040 F/month

4) TOTAL ANNUAL (MONTHLY x 11 MONTHS) 1,023,444 F

5) SOCIAL SECURITY, HEALTH BENEFITS, RETIREMENT (55% of Monthly Salary x 11 months) 486,039 F

6) YEAR END BONUS 55,000 F

7) GRAND TOTAL ANNUAL LABOR COST $\boxed{1,564,483 F}$

NOTE: 12TH MONTH COVERED BY ITINERANT OPERATOR, PAID OUT OF REGIONAL FUNDS

WASH O&M COST ESTIMATING HANDBOOK	PAGE 2	LABOR ESTIMATE

SITE: BONIERE AGENCY: ______

POPULATION: ______ PREPARED BY: ______

ANNUAL WATER PRODUCTION, m3: ______ DATE: ______

2) DIRECT LABOR - OVERTIME

Classification	No. in Class.	Average Overtime Hrs.	Hourly Rate	% Time	Total
None					

MONTHLY SUBTOTAL ______

ANNUAL SUBTOTAL 0

3) ADMINISTRATION

Classification	No. in Class.	Average Monthly Wage	% Time	Total
Direct costs	only	tabulated in this estimate		

MONTHLY SUBTOTAL ______

ANNUAL SUBTOTAL 0

TOTAL LABOR ESTIMATE (1+2+3) = 1,564,483F

Figure 44. Labor Estimate Form (p. 2)

SITE: BONIERE AGENCY:

POPULATION: PREPARED BY:

ANNUAL WATER PRODUCTION, m3: DATE:

1) SUPPLIES

Item	Unit	Annual Quantity	Unit Cost	Total
SMALL REPAIRS SUPPLIES (PIPE BREAKS)		25	500F	12,500
FORMS, PAPER, MISC SUPPLIES				30,000
			SUBTOTAL	42,500

2) PARTS

Item	Unit	Annual Quantity	Unit Cost	Total
Parts for pump control panel, etc		.2 (i.e. monthly)	5000F	60,000
			SUBTOTAL	60,000

3) TOOLS

Item	Unit	Annual Quantity	Unit Cost	Total
(cost included as a labor allowance)				
			SUBTOTAL	0

TOTAL MATERIALS ESTIMATE = 102,500F

Figure 45. Materials Estimate Form

SITE: BONIERE AGENCY:

POPULATION: PREPARED BY:

ANNUAL WATER PRODUCTION, m3: DATE:

CHEMICAL CONSUMPTION

Chemical Used	Desired Dosage (mg/l)	Commercial Strength, %	Required Dosage (mg/l)	Water Production (m3/~~day~~ yr	Net Consumption (kg/~~day~~ yr
Calcium Hypochlorite			0.15g/m³	8864	1.33 kg/yr
	a	b	c=a/b	d	e=c*d/1000

CHEMICAL COST

Chemical Used	Net Consumption, kg/~~day~~ yr	Chemical Unit	No. of Units/yr	Unit Cost	Total Cost
Calcium Hypochlorite	1.33 kg/yr			615 F/kg	818 F
				ANNUAL SUBTOTAL	818 F

TOTAL CHEMICALS ESTIMATE = 818 F

Figure 46. Chemicals Estimate Form

WASH O&M COST ESTIMATING HANDBOOK — PAGE 5 UTILITIES ESTIMATE

SITE: BONIERE AGENCY: ____

POPULATION: ____ PREPARED BY: ____

ANNUAL WATER PRODUCTION, m3: ____ DATE: ____

1) ELECTRIC POWER — See Attached Sheets for Details

A) DEMAND CHARGE

Peak Power (KW)	Demand Charge / KW	Annual Demand Charge
PUMP HOUSE	1200 F/KW every 2 months	143,160 F
OFFICE/HOUSE	" " " "	32,280 F

B) ENERGY CHARGE

Equipment	# of units	Rated Power (Hp)	Power Draw (kw)	Daily Operating Period (hr)	Average Daily Energy Consumption (kwh)	Days Use per Year	Energy Cost/kwh	Total Cost
PUMP HOUSE								
Well Pump	1	5	3.46 KW	3.33	11.52	365	59.2 F	248924 F
Dosing Pump	1	0.1	0.075 KW	3.33	0.25	365	59.2 F	5397 F
OFFICE/HOUSE								254,321 F
LAMPS	6		25 W	8	1.20	365	59.2	25932 F
FRIDGE	1		150 W	12	1.80	365	59.2	38894 F
MISC			100 W	2	0.20	365	59.2	4322 F
								69,148 F
	a		b	c	d=b*c	e	f	g=a*d*e*f

ELECTRIC ENERGY SUBTOTAL 323,469 F

2) FUEL

Equipment	# of units	Power (Hp)	Type of Fuel Used	Daily Operating Period (hr)	Average Hourly Fuel Consumption	Days Use per Year	Unit Fuel Cost	Total Cost
	a			b	c	d	e	f=a*b*c*d*e

FUEL SUBTOTAL ____

TOTAL UTILITIES ESTIMATE = 498,904

Figure 47. Utilities Estimate Form

PUMP HOUSE — PUMP + DOSING PUMP

PUMP CALCULATIONS

Grundfos SP 10/18 3φ 5 hp 7.5 A

$Q = 7.14\ m^3/hr = 1.983\ l/s$

Total Head = 37 m (well) + 40 (to tank top) + 3 m (losses) ≃ 80 m

Pelectric = 1.983 x 80 x 9.81 / 0.45 = 3.46 kw

Pnominal = 5 hp = 3.73 kw

Hours used/day			
	Wet Season	4 months	2 hrs/day
	Dry Season	8 months	4 hrs/day
	Weighted Average		3.33 hrs/day

Dosing Pump 0.1 hp => 75 watts

Total Power Subscription 19.8 kw

Demand Charge = 19.8 kw x 1200 F every 2 months
+ 100 F every 2 months
= 143 160 F/year

OFFICE HOUSE (Subscription = 4.4 kw), 1φ

Lamps	6 x 25 W x 8 hrs
Fridge	150 W x 12 hrs
Misc	100 W x 2 hrs

Demand Charge = 4.4 kw x 1200 F every 2 months + 100 F every 2 months
= 32 280 F/year

SITE: BONIERE AGENCY:

POPULATION: PREPARED BY:

ANNUAL WATER PRODUCTION, m3: DATE:

TRANSPORT NEEDS

Transport Purpose	Vehicle Type	Annual Trip Frequency	~~Average Trip Distance~~	~~Total Distance~~
DEPOSIT FEES IN BANK AT KATIOLA	PUBLIC BUS	4/month x 11 months =	44 trips/year	
ATTEND OPERATORS MEETING IN BOUAKE	PUBLIC BUS	2/month x 11 months =	22 trips/year	
MISC TRANSPORT AT SITE	MOTORBIKE	MANY SHORT TRIPS		

TRANSPORT COSTS

Vehicle Type	Total Distance for Vehicle Type	Unit Travel Cost	Total Cost
PUBLIC BUS TO KATIOLA	44 trips	750F	33000F
PUBLIC BUS TO BOUAKE	22 trips	2100F	46 200F
TRAVEL EXPENSES:			
Deposit Fees	Meals. 1/trip x 44	1100F	48 400 F
Attend Meeting	Meals. 5/trip x 22	1100F	121 000 F
	Hotel: 2/trip x 22	1800F	79 200 F
			[illegible]
MOTORBIKE	FUEL 60 liters/month x 11 months	450 F/liter	297,000 F
		TOTAL TRANSPORT COST	624,800F

TOTAL TRANSPORT ESTIMATE = 624,800F

Figure 48. Transport Estimate Form

SITE: BONIERE AGENCY:

POPULATION: PREPARED BY:

ANNUAL WATER PRODUCTION, m3: DATE:

1) PRIVATE CONTRACTORS (DAILY LABORERS)

A) SCHEDULED

Task / Service Performed	Annual Frequency of Service/Contract	Service / Contract Cost	Total
Clean Elevated Storage Tank	2/year	2400F	4800F
Groundskeeping @ Tank, Pump House, etc	12/year	2500F	30,000F
		SUBTOTAL	34800F
	DAILY LABOR SURCHARGE (25%)		8700F
		ANNUAL SUBTOTAL	43500F

B) UNSCHEDULED

Task / Service Performed	Frequency of Service	Service / Contract Cost	Total
PIPE BREAK REPAIRS	25/year	800F	20000F
	DAILY LABOR SURCHARGE (25%)		5000F
			25000F
		ANNUAL SUBTOTAL	

TOTAL PRIVATE CONTRACTOR ESTIMATE = 68,500F

2) OTHER COSTS

LAB ANALYSES: 4 samples × 4 times/year × 10000F/each = 160,000

TELEPHONE 0

LODGING 0

TOTAL OTHER COSTS ESTIMATE = 160,000

Figure 49. Contractors/Other Costs

WASH O&M COST ESTIMATING HANDBOOK	SUMMARY SHEET
SITE: BONIERE	AGENCY: SODECI
POPULATION: 71 connections	PREPARED BY: A WYATT
ANNUAL WATER PRODUCTION, m3: 8864 m³	DATE: 1/26/88

SUMMARY OF ANNUAL OPERATIONS AND MAINTENANCE COST

		Annual O&M Cost		Percent of Total
1) LABOR				
- Regular		1,564,483		
- Overtime				
- Administration				
	SUBTOTAL	1,564,483	1,564,483 F	51.8%
2) MATERIALS				
- Supplies		42,500		
- Parts		60,000		
- Tools				
	SUBTOTAL	102,500	102,500F	3.4%
3) CHEMICALS			818F	0.03%
4) UTILITIES				
- Electric Power		498,909		
- Fuel				
	SUBTOTAL	498,909	498,909 F	16.5%
5) TRANSPORT			624,800F	20.7%
6) PRIVATE CONTRACTORS			68,500F	2.3%
7) OTHER			160,000F	5.3%
NOTE: DIRECT COSTS ONLY !				
	TOTAL O&M COST		3,020,010 F	100.03%
	TOTAL O&M COST PER ~~CAPITA~~ CONNECTION		42,535 F	(Rounding error)
	TOTAL O&M COST PER m3		341 F	

Figure 50. Summary Sheet

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REFERENCES

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APPENDIX

Compound Interest Factors

Compound Interest Factors

Present Worth (PW)

What $1 Due in the Future is Worth Today

(Present Worth) Single Payment

Yrs	6% Present Worth	7% Present Worth	8% Present worth	9% Present worth	10% Present worth	12% Present worth	14% Present worth	16% Present worth	18% Present worth	20% Present worth	Yrs
1	0 943396	0 934579	0 925926	0 917431	0.909091	0 892857	0 877193	0 862069	0 847458	0 833333	1
2	0 889996	0 873439	0 857339	0 841680	0 826446	0.797194	0 769468	0 743163	0 718184	0 694444	2
3	0 839169	0 816298	0 793832	0 772183	0 751315	0 711780	0 674972	0 640658	0 608631	0 578704	3
4	0 792094	0 762895	0 735030	0 708425	0 683013	0 635518	0 592080	0 552291	0 515789	0 482253	4
5	0 747258	0 712986	0.680583	0.649931	0 620921	0 567427	0 519369	0 476113	0 437109	0 401878	5
6	0 704961	0 666342	0 630170	0 596267	0 564474	0 506631	0 455587	0 410442	0 370432	0 334898	6
7	0 665057	0 622750	0 583490	0.547034	0 513158	0 452349	0 399637	0 353830	0 313925	0 279082	7
8	0 627412	0 582009	0 540269	0 501866	0 466507	0 403883	0 350559	0 305025	0 266038	0 232568	8
9	0 591898	0 543934	0 500249	0 460428	0 424098	0 360610	0 307508	0 262953	0 225456	0 193807	9
10	0 558395	0 508349	0 463193	0 422411	0 385543	0 321973	0 269744	0 226684	0 191064	0 161506	10
11	0 526788	0.475093	0 428883	0 387533	0 350494	0 287476	0 236617	0 195417	0 161919	0 134588	11
12	0 496969	0 444012	0 397114	0.355535	0 318631	0 256675	0 207559	0 168463	0 137220	0 112157	12
13	0 468839	0 414964	0 367698	0 326170	0 289664	0 229174	0 182069	0 145227	0 116288	0 093464	13
14	0 442301	0 387817	0 340461	0 299246	0 263331	0 204620	0 159710	0 125195	0 098549	0 077887	14
15	0 417265	0 362446	0 315242	0 274538	0 239392	0 182696	0 140096	0 107927	0 083516	0 064905	15
16	0 393646	0 338735	0 291890	0 251870	0 217629	0.163122	0 122892				16
17	0 371364	0 316574	0 270269	0 231073	0 197845	0 145644	0 107800				17
18	0 350344	0 295864	0.250249	0 211994	0 179859	0 130040	0 094561				18
19	0 330513	0 276508	0.231712	0 194490	0 163508	0 116107	0 082948				19
20	0 311805	0 258419	0 214548	0 178431	0 148644	0 103667	0 072762	0 051385	0 036506	0.026084	20
21	0 294155	0 241513	0 198656	0 163698	0 135131	0 092560	0 063826				21
22	0 277505	0 225713	0 183941	0 150182	0 122846	0 082643	0 055988				22
23	0 261797	0 210947	0.170315	0 137781	0 111678	0 073788	0 049112				23
24	0 246979	0 197147	0 157699	0 126405	0 101526	0 065882	0 043081				24
25	0 232999	0 184249	0 146018	0 115968	0 092296	0 058823	0 037790	0 024465	0 015957	0 010482	25
26	0 210810	0 172195	0 135202	0 106393	0 083905	0 052521	0 033149				26
27	0 207368	0 160930	0 125187	0 097608	0 076278	0 046894	0 029078				27
28	0 195630	0 150102	0 115914	0 089548	0 069343	0 041869	0 025507				28
29	0 184557	0 140563	0 107328	0 082155	0 063039	0 037383	0 022375				29
30	0 174110	0 131367	0 099377	0 075371	0 057309	0 033378	0 019627	0 011648	0 006975	0 004212	30
31	0 164255	0 122773	0 092016	0 069148	0 052090	0 029802	0 017217				31
32	0 154957	0 114741	0 085200	0 063438	0 017362	0 026609	0 015102				32
33	0 146186	0 107235	0 078889	0 058200	0 043057	0 023758	0 013248				33
34	0 137912	0 100219	0.073045	0 053395	0 039143	0 021212	0 011621				34
35	0.130105	0 093663	0 067635	0 048986	0 035584	0 018940	0 010194	0 005546	0 0030488	0 001693	35
36	0 122741	0 087535	0 062625	0.044941	0 032349	0 016910	0 008942				36
37	0 115793	0 081809	0 057986	0.041231	0 029408	0 015098	0 007844				37
38	0 109239	0 076457	0 053690	0 037826	0 026735	0 013481	0 006880				38
39	0 103056	0 071455	0 049713	0 034703	0 024304	0 012036	0 006035				39
40	0 097222	0 066780	0 046031	0 031838	0 022095	0 010747	0 005294	0 002640	0 001333	0 000680	40

Formula

$$P = F\left[\frac{1}{(1+i)^n}\right]$$

i Represents an interest rate per interest period
n Represents a number of interest periods
P Represents a present sum of money
F Represents a sum of money at the end of n periods from the present date that is equivalent to P with interest i

Compound Interest Factors

Periodic Payment (PP)

Periodic Payment Necessary to Pay Off a Loan of $1
(Capital Recovery) Annuities (Uniform Series Payments)

Yrs	6% Capital recovery	7% Capital recovery	8% Capital recovery	9% Capital recovery	10% Capital recovery	12% Capital recovery	14% Capital recovery	16% Capital recovery	18% Capital recovery	20% Capital recovery	Yrs
1	1.060000	1.070000	1.080000	1.090000	1.100000	1.120000	1.14000000	1.16000000	1.18000000	1.20000000	1
2	0.545437	0.553092	0.560769	0.568469	0.576190	0.591698	0.60728972	0.62296296	0.63871560	0.65454545	2
3	0.374110	0.381052	0.388034	0.395055	0.402115	0.416349	0.43073148	0.44525787	0.45992386	0.47472527	3
4	0.288591	0.295228	0.301921	0.308669	0.315471	0.329234	0.34320478	0.35737507	0.37173867	0.38628912	4
5	0.237396	0.243891	0.250156	0.257092	0.263797	0.277410	0.29128355	0.30540938	0.31977784	0.33437970	5
6	0.203363	0.209796	0.216315	0.222920	0.229607	0.243226	0.25715750	0.27138987	0.28591013	0.30070575	6
7	0.179135	0.185553	0.192072	0.198691	0.205405	0.219118	0.23319238	0.24761268	0.26236200	0.27742393	7
8	0.161036	0.167468	0.174015	0.180674	0.187444	0.201303	0.21557002	0.23022426	0.24524436	0.26060942	8
9	0.147022	0.153486	0.160080	0.166799	0.173641	0.187679	0.20216838	0.21708249	0.23239482	0.24807946	9
10	0.135868	0.142378	0.149029	0.155820	0.162745	0.176984	0.19171354	0.20690108	0.22251464	0.23852276	10
11	0.126793	0.133357	0.140076	0.146947	0.153963	0.168415	0.18339427	0.19886075	0.21477639	0.23110379	11
12	0.119277	0.125902	0.132695	0.139651	0.146763	0.161437	0.17666933	0.19241473	0.20862781	0.22526496	12
13	0.112960	0.119651	0.126522	0.133567	0.140779	0.155677	0.17116366	0.18718411	0.20368621	0.22062000	13
14	0.107585	0.114345	0.211297	0.128433	0.135746	0.150871	0.16660914	0.18289797	0.19967806	0.21689306	14
15	0.102963	0.109795	0.116830	0.124059	0.131474	0.146824	0.16280896	0.17935752	0.19640278	0.21388212	15
16	0.098952	0.105858	0.112977	0.120300	0.127817	0.143390	0.15961540				16
17	0.095445	0.102425	0.109629	0.117046	0.124664	0.140457	0.15691544				17
18	0.092357	0.099413	0.106702	0.114212	0.121930	0.137937	0.15462115				18
19	0.089621	0.096753	0.104128	0.111730	0.119547	0.135763	0.15266316				19
20	0.087185	0.094393	0.101852	0.109546	0.117460	0.133879	0.15098600	0.168667	0.186820	0.205356	20
21	0.085005	0.092289	0.099832	0.107617	0.115624	0.132240	0.14954486				21
22	0.083016	0.090106	0.098032	0.105905	0.114005	0.130811	0.14830317				22
23	0.081278	0.088714	0.096422	0.104382	0.112572	0.129560	0.14723081				23
24	0.079679	0.087189	0.094978	0.103023	0.111300	0.128463	0.14630284				24
25	0.078227	0.085811	0.093679	0.101806	0.110168	0.127500	0.14549841	0.164012	0.182919	0.202119	25
26	0.076904	0.081561	0.092507	0.100715	0.109159	0.126652	0.14480001				26
27	0.075697	0.083426	0.091448	0.099735	0.108258	0.125904	0.14419288				27
28	0.074593	0.082392	0.090489	0.098852	0.107451	0.125244	0.14366449				28
29	0.073580	0.081449	0.089619	0.098056	0.106728	0.124660	0.14320417				29
30	0.072649	0.089586	0.088827	0.097336	0.106079	0.124144	0.14280279	0.161886	0.181264	0.200846	30
31	0.071792	0.079797	0.088107	0.096686	0.105496	0.123686	0.14245256				31
32	0.071002	0.079073	0.087451	0.096096	0.104972	0.123280	0.14214675				32
33	0.070273	0.078408	0.086852	0.095562	0.101499	0.122920	0.14187958				33
34	0.069598	0.077797	0.086304	0.095077	0.104074	0.122601	0.14164604				34
35	0.068974	0.077234	0.085803	0.094636	0.103690	0.122317	0.14144181	0.160892	0.180550	0.200339	35
36	0.068395	0.076715	0.085345	0.094235	0.103343	0.122064	0.14126315				36
37	0.067857	0.076237	0.084924	0.093870	0.103030	0.121840	0.14110680				37
38	0.067358	0.075795	0.084539	0.093538	0.102747	0.121640	0.14096993				38
39	0.066894	0.075387	0.084185	0.093236	0.102491	0.121462	0.14085010				39
40	0.066462	0.075009	0.083860	0.092960	0.102259	0.121304	0.14074514	0.160423	0.180240	0.200136	40

Formula

$$A = P\left[\frac{i(1+i)^n}{(1+i)^n - 1}\right]$$

SITE: ____________ AGENCY: ____________

POPULATION: ____________ PREPARED BY: ____________

ANNUAL WATER PRODUCTION, m3: ____________ DATE: ____________

1) DIRECT LABOR - REGULAR TIME

A) MANAGEMENT/SUPERVISION

Classification	No. in Class	Average Monthly Wage	% Time	Total

B) SKILLED LABOR

Classification	No. in Class	Average Monthly Wage	% Time	Total

C) UNSKILLED LABOR

Classification	No. in Class	Average Monthly Wage	% Time	Total

MONTHLY SUBTOTAL ____________

ANNUAL SUBTOTAL ____________

SITE: ______________________ AGENCY: ______________________

POPULATION: ______________________ PREPARED BY: ______________________

ANNUAL WATER PRODUCTION, m3: ______________________ DATE: ______________________

2) DIRECT LABOR - OVERTIME

Classification	No. in Class.	Average Overtime Hrs.	Hourly Rate	% Time	Total
				MONTHLY SUBTOTAL	
				ANNUAL SUBTOTAL	

3) ADMINISTRATION

Classification	No. in Class.	Average Monthly Wage	% Time	Total
			MONTHLY SUBTOTAL	
			ANNUAL SUBTOTAL	

TOTAL LABOR ESTIMATE (1+2+3) = ______

SITE: ______________________ AGENCY: ______________________

POPULATION: ______________________ PREPARED BY: ______________________

ANNUAL WATER PRODUCTION, m3: ______________________ DATE: ______________________

1) SUPPLIES

Item	Unit	Annual Quantity	Unit Cost	Total
			SUBTOTAL	

2) PARTS

Item	Unit	Annual Quantity	Unit Cost	Total
			SUBTOTAL	

3) TOOLS

Item	Unit	Annual Quantity	Unit Cost	Total
			SUBTOTAL	

TOTAL MATERIALS ESTIMATE = ________

SITE: ____________ AGENCY: ____________

POPULATION: ____________ PREPARED BY: ____________

ANNUAL WATER PRODUCTION, m3: ____________ DATE: ____________

CHEMICAL CONSUMPTION

Chemical Used	Desired Dosage (mg/l)	Commercial Strength, %	Required Dosage (mg/l)	Water Production (m3/day)	Net Consumption (kg/day)
	a	b	c=a/b	d	e=c*d/1000

CHEMICAL COST

Chemical Used	Net Consumption, kg/day	Chemical Unit	No. of Units/yr	Unit Cost	Total Cost
				ANNUAL SUBTOTAL	

TOTAL CHEMICALS ESTIMATE = ____________

SITE: ____________________ AGENCY: ____________________

POPULATION: ____________________ PREPARED BY: ____________________

ANNUAL WATER PRODUCTION, m3: ____________________ DATE: ____________________

1) ELECTRIC POWER

A) DEMAND CHARGE

Peak Power (KW)	Demand Charge / KW	Annual Demand Charge

B) ENERGY CHARGE

Equipment	# of units	Rated Power (Hp)	Power Draw (kw)	Daily Operating Period (hr)	Average Daily Energy Con- sumption (kwh)	Days Use per Year	Energy Cost/kwh	Total Cost
	a		b	c	d=b*c	e	f	g=a*d*e*f

ELECTRIC ENERGY SUBTOTAL ________

2) FUEL

Equipment	# of units	Power (Hp)	Type of Fuel Used	Daily Operating Period (hr)	Average Hourly Fuel Consumption	Days Use per Year	Unit Fuel Cost	Total Cost
	a			b	c	d	e	f=a*b*c*d*e

FUEL SUBTOTAL ________

TOTAL UTILITIES ESTIMATE = ________

SITE: ______________________ AGENCY: ______________

POPULATION: ______________________ PREPARED BY: ______________

ANNUAL WATER PRODUCTION, m3: ______________ DATE: ______________

TRANSPORT NEEDS

Transport Purpose	Vehicle Type	Annual Trip Frequency	Average Trip Distance	Total Distance

TRANSPORT COSTS

Vehicle Type	Total Distance for Vehicle Type	Unit Travel Cost	Total Cost

TOTAL TRANSPORT COST ______________

TOTAL TRANSPORT ESTIMATE = ______________

SITE: ______________________ AGENCY: ______________________

POPULATION: ______________________ PREPARED BY: ______________________

ANNUAL WATER PRODUCTION, m3: ______________________ DATE: ______________________

1) PRIVATE CONTRACTORS

A) SCHEDULED

Task / Service Performed	Annual Frequency of Service/Contract	Service / Contract Cost	Total
		ANNUAL SUBTOTAL	

B) UNSCHEDULED

Task / Service Performed	Frequency of Service	Service / Contract Cost	Total
		ANNUAL SUBTOTAL	

TOTAL PRIVATE CONTRACTOR ESTIMATE = __________

2) OTHER COSTS

TOTAL OTHER COSTS ESTIMATE = __________

WASH O&M COST ESTIMATING HANDBOOK — SUMMARY SHEET

SITE: ______________________ AGENCY: ______________

POPULATION: ______________________ PREPARED BY: ______________

ANNUAL WATER PRODUCTION, m3: ______________________ DATE: ______________

SUMMARY OF ANNUAL OPERATIONS AND MAINTENANCE COST

		Annual O&M Cost	Percent of Total
1) LABOR			
- Regular	____		
- Overtime	____		
- Administration	____		
SUBTOTAL	____	____	____
2) MATERIALS			
- Supplies	____		
- Parts	____		
- Tools	____		
SUBTOTAL	____	____	____
3) CHEMICALS		____	____
4) UTILITIES			
- Electric Power	____		
- Fuel	____		
SUBTOTAL	____	____	____
5) TRANSPORT		____	____
6) PRIVATE CONTRACTORS		____	____
7) OTHER		____	____
TOTAL O&M COST		____	____
TOTAL O&M COST PER CAPITA		____	
TOTAL O&M COST PER m3		____	

WASH