PRAGMATIC WATER PLANNING

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INTRODUCTION

The present work, "Pragmatic Water Planning", is best described as common sense applied to water development. It attempts to achieve its objectives by providing necessary theoretical foundations and thereafter illustrating their application in a large number of case studies.

"Pragmatic Water Planning" has been conceived to augment the efficiency and relevance of water planning in developing countries and therefore addresses itself to those active in the actual planning and implementation of water investment plans. It does not provide much new theory but could well serve as a textbook for courses in applied planning. The reluctance to go too deep into theoretical aspects is motivated by the fact that at present, water sector planning in most instances makes use of almost no theory whatsoever. Under the circumstances, there are no fruitful results to be expected from engaging in further theorizing when as abyss already separates what is known to be the ideal, and what is actually carried out.

One explanation for this unfortunate gap between theory and practice is the absence of firm data in many developing countries which prevents sophisticated planning. This deficiency can only be amended over time, spurred by the growing realization that investing in a good data base rapidly pays for itself in the form of better planning and more economical use of scarce resources.

A second explanation is that planners have at times neglected the "nuts and bolts" planning of the water sector. Planning has often been synonymous with macroeconomic planning which has rarely reached the implementing level. Undoubtedly, in the field of water development the problem has been compounded by difficulties to measure progress. However, it may also have been that the right kind of professionals has been missing who could talk with macroeconomic planners in their language, and with the implementing engineers in theirs. This book correspondingly tries to bridge the gap by furnishing a common language for economists and engineers alike. It should therefore be of interest to both disciplines but most of all it should help economists contribute more to investment implementation by indicating where their input is especially timely.

The term water development is broad and spans many economic activities, such as irrigation, hydroelectric development, and community water supply and waste water disposal to mention only a few. It is impossible to cover the entire field lest the exercise become very general, and this book concentrates on community water supply and to a small degree on waste water disposal. Some of the theory and illustrations can however be of interest to other areas of water development.

The book contains four major sections. The first gives the rudiments of macro-economic planning and illustrates their application with regards to the water sector by discussing two countries' water development in the context of their overall economic strategy. One of them, Cameroon, has integrated water planning only tangentially in its macro-planning. This would seem acceptable given the country's priorities and the fact that water resources are no impediment to economic development. The Cameroon case study may be useful for staff active in the water supply and waste disposal field since it will help them understand/interact with macroplanners with a realistic perspective of the water sector's relative importance. The second case study is that of Israel which may not be characterized as a developing country from the viewpoint of water development. On the contrary, it has successfully developed its water resources almost fully although the premises may have been more favorable than for most other developing countries. Even so, Israel has many problems in common with other developing countries, and its advances in water development can guide other countries in a similar situation, particularly those with scarce water resources.

The second section of the book deals with sector planning for water supply and waste disposal. This is a much neglected field which partly explains why macroeconomic planners and investment planners seem to find difficulties communicating and working together. Sector planning should serve precisely as a bridge between the two and help translate macro-goals into action through investment projects. If only for this reason it deserves more attention than has been accorded in the past. At the same time it has to avoid the risk of degenerating into another theoretical planning exercise and its goal should be more vigorous sector development through the execution of investment projects.

The third section is that of project planning, sometimes known as investment planning. It is an area dominated by cost/benefit analysis which has been intuitively applied by engineers for a long time and where the theory was subsequently developed by economists. Just as any theory precedes actual practice by varying lengths of time, the cost/benefit theory may at times have overshot the targets and in the process ivory-towers have been erected. This may have earned economists a worse name than they deserve among water sector staff. Accordingly this book tries to restrict the theoretical discussion to what is truly useful, in the conviction that theory need not be complicated to achieve results. A large number of examples from project planning are discussed to show how with small means planning can be improved to a level commensurate with the data quality. Although the case studies are from a number of countries in different parts of the world, it should be cautioned that generalizations are dangerous from one country to another and even within a given country.

The section on project planning repeatedly stresses the theme that the best investment is the one that is not made at all but is substituted by a better use of existing facilities, possibly supported by cheap works to upgrade what is already available. The fourth section explores this theme further and describes operational planning to optimize the use of existing

facilities. Operational planning is a vast field and the discussion is here largely limited to the proper tariff and connection policies to be followed. The approach is one of marketing, i.e. the water supply manager should actively promote the population's demand for good and safe water and sanitation, and thereafter meet demand at a cost compatible with the population's income levels. It is stressed that tariffs should be set so as to recuperate current and capital costs. Such a message may be anathema to those who believe that water supply and sanitation is a basic human right which should be provided at no or nominal charges. However generous such a position may seem, it is well known that hundreds of millions of the inhabitants in developing countries continue to lead wretched lives deprived of their basic human rights for lack of investment funds. Until such a situation is remedied it will certainly be the responsibility of the water planner to raise needed funds from wherever he can. The only dependable one in the long run is from tariffs levied on the consumers themselves. It is further demonstrated that properly designed water supply and sewerage tariffs with cross subsidies can help redressing income inequalities and consequently support those population segments most in need of help.

Finally, before reading this book the words from Ecclesiastes 12:12 should be recalled: "Of making many books there is no end; and much study is weariness of the flesh". A word of caution would be that this book should be seen only as a help to more effective project then implementation, and it will only be from action that the real lessons will be learnt. To the extent that action is stimulated and improved this book will not have been in vain.

MACRO-ECONOMIC PLANNING

The purpose of the section on macro-economic planning is not to give a comprehensive and exhaustive treatment of the vast subject but instead provide some of the simplest terminology and a brief version of how overall planning is carried out in practice. The underlying thought is ultimately to establish common ground between macro-economic planners and professionals active in the water sector so that there should be no misunderstandings at least on grounds of terminology. In particular, water sector staff should understand how their own sector fits within the overall economy. With a better perception they will be able to plan investments that fit with other sectors' investment plans and there will be a better chance of having water sector proposals accepted for financing.

The term macro-economics may need be explained. It is primarily concerned with the study of aggregate economic activities without identifying separate firms or individuals. Typically it will describe, analyze, and project economic activity in one country or include other countries as well. In the latter case it is called international economics. Although successful macroeconomic analysis at times will require a closer study of, for example consumers and their reasons for buying or saving, such studies are more characteristic of microeconomics. The latter will also analyze the behaviour of firms, particularly as regards the supply and demand of goods, and the role of pricing.

Growth Theory

As their name already implies developing countries are most concerned with one special branch of macro-economics, growth or development economics. These countries are well aware that their ability to produce goods and services is insufficient to satisfy and guarantee the well-being of their inhabitants. Faced with a wide gap between aspirations and what is actually provided in terms of material and spiritual welfare, it is of prime interest to grow and become more affluent. Fuelled by demonstration effects of the wealth of more developed nations, aspiration levels have risen much faster than economies have grown and the populations have become impatient. What took centuries to achieve in the so called developed countries will have to be accelerated in today's developing world.

The urge to develop faster coupled with a better understanding of economics have led more and more countries to attempt controlling more of their economies. This trend includes not only those countries that on ideological grounds want to emulate the Soviet model of aplanned economy but also those that can be characterized as free-market or mixed economies. In the latter the share of economic activities controlled by the state or public sector is steadily growing and requires management criteria which macro-economic planning should provide.

Measuring Progress

The ultimate purpose of economic activities are not disputed: they should lead to greater welfare for the entire population or at least, nobody should be worse off than before while at the same time others get their lot improved. However logical this proposition from classical welfare theory may be it is not very practical for the simple fact that it is difficult to measure welfare, be it for one individual or for a country's population. Some proxy for welfare has to be invented or constructed. And one such yard-stick is the gross national product or, for short, GNP. The gross national product may be said to be the economy's capacity to produce welfare by supplying goods and services. In free-market economies, it loosely stands for the value of all goods and services that the economy produces during a given period, for instance during a given year. Using a popular analogy, GNP is the size of the cake that a family can eat.

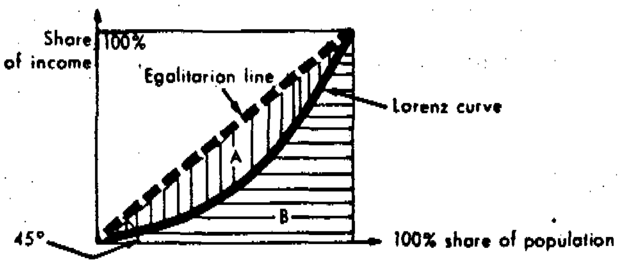
GNP and its changes from year to year can be measured in two ways, either in current prices or in constant prices. The former include the inflationary effects with money buying less and less goods whereas the latter corrects for these. This correction is achieved by deflating the current output of goods and services by the GNP deflator which is related to prices in a given base year. What is of prime interest is of course the changes in the real GNP which is expressed in constant money, or in volume terms.

A better welfare measure is to see how much GNP each inhabitant has. The measure which follows from dividing GNP by the total population, is called the gross national product per capita. It is commonly used to compare how well off a country is on the economic development scale. Converting the annual GNP into one per capita also clearly shows whether the country is increasing its welfare faster or slower than its population. This is precisely the dilemma of many of the developing countries. Their total GNP may be growing rather fast but so do their populations and the per capita result may be meager in the end.

Per capita GNP estimates are averages and the reality in developed and developing countries alike is very distant from average income distribution. Some can enjoy life unburdened by material limitations whereas others live in abject poverty. Some measure has to be found to describe this vital characteristic and it is given by income distribution curves. Again drawing an analogy to the cake, the income distribution describes how the cake, the GNP, is sliced between the different family members. Economists use income distribution graphs that they call Lorenz curves to show how much of total national income, or GNP, is received by each population group, respectively. Usually the population is divided into income deciles and each decile's share of national income is plotted against its share of the population in numbers. A Lorenz curve will have the shape shown in the Figure below:

Figure Illustration of Lorenz curves and Gini coefficients.

FIGURE Illustration of Lorenz curves and Gini coefficients.



As is evident, in case total income were divided perfectly equally the Lorenz curve would become a 45-degree straight line since there would be straight proportionality between the shares of income and population. As a handy measure of the degree of imperfection of a country's income distribution economists use the Gini coefficient which is the ratio between the area between the Lorenz curve and the egalitarian line, and the total triangular area under the 45-degree line. With the connotations in the figure above the Gini coefficient is A/A+B. Its value can thus be seen to vary from zero to one with decreasing equality. Although comparisons between different countries should be viewed with caution it can be mentioned that in 1970 the Gini-coefficient for Peru was 0.59 signifying a skewed income distribution whereas the same coefficient in the more egalitarian Sweden was 0.39.

Qualifications of the GNP-concept

Upon closer examination the handy GNP-measurement reveals shortcomings which have to be kept in mind particularly when comparing different countries' GNP. For one thing since the GNP has to be expressed in a common currency for inter-country comparisons the value of the country's currency matters much. Countries with overvalued currencies will appear in a more favorable light and a sudden currency adjustment may drastically change the position of individual countries in the GNP per capita ranking. In free-market economies the GNP is measured in the prices of the market and it is an open question how well these represent economic costs, i.e. resource requirements. For instance, market prices do not generally include any charge for negative external effects, such as pollution of water and air caused by indiscriminate industrialization. To the extent that such costs are neglected the GNP overestimates the capacity to create welfare as it ignores a tangible component of what is quality of life.

Another factor that obscures direct international comparisons are different patterns and development of production and distribution. In developing agricultural nations household production unregistered by the market is more significant than in developed countries with larger job specialization. The result is comparatively lower GNP estimates for developing countries. On the other hand, it could be argued that increased specialization produces goods or services of higher quality which may not be fully reflected in the prices charged.

Another difficulty for international comparisons is the different treatment accorded intermediate goods and services, i.e. those that are not for immediate consumption. One has to be careful so that products are not double counted as they appear in the various stages in the production process. To this end only what is value added in each production stage should be included in the GNP-estimate. A particular kind of intermediate services are those of the banking system, individual transportation, and the public administration which all have dual functions. Part of them are for final consumption, part for keeping the productive apparatus going. Here the market economies and the Soviet-type planned economies differ in their treatment. The market economies include in the GNP the entire value of these intermediate services thus exaggerating the GNP's welfare capacity. The planned economies exclude them completely, and understate their importance. The planned economies' resulting material products therefore have to be corrected before they can be compared with the GNP of market economies.

Part of the GNP will not be consumed immediately but is saved and invested. Although this share is withdrawn from immediate consumption it is expected to be available at a later time for consumption and investments are therefore included in the GNP. This is logical as the country's welfare capacity has to be seen in a longer time perspective. Conversely, if a country's productive apparatus is slowly being worn out or made obsolescent and is not being replaced there should be a corrective post in the GNP to account for this capital depreciation. In some countries such a net calculation is made, and the corresponding measure is appropriately termed net national product.

Consumption versus Investment/Savings

The GNP can grow in two ways. The cheapest way is to use existing productive capacity better and get closer to the capacity ceiling. An example would be where factories are operated by one shift of workers 8 hours each day. By adding another two shifts of workers and operating the machines continuously the GNP will grow without any further investments in machines. Similarly in the service sector or public sector, school buildings can be better utilized by teachers working two shifts a day.

The second way to increase production and GNP becomes necessary when all the simple solutions to increase the capacity utilization have been exhausted. Investments in additional productive capacity then become necessary before production can be further raised. In a closed economy such investments will be financed by savings. Again the analogy with the cake can illustrate what happens. The cake can be eaten or saved for future consumption, and similarly the GNP-cake is partly consumed and partly saved/invested for future consumption. If the simplification of a closed economy is relaxed and the transactions with other countries included, domestic savings need not correspond to the investment volumes since the latter can partly be financed by borrowing money abroad.

The savings ratio, or the share of a country's GNP that is set aside from immediate consumption, is clearly dependent upon the income levels in the different countries. In very poor nations it is difficult to save since most income goes for mere subsistence. With higher incomes and the most urgent needs satisfied, it becomes feasible to direct a larger share of GNP to future consumption.

Similarly, the investment ratios vary widely between countries. Other things being equal countries investing more of GNP will grow faster. For instance Japan invested over a long period around a third of its GNP whereas poor developing countries with difficulties to mobilize internal resources may have to supplement these with external borrowings or grants.

Capital/Output Ratios

It is not sufficient to invest a large share of GNP to be able to grow but the funds have to be used wisely for productive purposes. The efficiency of investments is measured by the incremental capital/output ratio (ICOR) which is defined as the investment volume divided by the annual incremental output or contribution to GNP. Assuming for the time being that this ratio is a constant, "a" we can write

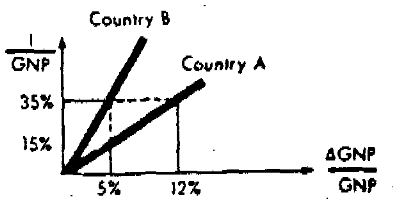
$$\frac{I}{\Delta GNP} = a \qquad \text{Where } I = \text{Investments}$$
$$\Delta GNP = \text{Annual GNP change}$$

By dividing through with the GNP we obtain $\frac{I}{GNP} = a.\ \frac{\Delta GNP}{GNP}$

Now this expression represents a straight line through the origin and with the variables being $\frac{I}{GNP}$ and $\frac{\Delta GNP}{GNP}$. Two lines representing this linear function are shown in the Figure below:

Figure Relation between Investment Ratios and Growth Rates

FIGURE between Investment Ratios and Growth Rates



The figure illustrates how different countries' growth rates can be different in spite of identical shares of GNP being invested. For instance, consider country A which has an investment ratio of some 35% and is growing at around 12% annually. Its investments are fast in producing additional GNP and they are paid back in three years, and the capital/output ratio is 3. Country B in contrast, has an identical investment ratio, 35%, but its growth rate is only 5% per annum, since the ICOR is 7.

High capital/output ratios such as country B's 7 and low ones such as 3 enjoyed by country A do not necessarily mean that B is managing its economy badly and that A is more skilful. Differences can be explained by country B's need to invest heavily in infrastructure that does not immediately contribute to GNP growth. An example would be a potentially rich agricultural producer that will first have to invest large amounts in transport infrastructure and storage before it can fully use its agricultural potential and expand output.

Extensions of the Simple Growth Model

The simplified growth theory presented so far has focused at the growth of investments as one important factor producing growth. In a closed economy the share of GNP invested was determined by how much the population was willing to set aside, to save part of available goods and services. This simple model in practice has to be abandoned and include another two important factors that determine the amount of investments.

The first refinement includes transactions with other countries and the flow of goods and services to and from these. Importing goods and services from abroad makes them available for consumption and investment or, in other language, the amount of resources has grown. In contrast, exporting goods and services withdraws them from the use of the country's population and the amount of resources diminishes. In case a country's imports exceed its exports its trading partners must provide credit i.e. permit it to receive more goods and services than it supplies to the others. This is the typical situation of developing countries that are capital importers. They receive more goods and services than they export in order to build up their countries' productive capacity. In a future they should then be able to pay back the credits with goods and services that the previous capital exporters will accept. External assistance, which may be in the form of grants or loans, is nothing else than the monetary recording of goods and services supplied to a given country. In addition to grants and credits the country is obliged to use its foreign exchange to pay for the goods and services it needs. The amount of foreign exchange available is often a limiting factor to a country's growth and is one of the prime reasons for providing external assistance to a country that is developing its economy by investing in productive enterprises. Some external lenders only supply up to the foreign exchange amount of a given investment programme since this is the share the country needs to buy from abroad. The component in local currency should be provided by the country's own productive apparatus.

Examples of local components are labor and natural resources. The domestic goods and services have to be paid for however, and the entity carrying out the investments has to elaborate a financing plan to this end. Often the executor will be the public sector in the country and public savings need be mobilized to pay for the domestic products. Such public savings will frequently be another limiting factor for boosting investments. It may be that public revenue is there but that it is used for current expenditure such as salaries for public sector employees in lieu of investments. Insufficient public savings should lead to efforts to collect more taxes, or levy higher tariffs on different public services. Governments may also opt for a momentarily easier solution and print money to buy needed goods. Such deficit financing will however entail the risk of fanning inflation since no additional goods are produced by the mere printing of money. The end effect is that more money is chasing the same amount of domestic goods and services, and prices rise.

Growth Planning in Practice

The actual planning of a country's economy will comprise three distinct phases, the macro-phase, the intermediate phase, and the micro-phase.

The purpose of the macro-phase is to choose a suitable growth rate for the country. The planners will to this end study a series of growth rates and for each one investigate what the necessary consequences in investments will be. When doing this some assumptions will be made as to what the appropriate capital/output ratios are as illustrated above. For example, if the economy's capital/output ratio is 4, a 5% growth rate will require an investment ratio of 20%, a 6% growth rate will necessitate investments amounting to 24% of GNP and so on.

For each investment ratio the country's ability to mobilize the goods and services to implement the volume of investments will be studied. Foreign exchange is taken as a measure for the requirements in goods and services from abroad. In case the amount of foreign exchange available to the country is insufficient for the requirements there exists a foreign exchange gap and it will then be necessary to borrow or obtain grants to cover this deficit. On the domestic side, the share of goods and services that can be procured within the country has to be financed and savings have to be mobilized to this end. In case of a savings deficit it may be necessary to seek ways to augment public revenue or borrow the funds on the internal capital market.

The intermediate phase follows the selection of a desirable growth rate and investment ratio and should decide in which sectors of the economy investments should be made. For instance, in an effort to spread economic development more evenly over the country it may be desirable to invest relatively more in certain geographical regions. Sector-wise it would seem to make sense to invest in those sectors that have low capital/output ratios so that output will grow fast. This may indeed be one guiding principle particularly during the early stages of development but it cannot be the only one. The impact of investments upon the foreign exchange generation is another consideration that may be at variance with the simple capital/output criterion and there are others. Moreover, it is likely that investments in a directly productive undertaking will demand investments in complementary infrastructure such as roads, power generation, water supply, housing for workers and so on, and the combined result is that one has to think in terms of investment packages instead of directly productive investments only.

There are varying gestation periods for investments before they start producing. Irrigation projects yield quick results initially but for dramatic and lasting productivity increases the agricultural workers have to be educated to take advantage of more sophisticated production methods. Education is a slow process, however, which has to be planned with much lead time as compared to simple irrigation works. To take into account the varying time dimension of different components, several macro-plans are commonly elaborated. Some may be long-term and bridge a period of say 15 years, others may be medium-term and cover 5 years, whereas others yet are short-term and intended for one year only.

The micro-phase is the project planning stage which decides precisely which investment projects should be executed within the chosen sectors or regions. Due to the lead time required to prepare projects there is not much of a choice of projects to be executed over the first years of the investment plan. Many of the investments are pre-determined, either because they are already under construction or because they are ready for execution. The exact selection and design of investment projects is not handled by the macroplanners but by those more familiar with the sectors and projects. Apart from fitting well within the overall sectoral and regional priorities, each individual project should be economically justified. For this calculation cost/benefit analysis is employed to ensure that benefits over the project's life-time will exceed costs using discounted values. For the cost/benefit analysis it will often be necessary to correct for price distortions by so called shadow pricing. The application of shadow prices, or accounting prices, is necessary to translate the financial market prices of products and services into more realistic economic costs. In particular the market prices of unskilled labor and foreign exchange are often distorted and need correction.

Water's Role in Macro-Planning

Water is a dual good since it is both an intermediate product and a consumption good. As a consequence when water is a production input for other sectors, such as irrigated agriculture, or industry the related investments will be treated as part of those particular sectors and will not appear separately. In contrast the provision of water for human consumption will be treated separately in the investment plans. In either case, in most countries water is not among the scarcest resources and does not constitute a bottleneck to overall economic development. In those water-scarce countries where more water could significantly increase growth it may be useful to use water as a cornerstone in the macro-economic planning and group the other investments around the water sector investments. More typically though, the share of overall investments earmarked for water supply will be a residual after directly productive investments and those in supportive infrastructure have received their shares.

Water supply projects are frequently not separated in macroplans since they are as a rule small in relation to overall investments. Most countries will invest a few percentage points of their total public investments in water supply and sanitation projects.

The water and sanitation sector may be receiving more attention when a country moves away from a purely growth-oriented policy to one where greater efforts are made to redistribute income. Although both water supply and sewerage can be shown to have a positive impact upon the health of the population served, and thus indirectly upon the productivity of workers, foremost it is an end in itself to provide safe water supply and adequate sanitation. A public investment programme concerned with giving the population an equal standing with regards to education, health care and so on will evidently use the provision of good and safe water supply and sanitation to achieve real income redistribution.

CASE STUDY ONE - MACRO-ECONOMIC PLANNING FOR CAMEROON

Background:

During the first decade after independence, Cameroon experienced satisfactory economic growth with annual rates averaging 7% in real terms and gross fixed investments increasing from 12 to 15 percent of GDP, nearly 60 percent of which in the private sector. This favorable situation worsened suddenly towards the end of the 1960's; private investments sharply declined beginning in 1969 and overall economic progress during the early 1970's slowed to 3% or little more than population growth.

The main causes for this deterioration were a combination of factors largely outside Government control such as (i) low export prices for cocoa and coffee during 1971 and 1972; (ii) several years of drought in the north; (iii) a drop in world demand for cocoa and timber in 1974/75; and (iv) a relative stagnation of demand for manufacturing products in the rural sector at a time when most of the easy and obvious import substitution projects in industry had been completed. In addition, the Government's policy of accelerating Cameroonization may have dampened private investment.

The Government responded on the one hand by slowing down expansion of current expenditures; on the other hand, however, it stepped up markedly public investments, financed by drawing down accumulated treasury reserves and by substantial current budget surpluses. However, as most of the additional public investment was made in sectors in which the contribution to domestic output is both indirect and slow, its impact on production remained limited, while the severe austerity measures on current budget outlays resulted in serious underspending in several key sectors such as maintenance and agriculture.

It was against this somewhat gloomy background that the work on the investment plan under the Fourth Plan was initiated in 1975. It was clear that the relatively difficult macro-economic situation dictated a careful use of available resources. The purpose of the exercise became to determine the size of the public investment program, given the likely constraints exercised by the balance of payments, by public savings and by foreign debt management.

THE MACRO PHASE

Analysis:

The determination of the optimum size and composition of the public investment program was carried out in two steps: overall economic growth, export proceeds and public savings during the period of the Fourth Plan were projected Based thereupon local as well as foreign financial resources to finance public investments were forecast.

Overall economic growth was projected on the basis of foreseeable developments in the five years 1976/77 through 1980/81; export projections were based on likely domestic supply and world market conditions while public revenues were projected on the assumptions of little change in fiscal structure and feasible tax effort. For all three variables, projections were made independently from the proposed level of public investments during the plan period. This approach was based on the conviction that whatever investment decisions a Government is likely to take shortly before beginning of a new plan will have only a very marginal impact on economic growth during the plan period.

Thus, the approach was to determine exogenously the likely overall economic growth, including the availability of foreign exchange and of public savings, and based thereupon to determine the maximum level of public investments Cameroon would likely be able to finance. The reasoning is somewhat in contradiction with the conventional wisdom that assumes a close impact of public investment decisions on economic growth over the plan period and where planning exercises often start off by establishing overall macro-economic growth targets and then tailoring the investment program around this goal. The approach adopted here was based on three inter-related reasons:

(a) Considering that the average time lag between the moment a public investment is completed and the time it starts to have an impact on output is at least two years, public investments during the last two years of the plan period are assumed to have no impact on economic growth during this period; thus, only public investments made during the first three years count;

(b) Considering the expected improvement in Cameroon's absorptive capacity, as well as continuing inflation, public investments are likely to increase substantially towards the end of the plan period but to be relatively small during the first years; thus, the amount of investments made in years that do matter for the purpose of projecting growth is well below the five year average;

(c) Most public investments carried out during the first two years are already in the pipeline now, and will be carried out irrespective of Government decisions concerning the overall volume and sectoral composition of the Fourth Plan; such decisions will affect primarily projects in later years of the Plan.

Determining the Size of the Investment Program

Prospective changes in the utilization of the Gross Domestic Product (GDP) shown in the table below, bring out very clearly the limits to a massive increase in investments during the period of the Fourth Plan. Indeed, the rise in gross fixed investments to about 17.4% of GDP in 1980/81 - which seems the necessary minimum to achieve satisfactory economic growth in the early 1980's - can only be sustained through a widening in the foreign trade and services deficit and an even larger increase in the savings gap amounting to nearly 7.5% of GDP by 1980/81 or over 38% of total investments. Clearly, this is about the maximum Cameroon can reasonably expect to finance from abroad. At the same time, however, it would be difficult to imagine a further increase in local savings. The table gives the actual use of resources in year 70/71 and the projection in year 80/81. The projections have been made in terms of the Gross Domestic Product, GDP, which is conceptually very close to the Gross National Product, GNP. For the purposes of illustration they are interchangeable.

Projection of the Use of Resources

(3 year averages in current market prices)

	In billion of CFA Francs		In % of Total GDP	
	1970/1971 Actual	1980/1981 Projection	1970/1971	1980/1981
Consumption:				
Public	45	181	15	15
Private	220	826	73	70
Total	265	1,007	88	85
Investments:				
Public	27	125	9	11
Private	15	81	5	7
Stocks	7	24	2	2
Total	49	230	16	20
Exports	83	343	28	29
Imports	-96	-399	-32	-34
Total GDP	301	1,181	100%	100%
Savings:				
Gross domestic savings	37	175	12	15
Net factor payments abroad	- 2	- 33	- 1	- 3
Gross national savings	35	142	11	12
Savings gap (Investments less National Savings)	14	88	29	38
			(As a percentage of investments)	

Projection of Balance-of-Payments

Cameroon's balance of payments projections which are contained in the table above, are dominated by the likely development of its terms of trade. At constant prices, the balance of goods and services was expected to develop quite favorably with an overall deficit remaining at about the same level during the period under consideration and with the coverage of imports by exports improving from 90% in 1972/1973 to nearly 93% by 1980/1981. Substantial increases in exports of secondary rural products such as rubber, bananas and vegetables, resumed growth of timber exports and a sharp decline in imports of such basic foodstuffs could be foreseen.

Analysis and Projections of Public Savings

Projecting public finance trends is somewhat different from that of other macro-economic variables; particularly it is more difficult to draw the line between objective and normative projections (i.e. between what is likely to happen and what would happen in the event of advisable policy changes).

The projected public sector savings are shown in the table below which comprises the central Government, the municipalities, and other public enterprises.

Projection of Public Savings
(Three year averages in billion CFA Francs at current prices)

	1970-1971 Actual	1980-1981 Projection
Central Government:		
Total budgetary revenues	52	201
Total current expenditures	43	166
Gross budgetary savings	9	35
Municipalities: Gross savings	1	1
Stabilization funds: Annual surpluses	1	2
Public enterprises: Gross cash-flow	4	17
Total gross public savings	15	55
Debt service	3	36
Total net public savings (net investable surplus)	12	19

Government's current expenditures have increased at around 4% in real terms since independence. For the remainder of the 1970's there will be little possibility to reduce this trend in line with the projected much lower growth of revenues. On the contrary during the last 10 years there has been considerable under-spending in Cameroon's current budget, particularly in such key sectors as maintenance (roads, schools and hospitals), material and equipment for education and health and for the rural sector, including livestock, fisheries and forestry. Thus, while the future growth of current expenditures ought to be kept to a minimum for financial considerations there is an urgent need to speed up such expenditures in the priority sectors. These conflicting aims can only be resolved through a systematic resetting of priorities within the current budget, by keeping to a minimum expansion in low priority sectors, so as to allow a much faster growth in other sectors without exceeding a growth rate of 4% per amount overall.

To do this, it is necessary to broaden the concept of development, which in the past was narrowly defined by budgetary procedures to include only new fixed investments, while current outlays were entirely treated as non development-oriented. De facto, within the current budget priority was usually given to salaries while the necessary austerity measures hit primarily outlays for maintenance, materials, and supplies. However, the current budget is as much an instrument of development as the investment budget, and priorities within the current budget ought to be set with this very purpose in mind. Clearly, there is no point in building new roads if they are not properly maintained afterwards, nor to build new hospitals if there is not enough medicine and food for the patients. A case in point is forestry, where at this stage it seems much more urgent to build up a competent and well functioning forestry service than to increase fixed investments in forestry roads, saw-mills or anything else.

Financing of Public Investments and the Optimum Size of a Public Development Program during the Period of the Fourth Plan

Inherent in the general macro-economic and public finance situation outlined above are three main financial constraints, limiting public development outlays:

- the relation between the amount of local funds available to finance new investments (net public savings) and the amount of foreign capital inflow, as most foreign aid usually requires a certain minimum of local cost sharing;

- the maximum amount of foreign borrowing consistent with prudent long term management of the country's foreign debt;

- the maximum amount of capital the country can raise abroad, at terms consistent with prudent debt management, considering the expected general shortage of investment capital in the world and the recent difficulties of many governments in the industrialized world to increase their foreign aid.

It is particularly this third factor which is likely to become the main bottleneck limiting borrowing from abroad and thus limiting the size of Cameroon's public investment program during the period of the Fourth Plan.

The projections of gross and net public savings and the expected trends in the balance of payments suggest that a public development program of some CFAF 465 billion (at current prices) will be about the maximum that Cameroon can possibly hope to finance during the period of the Fourth Plan. Thus, it is proposed to set this figure as a goal for total public development outlays during this period. A total of CFAF 465 billion in current prices corresponds to some CFAF 310 billion in constant 1974/1975 prices, which is the price basis chosen by Cameroon for the elaboration of the Fourth Plan.

THE INTERMEDIATE PHASE

Approach Used in Determining the Proposed Sectoral Composition

In determining the sectoral allocation of investments, any short and medium-term planning exercise must almost necessarily take into account two main factors: absorptive capacity within each sector and sectoral priorities. Its final proposals are likely to reflect a compromise between these two considerations. While "priorities" indicate what a Government would like to do, the "absorptive capacity" puts a limit on what it can do. Thus short-term sectoral allocation of resources can be characterized as pushing Government priorities as far as the absorptive capacity permits; any neglect by Government planners of the limitations imposed by absorptive capacity inevitably results in unrealistic and unachievable plan goals.

Undoubtedly, a major factor determining short and medium-term absorptive capacity in a given sector is the status of project preparation, i.e., the amount of projects in the pipeline that:

- are already being implemented at the time the new plan begins,
- are ready for implementation soon after the beginning of the new plan, or
- are at least sufficiently advanced in their planning so that a start of implementation will be possible before the end of the new plan period.

Given the long gestation period between the moment an important project is seriously considered for the first time and the time of its physical completion, few if any large projects are completed within a plan period that have not seen at least a beginning of preparation during the preceding plan.

Consequently, short and medium-term planning is largely limited in its choice to projects that are already in the pipeline at the time the planning exercise begins. Institution building is another important factor determining absorptive capacity; again, this is usually a long and difficult process, particularly if it concerns new fields of government activity, like low-cost housing or informal education and training. Even if the Government decides to give high priority to such sectors in a new plan, actual investments carried out will necessarily remain very limited for several years.

The limits imposed by absorptive capacity narrow the scope for project selection according to priorities in short and medium term plans. However, choices still have to be made among the many projects under preparation which often exceed the financial possibilities of a country. In addition, a number of smaller projects with relatively short gestation periods can and ought to be considered that could possibly be prepared for full or partial implementation during the later years of the plan.

The fact that absorptive capacity can only be increased over a relatively long period of time underlines the urgent need for longer-term planning, well beyond a four or five-year cycle. To a large extent, this is done in the form of planning of project preparation work (i.e. planning of sector studies, prefeasibility and feasibility studies, etc.), which will later lead into project execution. Indeed, it must be a major concern of each planning exercise not only to plan the implementation of public investments during a given period but also to plan all the preparatory work necessary to get projects ready for implementation during the following period. Only at this early stage in the project cycle, is it possible for the planner to bring fully into play considerations of sectoral priorities without-being unduly limited by considerations of absorptive capacity.

Actual Determination of Investment Sector Distribution

In line with the methodology the sectoral distribution of the investments was made by the following three steps:

(i) Listing all pre-determined projects.
(ii) Establishing a number of high-priority sectors in which particular efforts should be made to spur investments.
(iii) Establishing a number of high-priority projects in other sectors.

Pre-determined Projects

The pipeline of predetermined projects was highly oriented towards transport infrastructure, which accounts for over half of all such projects. This reflects past government priorities and is necessary to complete Cameroon's basic transport infrastructure. Since the returns on completing transport links are generally high, there can be little doubt about the justification of carrying them out even though this bears heavily on the overall sectoral distribution of public investments during the Fourth Plan and is responsible to a large extent for the continuous very high share of transport investments in the proposed program, despite the envisaged reorientation in overall priorities. Another third of predetermined projects concerns the rural sector and is very much in line with stated priorities for the Fourth Plan; projects in all other sectors together account for little over 13% of the total.

High Priority Sectors

After deduction of CFAF 90 billion of predetermined projects from the proposed Plan total of CFAF 310 billion, the actual planning exercise was limited to an amount of some CFAF 220 billion. Obviously, even within this group, the choice of the planner is limited by considerations of absorptive capacity as discussed above, that will narrow project selection largely to such projects that are already under preparation.

In line with the Government's own thinking, five priority sectors were determined:

(i) rural sector
(ii) energy
(iii) forestry roads, rural access roads and road maintenance
(iv) post-primary training (formal and informal) and first cycle of secondary education
(v) low cost urban housing (site and services).

For these five areas only, it was proposed to expand public investments as far as absorptive capacity permited, i.e., to allocate in the Plan sufficient funds to allow the implementation of as large a volume of public investment as physically possible.

The interaction between priority and absorptive capacity becomes particularly relevant here. Indeed, in spite of the high priority attributed to these five fields the proposed public investment program remains relatively small (CFAF 109 billion of new projects or little over one-third of the total proposed investment program).

High Priority Projects in Other Sectors

After allowance was made for CFAF 90 billion for predetermined projects and CFAF 109 billion for projects in the five high priority sectors and subsectors, there remained a sum of some CFAF 110 billion (or somewhat over one-third of the total program) to be allocated to new projects in other than the high priority sectors (third category).

THE MICRO PHASE

Project Selection Criteria

In a nutshell, it was proposed then to give highest priority to directly productive investments, primarily in the rural sector (including construction and maintenance of rural access and forestry roads, and expansion of rural training), and secondarily in electricity production. Emphasis on transport infrastructure, which had received top priority in the past, should be reduced in the Fourth Plan and progressively more so in later years. Concerning social infrastructure, the situation was more difficult and varied from sector to sector; but overall it was proposed to give the social sectors somewhat less importance in the Fourth Plan in favor of more directly productive investments; however, unlike transport infrastructure, this change in emphasis was proposed to be only temporary, and with the beginning of the Fifth Plan, the development of social infrastructure should be given increasing importance.

The rationale behind this ordering of priorities was threefold:

(i) low economic growth during the past several years urgently demands that increasing emphasis be given to the development of directly productive sectors; local food production as well as

Summary Proposals for a Public Investment Program during the Fourth Plan
(In percentage of total)

	Third Plan Estimated Real Disbursements	Fourth Plan Proposed Program
Directly Productive Sectors		
Rural	18%	24%
Energy	6%	15%
Industry and Services	3%	2%
Sub-total	27%	41%
Transport and Communications Infrastructure	42%	39%
Social Infrastructure		
Education, health, water, housing	20%	15%
Sports, urban streets, administrative buildings	11%	5%
Total	100%	100%

production of export crops lagged behind expectations. Over the coming years, the worsening of Cameroon's terms of trade made it even more urgent to stimulate local production;

(ii) as a result of the heavy investment in transport infrastructure since Independence, the country's basic transport infrastructure is approaching completion, justifying a gradual reduction in the importance to be given this sector in the future and a shift to more productive activities which will utilize the new capacities;

(iii) in the social sector, which received considerable attention in the past, a slight temporary slowdown in the expansion of public development outlays in favor of more directly productive investments can be justified, particularly since in several sectors basic decisions concerning longer term development strategies are actually pending that have to be solved before major new investment efforts are undertaken.

Priority Tranches

In addition it was proposed to have the total public development program, divided in three parts, a core program of about 75% of the total, comprising the highest priority projects, plus two additional tranches of 15% and 10% respectively containing projects of somewhat lower priority. The idea was that during the first two to three years of the plan period, Government should concentrate on implementing the core program and should only take up the two additional tranches if and when the necessary financing was assured. Such a set up is instrumental to avoid unwanted major deviations from originally established priorities in the course of plan implementation. Such deviations are often caused by an excessive amount of lower priority projects undertaken during the early years of a Plan, based on optimistic projections of available financing, which in later years of the plan period forces the Governments into substantial cutbacks in higher priority projects, when financing turns out to be less plentiful than expected.

Proposed Public Development Program by Tranche
(In percentage of total)

	Core Program	1st additional	2nd additional	Total (average)
Directly productive	48	27	16	41
Transport infrastructure	37	48	48	39
Social infrastructure	17	25	36	20
Total	100%	100%	100%	100%

The five high priority sectors account for over 53% of the core program, but only 23% of the two additional tranches.

The Role of Social Infrastructure and Water Supply

Social infrastructure investments have been divided into two groups, according to their projected impact on overall economic growth and on the standard of living of the rural and urban poor. For education, health, water supply/sewerage and housing (including the high priority sub-sector low-cost housing) only a slight decline in their relative share has been proposed, resulting in 12% increase in proposed public investment in real terms. On the other hand, for sports, urban roads and administration buildings, a real decline is proposed.

Concerning urbanization and water supply, the need for substantial public action is obvious. However, if the Fourth Plan is to focus primarily on directly productive investments, it would be difficult to expand public investment in urban infrastructure substantially above the level of the Third Plan except for low cost housing (site and services) that is one of the five high-priority subsectors. Thus, the proposed increase is limited to about 10% at constant prices. On the other hand, even with a relatively limited expansion in overall urban investment, it would be possible to step up assistance to the urban poor significantly by concentrating the development effort on a few important sub-sectors such as low-cost urban housing and sewerage to the detriment particularly of urban streets.

The public investment program elaborated for this sector is characterized by a below average overall expansion (9.3% at constant prices), along with a marked reorientation toward projects directly designed to raise the standard of living of the urban and rural poor.

Sewerage and water supply are the sub-sectors deserving second highest priority after low-cost housing. Sewerage has been largely neglected during the Third Plan and considerable investments are urgently needed, particularly in Douala. On the other hand, water supply investments are an extension of programs that have been executed continually by two well managed public institutions. Increasing emphasis ought to be given to rural water supply. Such projects should be conceived and implemented more and more within the framework of integrated rural development projects.

A Water Planner's Comment on the Cameroon case Study

It is of prime interest to note how water supply and sanitation investments have been determined. Here as is typical they are included in the group of lowest priority since they are not considered to be directly productive. Accordingly, their share of investments was determined as a residual after directly productive and high-priority sectors have seen their needs met as far as absorptive capacity goes.

It should be further noted that water supply and sanitation investment volumes are not fixed through comparisons between say the cost efficiency of preventive health, exemplified by water and sewerage, and curative health care, such as in the form of hospitals. Neither does the macro-planner use any data on service levels to see whether the Cameroonian population is better served with water and sewerage than say 10 years ago, or if Cameroon has high service levels in relation to its economic development. There simply is no firm basis for specifying that a certain sector should receive such and such a share of the total. It is rather the macro-planner's own personal impressions from the sector's importance, reinforced by the sector entities' efforts to promote their cause, that decide.

The fact is that project pipeline and absorptive capacity considerations are of such overwhelming importance. The upshot is that any sector with a reasonable investment project vastly increases its chances of having it financed simply by preparing it. This is especially true in those sectors where cost-benefit analysis is not feasible, of which the water supply and sanitation sector is one example. Promotion may not be only through feasibility studies but can be of a more direct kind by simply informing decision-making bodies and individuals what a certain sector does and stands for.

CASE STUDY TWO - ISRAEL'S WATER DEVELOPMENT

Ancient Water Development

One of the earliest references to water recorded anywhere is the first chapter of Genesis where the Bible seeks to explain the existence of water on earth as being of heavenly origin. Later the Garden of Eden is described as a place where water was plentiful and where four rivers irrigated the lands. These four rivers might well correspond to the Tigris and the Euphrates in Mesopotamia, the Nile in Egypt, and the Jordan in Israel.

Further on in Genesis it is related how the shepherds of Isaac dug wells for water and came into conflict with a neighbouring tribe over the source of water. The strife was settled when a more abundant supply was developed near Beer Sheba in the northern Negev desert.

Still later, in Deuteronomy 11:10-11, the Bible describes Israel's water resources as not only being insufficient in quantity but also unreliable and varying much from year to year: "For the land whither thou goest in to possess it, is not as the land of Egypt from whence ye came out where thou didst sow thy seed and didst water it with thy foot, as a garden of herbs. But the land whither ye go over to possess it is a land of hills and valleyes and drinkest water as the rain of heaven comest down."

Remnants of ancient systems to collect rainwater from hill-slopes have been found in the Negev desert at Avdat and bear witness to the efforts to harvest rainwater to irrigate arid lands. They also show that ancient Israel had a highly developed agriculture which was "flowing with milk and honey". Then as now agriculture was developed between the desert of Sinai in the south and the deserts to the east and the north-east in Syria. The cultivated land was constantly threatened by nomadic desert tribes who entered the green areas to feed their flocks of sheep and goats. Knowing the results of indiscriminate grazing the farmers actively opposed their entry and later excavations have revealed old fortifications that the farmers erected to keep the nomads out of their fields. Success varied though. Whenever there was a strong government in the capital city Jerusalem the farmers could maintain and even extend their cultivated area with individual settlements as far south as Eilat. Under weak governments the nomads waged war against the farmers and advanced up to larger towns in central Israel.

It has been estimated that at the beginning of the Common Era shortly before the Roman conquest of Judea that the total population sustained in the ancient land of Israel was around 5 million, a population which has only recently been exceeded. After the Roman and Byzantine reigns the population dropped and numbered around one million shortly before the Arab conquest in year 638. The dwindling population could not be supported by the shrinking cultivated areas which were increasingly taken over by desert nomads. The decline accelerated after year 750 when the Abbasic dynasty in Bagdad replaced the Umaijah dynasty in Damascus as rulers of the country. The greater distance from Israel weakened the administration and in 1480 desert nomads even managed to penetrate Jerusalem and plunder the city. Gradually farming and commerce ceased and when the new Turkish rulers organized a census in the 16th century the population in the Land of Israel was gauged at some 300,000. This population remained constant in numbers until the end of the 19th century when Jewish immigration started.

The new farmers and settlers met the same adverse climatic conditions as those described in the Bible. Not only is the average rainfall of 350 mm a year insufficient for profitable dry farming but the variations are large with northern Israel receiving up to 1,000 mm and the southernmost a negligible 10 mm. This puts the northern half with an average 600 mm in the semi-arid category and the southern half among the arid zones. The scarce rainfall in the South is especially unfortunate as this is where two-thirds of the best arable lands are.

The seasonal distribution also is a source of problems as practically all rains fall during the four-month winter. Some of the rains are of high intensity causing flooding and much water is lost to the sea. The flat topography adds to the difficulties as it offers few opportunities to construct dams to store water from the rainy winter to the dry summer. Actually there is only one interseasonal surface reservoir of importance, the Sea of Galilee in the north.

Present Days' Water Development

The development of water resources prior to and after Israel's independence took place in three stages. The first generation water systems were local and piecemeal and were largely determined by resettlement efforts by Jewish farmers on randomly distributed lands that could be purchased under the prevailing, extremely restrictive legislation. Water was usually drawn from shallow wells drilled into the coastal sandstone aquifer.

The approach changed abruptly with the establishment of the State of Israel in 1948. A large influx of immigrants and the need to absorb them in agriculture led to sharply higher water demand and a second generation of water projects were implemented. They were generally further inland and derived their water from springs and deep wells drilled into the water-bearing limestone formation of the Judean mountains. Gradually these later projects were interconnected with the first generation projects along the Mediterranean coast and elsewhere to form regional systems.

The newly won independence also changed the water planning. A first draft plan for water development was adopted already in 1950 and initiated an energetic planning and revision process that has continued ever since. Water development was actually one of the very first sectors for which long-term plans were drawn up and implemented. The inventory of water resources which preceded large-scale investments confimed the picture of a country with scarce water quantities which were furthermore poorly distributed in time and space and the quality of which was not suitable to all kinds of agriculture. Another negative aspect was the overwhelming negative energy balance with the main reservoir, the Sea of Galilee, situated some 200 m below sea level. Not only did this preclude large-scale hydroelectrical development, but it meant that full utilization of existing waters would consume large amounts of energy.

Against this unfavorable background a water development plan was drawn up envisaging action in many fields simultaneously. In order to boost supplies and correct some of the spatial maldistribution a third generation of water investments were designed and construction was initiated in the late 50's. This was the Jordan River System which was to pump the Jordan waters from the Sea of Galilee through the National Water Carrier to the central and southern parts of the country. Through this large-capacity (20 m^3/sec) water conduit an annual 365 million m^3 can be transported, amounting to some 20% of the annual water consumed. Another, less conspicuous, goal of the third-generation projects was to interconnect all first generation local and second-generation regional schemes, thus achieving nationwide maneuvrability and high utilization of total water resources. Such interconnection permitted switching from surface water to groundwater, from recharging of aquifers to overexploitation as climatic conditions required so. The excess production capacity that such overexploitation dictated was already installed in the mid 50's for the utilization of the one-time stocks in the underground reservoirs.

The rapid physical changes in the 50's and 60's were parallelled by an overhaul of existing legislation and resulted in a new Water Law being adopted in 1959. The new law made all water resources the property of the State and set conditions for efficient water use. For instance a by-law was passed making universal water metering mandatory and water allocations were drawn up assuming that irrigation methods applied would be capital-intensive and water saving. Accordingly sprinkler irrigation evolved, later to be followed by trickle irrigation.

In spite of economy measures demand growth proved so rapid that in the mid 70's all the easily developed water sources are fully utilized. Of the some 1,500 million cubic meters that can be counted upon annually all are utilized with agriculture consuming some 75%, domestic consumption another 20% and industry demanding the remaining 5%. Any further growth in water use can only come about through tapping marginal and much more expensive resources and through better utilization of the water already being withdrawn.

Future Water Sources

There are several measures to increase the quantity of water. Some are already economically viable whereas others may be more extensively used in a future. One of the most successful methods has been the cloud seeding with silver iodide practiced in the nothern parts of the country where cloud formations are more favorable. It has been statistically proven that the rains have increased by some 10 to 15% as a result.

Stormwater interception has also expanded much in later years. It involves the construction of dikes or dams with adjacent storage to catch flashfloods and store them for later use. Although it is not clear what is the net increment to the water balance, in most cases such interception would appear economically justified. At times the works are combined with infiltration into the underground from which water is later pumped for consumption.

Other techniques to increase the water yield are more experimental in nature. There are for instance ways to manipulate the vegetative cover in uncultivated areas where rainfall is between 300 and 600 mm annually and the results to increase runoff seem promising. Evaporation suppression from open surfaces seems to be too expensive to warrant extended use which also appears to be the case with soil treatment to increase surface runoff.

Desalting of sea-water which many thought would reduce Israel's water constraints has proved much costlier than envisaged and will likely not contribute much until the 21st century. Although there are a few desalting plants in operation, notably one supplying the southern town of Eilat, it is now clear that total production costs may be as high as one US dollar per m^3 when all capital and current costs are included. Moreover, the relative unreliability of the new technology and its heavy use of costly energy make it unlikely that a breakthrough in the form of lower costs can be expected soon. This implies that desalting will continue playing a subordinate role since its logical use would be in agriculture which cannot pay such high water costs.

The use of brackish waters is more economical. As of now some 10% of total water consumed is brackish. Some of it is used in industry, some in fish-ponds whereas the bulk goes to agriculture to irrigate salt-resistant crops. New irrigation techniques have been developed to prevent salt build-up in the soil and excellent results have been obtained with vegetables, wheat and cotton.

The chief means to increase the country's water potential will be the reuse of sewage that is currently discharged as waste. Both municipal and industrial waste waters can be used after suitable treatment with the double purpose of preventing pollution and adding to usable water quantities. Sewage reuse is attractive from the point of view of dependability as climatic fluctuations matter less. There is a danger of extending recycling of sewage indiscriminately, though. In a closed water cycle of ground water, salinity builds up and there is an increase of harmful elements such as pesticides and heavy metals.

The more intensive water-use and the closed water cycle in the coastal areas have interfered with the natural hydrological cycle. An example would be the National Water Carrier which has led to lower quantities of water entering the Jordan river and quality suffering as well. The problems have been compounded by large-scale diversion and irrigation works that Jordan has constructed on the east bank of the river.

The smaller water quantities and lower water quality in the Jordan river have damaged the flora and fauna and led to dropping water levels in the Dead Sea. About 2,000 million cubic meters evaporate from its shrinking surface each year and only some 500 million go back in. The level which some 100 years ago was 394 m below sea level is now down to 400 m below and subsiding by 30 cm each year. In order to reverse the shrinkage an old idea to construct a tunnel or channel from the Mediterranean to the Dead Sea has been revived and studied in detail. Such a tunnel was suggested by Theodor Herzl as early as 1902 in his book "Altneuland" and would serve to generate hydroelectric energy in addition to replenish the Dead Sea with water and salts.

ECONOMIC ANALYSIS OF PAST AND FUTURE WATER DEVELOPMENT

Water development in general is undertaken to correct to the extent possible the maldistribution in time, quality and location of natural water resources. In the particular case of Israel, from all three aspects the maldistribution is pronounced. There are three fundamental questions that should be raised when maldistributions need be corrected:

(i) What kind of system should be built to minimize the discrepancy between the natural availability in time, space, and quality and the demanded types of water?

(ii) To what extent should existing water resources be developed and how extensive should the region be that is to be served by the system?

(iii) Once built, how should the system be operated so as to achieve a given set of objectives in the optimal way?

The answers to the first two questions have already been answered de facto in the case of Israel's water development whereas the third question is still partly unresolved.

"What system should be built?"

Little economic analysis was undertaken when deciding what systems should be built in the various stages of development. What mattered more at the time was the need to find any water whatsoever within an area to be developed in the face of legal restrictions. For instance the Ottoman law in force during pre-State days explicitly prohibited the transfers of water from one region to another and supplies thus had to be solved on a local or at the most regional basis. Later on during the early days of statehood other economic and social questions such as the need to absorb some 700,000 immigrants during a period of four years dominated over economic analysis. The water resources had to be developed to serve the agricultural settlements and new towns that sprung up and there was not much time for economic analysis. The absence did not mean that the development would have been very different had economic analysis been applied.

As mentioned, the first round of water schemes were local, and most of them were constructed before independence. Technically they were not very sophisticated and in some instances they upset the water balance. For instance, due to excessive extraction in the Mediterranean Coastal Zone salt water intruded into the sweet water aquifer and extraction rates had to be diminished.

The second round of regional schemes were executed in the early years of statehood and had an element of economic analysis in them. Early on it became clear that the country's water resources would constitute a relative bottle-neck for economic development and water economy was encouraged and built into the systems from the beginning. At the same time these second-generation schemes were constructed an intensive inventorying of the country's water resources was conducted, and the decision to construct the National Water Carrier was taken.

The choice of the third national system was fairly obvious. The bulk of water resources were in the north while the large tracts of suitable and under-developed agricultural land were in the south. Some form of massive transfer scheme had to be designed and the negative energy balance dictated a pumping scheme. The absence of natural sites for surface water reservoirs obliged the use of groundwater reservoirs for storing water between the rainy winter for use in the dry summer when agricultural demands were the greatest. All these pre-conditions shaped the National Water Carrier which was constructed to bring water from the northern Sea of Galilee to the southern Negev through large-scale pumping through a series of tunnels, open conduits and pipelines.

The fourth round of water development can best be described as developing marginal water sources and is the stage where economic analysis is most needed to determine whether certain sources should be developed at all. The choices available are well-known and comprise sewage reuse, storm-water interception, use of brackish waters and desalting. Production costs for all of them are so high that the interaction between supply and demand has to be examined whenever development should be decided upon.

"To what extent should water sources be developed?"

Technically speaking, Israel's water resources are unlimited since the adjacent sea provides unlimited amounts of water that could be desalted were only a cheap production process available. But economically it has to be ascertained that consumers will be willing to pay the much higher prices that such desalting implies. In the early years there was at times a healthy, almost anti-intellectual drive to act and ask less what it cost but the costs inherent in developing the marginal sources are such that careful deliberations are necessary before going ahead. In the 50's the alternative productive uses for investment capital were fewer and the answers easier. The country was poor in natural resources. There was some mining and salt extraction of limited extent but the other resources were its population, its water and land. The large influx of immigrants was an asset in the long run but a liability in the short run. Annual population increases in the order of 20% during the first years meant that large amounts had to be devoted to the housing and training of these immigrants.

Against this background the simple decision was taken to fully develop existing natural water resources so as to propel agricultural development. The ratio between land and water resources was such that there were no difficulties to absorb all the water produced and the needs to feed the larger population were such that there were no markets that had to be developed which might have restricted output. Based on such commonsense economic thinking large sums were devoted to water development which also had the advantage that it was a sector whose absorptive capacity was much larger than say industry with limited markets. From 1952 to 1954 some 20% of gross domestic fixed investments were for water development and as a matter of fact exceeded that of agriculture and forestry development which was around 17%. For a number of years the share accounted for by water development hovered around 7% of gross capital formation, excluding housing. It was not until after the completion of the National Water Carrier in 1964 that the share started to go down. In recent years only around 1% of gross fixed investments has been for water projects.

The share of water resources used in agriculture has continued high since the 50's; in later years it has been around 77% attesting to the importance of irrigated agriculture. The table below shows withdrawal rates for a series of countries as comparison:

Amounts and Distribution of Water Withdrawals in Selected Countries

Country	Total withdrawal (cu m) per capita	Distribution of withdrawals among major categories of water uses (percentage)		
		Municipal and rural water supply	Agriculture	Industry
Bulgaria	615	8	72	20
Czechoslovakia	285	13	6	81
France	540	13	38	49
German Democratic Republic	380	8	12	80
Germany, Federal Republic of	245	20	10	70
Great Britain	200	31	3	66
Hungary	390	9	45	46
India 1968	600	3	96	1
Israel 1960	630	16	80	4
Japan	710	10	72	18
Mexico 1970	920	4	91	5
Mongolia	135	12	80	8
Poland	250	13	17	70
United Republic of Tanzania, 1970	36	63	35	2
United States of America	2,300	10	42	48
USSR	1,000	8	53	39

Source: "The Demand for Natural Water Resources", United Nations

Since 1960 Israel's total withdrawal per capita has shown a downward trend since population has increased but the water use has approached the capacity ceiling. In later years total withdrawal per capita has been slightly under 500 m^3 per year, in some years higher when generous precipitation and higher summer temperatures have influenced agricultural requirements. This downward or erratic trend in per capita withdrawals is expected to continue. The question arises whether the downward trend with limited water will slow the economic growth of Israel in general and that of its agriculture in particular. The answer will have to be found in the way the scarce water resources are allocated and utilized.

"How should the water system be operated?"

The table showing the varying withdrawal rates of selected countries hints at the answer to the question whether scarce water resources will lower Israel's economic growth. It can be observed that many of these countries have lower withdrawal rates than Israel and yet enjoy higher standards of living. Of course, some of these do not have agricultural sectors requiring large-scale irrigation, or they may enjoy natural rainfall for these but nevertheless, water does not seem to be an absolute constraint to economic development.

An economist would further observe that each country can, if willing and able to change, adapt itself to its resource base, and produce and prosper by taking advantage of what in economic jargon is called a country's comparative advantages. This means that a country will position itself to produce the sort of goods and services for which it is relatively best suited. Accordingly as water grows scarcer the economy could learn to use less water in its production processes, either in agriculture or in industry. This would be achieved by substituting other production factors for water. In particular, it would be expected that capital, in the form of water-saving devices, would be substituted for water.

Secondly, a country's supply of water is only limited by what consumers are willing to pay for it. As water grows scarcer its price would rise for two reasons. There would be a cost-push rise as more marginal production sources or processes would be exploited and their deployment would be in order of ascending costs. There would also be a demand-pull as more consumers would bid for the limited water quantities. The latter would only take place if there were a relatively free market in water. Irrespective of how water prices are determined, one would expect the projects in the water pipeline to be considerably more expensive than the present ones assuming that development in the past has been rational.

Thirdly, one would expect water prices to rise faster than those of other production factors in case authorities are willing to let the cost-push, demand-pull exert their influence on prices. Such higher relative prices should signal to consumers the increasing water scarcity. As a response, the economy could be expected to concentrate on those sectors and activities which give a high return on water.

Evidence of Capital Substituting Water

There is little doubt that much capital has been invested in Israel to make water use more efficient. Both Israeli industry and agriculture have learned to live with less water. Existing statistics show how water use has declined in relation to the production value. In industry water use per production value in constant money dropped around 40% from 1962 to 1971 and the trend has continued.

The tendency in agriculture is even more impressive. The water use per production value decreased by some 60% during the corresponding period, and the average quantity used per irrigated ha went down by some 14% during the same period. The decreases imply not only investments in water-saving technology but also improved irrigation technology, more sophisticated application methods and different crop mixes. The relatively recent trickle irrigation method where water is applied close to the root zone in a controlled fashion is estimated to reduce water consumption by a third while at the same time improving yields. Innovations of this nature have enabled an expansion of the irrigated area over the 1960/71 period in spite of largely constant water consumption. Simultaneously the share of persons employed in agriculture of the total decreased over the 1970/74 period from 15% to a mere 6%. The productivity of those remaining rose sharply thanks to more capital intensive production methods.

The changed cultivation methods are also illustrated by the different growth rates of farm inputs. Whereas all inputs purchased by the agricultural sector rose by 530% during the 1952/75 period the corresponding increase for water only was 160%, the smallest raise of all production inputs.

Marginal Water Sources and Future Production Costs

In mid-78 Israeli water prices ranged from some US cents 4 per m^3 for agricultural water to US cents 8 per m^3 for industrial water and with municipal bulk consumers paying an intermediate price. The differentials seem to be based on notions of different capacity to pay for water.

These tariffs can be compared to production costs of representative future production schemes. One rather attractive project to be executed over the next years is the drilling of a series of wells parallel to the Mediterranean. Through pumping from these wells it is intended to intercept groundwater that has been leaking into the sea. The total production cost from this relatively low-cost scheme is estimated to be around US cents 16 per m^3.

Another marginal source, brackish water, is estimated to have a total potential of around 200 million m^3 but some 150 million are already being used, mostly in fish ponds. One remaining scheme that would be used for large-scale agricultural development in the Negev desert has been costed at some US cents 16 per m^3.

The reuse of treated sewage effluents may be the most promising of the marginal sources. Annually there are some 200 million m^3 sewage generated in the urban areas and only around 20% are presently being used. This share will however not rise fast for several reasons. First of all, part of the sewage is lost through evaporation, and part is generated during the winter season when irrigation demands are low. Although treated sewage could be injected into the underground for use during the peak summer season there are difficulties in the environmental field. It is uncertain what effect multiple reuse will have on the water quality and on the health of the population. Concern over health risks is the most important factor limiting the direct use of sewage for irrigation purposes. Representative production costs for large schemes of sewage reuse are those of the Tel Aviv region with an estimated US$0.16 per m^3 and around US$0.25 per m^3 for smaller cities.

Storm-water interception through the construction of intercepting dams is rapidly expanding. Through judicious interception with multiple fillings of the reservoir capacity costs per added m^3 can be lowered but even so representative schemes are costing in the order of US$0.30 per m^3.

Desalting, finally, has already been mentioned as a very expensive supply method and it would be prudent to calculate its present costs in the vicinity of US dollars 1 per m^3. There is at times a suggestion to desalt water in dual-purpose plants which primarily generate electric energy and where waste heat could be used for the desalting. Such water may not become appreciably cheaper, however, since it will in all likelihood require the construction of added storage as the desalting plant will need to follow the fluctuations in the power output. These fluctuations may not correspond to the patterns in water consumption.

Criteria for Water Allocation

The picture that emerges is one of steadily increasing demands and slowly rising supplies leading to an increasingly negative water balance. Already there is overpumping in the sense that more water than the natural replenishment is extracted. The reason as noted is to keep seepage of groundwater to the adjacent sea to a minimum. Continuing mining of groundwater can prove critical if the country has the bad fortune to experience a series of drought years like those from 1957 to 1964.

In the absence of technological breakthroughs the country will have to learn to live with the limited water resources and use them optimally to yield the highest possible return. There are two ways to allocate the limited water and achieve the highest possible returns. One is some form of enlightened, "bureaucratic" allocation procedure, the other is to rely upon prices in a free market to achieve the optimal allocation with maximum efficiency. Whichever method will be practiced, there is little doubt that Israel's priority right now in the water sector is to find a proper allocation and optimal use of what water it has.

Present Allocation System

Given the country's concern over equity and its tradition of centralism and bureaucracy it is not surprising that the water allocations have been based on bureaucratic decisions. The rationality of the criteria varies but the ultimate purpose is to induce frugal use of water. For the agricultural sector in which almost 80% of all water is consumed and where inefficiencies could be expected, water allocations are based on criteria concerning crop patterns and irrigation technology dating back to the early days of the respective settlement. The norms thus ignore rapid technological progress in irrigation techniques, in crop patterns and even population movements. The net result is that allocations are quite arbitrary on the whole and may for this reason be manip- ulated by political interest groups. Whatever water savings are achieved, result from limitations on the total water quantity available and from various incentives from the Government. The water rights that are allocated have the extra disadvantage of being non-transferable and efficiency gains through consumers trading in water rights are not achieved.

Tariffs and Resulting Inefficiencies

In addition to distributing water rights, tariffs are charged for consumption. Their impact upon water efficiency is unclear, though, since there are subsidies to the agricultural sector that blunt the tariff burden. Although tariffs have risen over the years, they have trailed average costs and been even further below marginal costs. In the agricultural sector, before taking into account subsidies on account of water consumption, the levied tariffs are only about a quarter of the cost of the cheapest incremental scheme. This fact per se does not make additional water development unjustified but indicates the large subsidies that go to the agricultural sector.

Further study reveals that there are indeed areas in which water is inefficiently used in agriculture. The results of one such study is shown in the Table below. It is based on the 1975 situation and compares the net return to water and land with different costs of water or tariffs charged.

Water Consumed According to Its Net Return
(million cubic meters)

Region	Negative	Up to 22 ag	22-41 ag.	41-65 ag.	Above 65 ag.	Total Mm3
North	4	62	32	105	203	406
Central	50	59	154	119	130	502
South	2	29	49	30	84	194
Total	56	140	235	254	417	1,102

Source Boaz, Revuon le kalkala, 1976

The chosen intervals are in agorot of which there are 100 to an Israeli lira. At the time 22 agorot was the average price/m^3 during 1975 for agricultural consumption, 41 agorot was the average historical production cost/m^3 of water supplied by the bulk supplier Mekorot which dominates on the supply side; 65 agorot was the estimated real production cost per m^3 when account was taken of subsidies to the agricultural sector rebating part of the tariff and in case capital costs on account of past investments were charged realistically at a 10% real discount rate.

According to the data presented there are substantial inefficiencies among agricultural users. Only some 420 out of 1,100 million cubic meters consumed by agriculture in 1975 produced net returns on water and land that exceeded the estimated real production costs. It would seem sensible on efficiency grounds to raise prices to more realistic levels before launching further investment plans aimed at exploiting marginal sources. On efficiency grounds tariffs charged should indeed approach the marginal cost of developing new schemes that is much higher than the tariffs that would recover past investments in real terms in addition to paying for operating costs.

The fact remains that agriculture in Israel has many more dimensions than efficiency. Agricultural settlements are closely connected with efforts to spread the population more evenly over the country and in particular to develop the underpopulated expanses in the south. It is unlikely, however, that higher water tariffs would hit those southern settlements particularly hard since they often rely upon local water sources and highly intensive, off-season production for export markets which yield very high returns. Higher tariffs would rather hit inefficient producers in other parts of the country which have failed to switch to higher-value crops and more efficient irrigation techniques. These are the true beneficiaries of the underpriced water.

Alternative Water Allocation

Alternative allocation systems would introduce pricing to encourage efficient water use and compel those earning an adequate return on water to increase overall efficiency or else leave the market for water. There are sev- eral ways in which tariffs could be set.

One method would continue periodic tariff increases by dictum which would be based on some form of calculation what the realistic price should be. There are disadvantages with such a procedure though. In an economy with rapid inflation, like the Israeli one, political pressure may cause prices in the public sector to lag inflation. It is argued that already high inflation is fuelled by additional increases for instance relating to public utilities such as water, electricity and so on. Apart from the fallacy in such an argument in case the inflation is of the demand-pull type, it does not seem obvious why agricultural water has to be subsidized. If the direct concern is the impact of inflation upon consumers it would seem sufficient to control tariffs for domestic water consumption.

In case such a tariff system is introduced the proper tariff would be the so called long-run incremental cost of water supply which would be approximately the cost of the marginal schemes about to be constructed. Such higher tariffs would signal the future cost of supplies of water to the consumers and allow them to adjust to the higher prices in advance. In particular the investments in future productive capacity in industry or agriculture, would have to take into account the signalled higher tariffs and invest in water-saving devices or simply choose a production process that would not be particularly sensitive to high water costs.

Water auctions

Another more ingenious allocation criterion, that would to a larger degree take into account rainfall fluctuations, would be to institute a system of public auctions each year in addition to legalizing trading in water rights. Under such a system a seller representing the state of Israel (that is the owner of all water and controls the producers) would auction off whatever water quantities it expects to be able to supply during the year to anybody willing to bid.

Under such a system a minimum floor price could be set represented by what it costs financially to produce the water. This would satisfy the financial requirements of the producers.

Moreover, the scarcity value of the water would be brought out into the open when potential consumers would bid for the water. It would also have the additional advantage of permitting adjustments on an automatic basis for inflation and would remove water pricing from the political arena. In case the Government at any rate would want to subsidize water consumption, it would be free to purchase water in competition with any other buyer and then onsell it at the desired lower price. In this case the subsidy implied would be clearly visible and its justification could be contested better than is now the case.

Further, water demand in Israel shows strong seasonal fluctuations with a peak during the hot and dry summer when irrigation demands such as cotton requirements are concentrated. The system of auctioning could put the burden more squarely on these peak consumers by auctioning off quantities for this limited period only. After the end of the rainy winter good estimates would be available of the possible production levels. The auction could then sell water for delivery during the next six months. The buyers who bought too little or too much water should be permitted and encouraged to buy or sell their options for water delivery whenever they wanted. This would assure a smoothly operating market where those water consumers would be favored who could best forecast trends in agricultural prices and rainfall and other climatic factors. A more efficient agriculture would follow.

In order to encourage the development of marginal water sources it could be considered to give long-term contracts to those willing to invest in their development. This would provide a guarantee that water could be extracted over a sufficiently long period to recuperate the investments. The financing of such works may come out of the temporary financial surpluses that would likely result from such a system of public auctions.

Concluding Remarks

Israel's rapid water development has been remarkably successful over her thirty years of statehood. Notwithstanding, there are considerable pockets of inefficient water use and these will be increasingly costly to support since the costs of necessary new production schemes are rapidly escalating. Much of the blame for such inefficiencies must be put on the allocation system which is based on water rights and which has survived itself. The price for water has to be introduced as a major allocation criterion to increase efficiency in present water use and direct the future investments to areas which are less water-intensive. The preferred way of pricing would be through establishing public water auctions where options for water delivery during certain periods and in certain quantities could be bought and sold.

SECTOR PLANNING

General

Sector planning should provide the link between the macro-planning and the subsequent project planning. Whereas the macro-plan will at best specify how much should be invested in the water supply and waste disposal sector over a period of time, the sector plan examines whether such investments are feasible. It will have to determine which geographical areas deserve priority and which population segments future investments should be directed at. At the project planning stage the individual investment projects will be identified and designed, and through the implementation of projects the sector is slowly reformed and developed.

The two key-words describing sector planning may indeed be "feasibility" and "action-oriented". Sector planning could be likened to a feasibility study to test whether the macro goals are achievable. To this end it will address itself to the financial feasibility of goals, to the organizational capacity, and to the question whether the human resources will be there in adequeate numbers and skills to make the plan come true. To meet this order the sector plan will go much deeper than the macro-plan. For instance, instead of merely recommending that public savings be increased as the macro-plan might do, the sector plan will have to explore in some detail how this can be achieved, to what levels tariffs might be raised, and how such increases could come about.

The differing depth of analysis distinguishing macro and sector planning is underlined by the staff required for the respective tasks. The macroplanner will almost invariably be a trained economist, or at least have a good grasp of economics. For good and solid sector analysis this is not enough but the sector planning team will have to be well acquainted with all the various aspects of the water supply and wastes disposal sector. Typically, sector plans are drawn up by engineers, who should be fully cognizant of the sector peculiarities. At the same time they should not suffer from myopia but be able to analyze the sector as a whole. Their expertise will frequently be supplemented by financial expertise and by micro-economists.

The focus of a sector plan is more narrow than a macro-plan for water. Although there are examples of water sector studies that attempt to analyze all aspects of water development, be it for agricultural, industrial, navigational or human uses, they will more typically analyze one sub-sector at a time. In the case of water supply and waste disposal, the focus may be even more narrow and concentrate on piped water for domestic, industrial, commercial and public users and then include water-borne waste disposal.

The setting of sector targets or objetives is more normative than the others facets of sector planning. Frequently, objectives detailing what the sector is expected to achieve within a given time period are lacking, and it will then be a prime task of the sector planner to propose targets with due regard to their feasibility. Targets should not be fixed too low, in a desire to be realistic but should be ambitious enough to ignite more vigorous sector development and force sector institutions to act.

Sector planning's orientation towards action provides the bridge to project planning where investments are planned and executed. Here as else-where, the proof of the pudding is in the eating, and if a sector plan cannot stimulate investments it has failed in one vital aspect. To minimize this risk it is customary to attempt to identify in a preliminary way individual projects during the elaboration of the sector plan.

A sector plan actually has to meet a tall order. It has to be sufficiently general to be of interest and help the non-specialists, such as the policy-making politician or the macro economist. This function can be described as the sector's face to others and may determine the sector's share of overall investments. On the other hand, the analysis has to be enough supported by data, and inspire confidence that the sector will use funds efficiently.

Outline for Water Supply and Sanitation Sector Studies. In line with what has been said above, sector planning should then focus on the objectives of the sector development, and on the feasibility of achieving them. The ultimate objectives are not difficult to find - to provide the entire population with safe and wholesome water and dispose of it safely - but they have to be operationally defined lest the sector plan degenerate into an exercise in wishful thinking.

At the same time it is important that the water and sewerage sector be integrated in more general development strategies to achieve a proper balance between directly productive, infrastructural, and social investments. The water sector investments are usually defined as social as their purpose is clearly to directly raise the well-being of the population. Such views are well enunciated for instance in the "basic needs strategy" where the provision of safe water and its adequate disposal appear alongside with the elementary needs for food, clothing, and shelter. The water supply sector may also be used to redistribute income since providing all consumers with water will make them equal where component of one essential quality of life is concerned.

In addition to water's social character it also has a considerable impact upon the population's health and consequently on the productive capacity of the economically active. Although these effects have never been satisfactorily quantified no one disputes their existence. Besides, the long-term positive health effect of water supply and waste disposal is achieved through a stress on preventive medicine instead of curative medicine, and is thus likely to be more cost-effective than most other health measures.

Some measurement will have to be used to gauge progress towards the general sector objectives. The most practical yard-stick would seem to be the concept of service levels in water supply and sewerage. These service levels which comprise quantitative as well as qualitative aspects, will then serve as a proxy for the more universal goals. Where a population has ready physical access to a well functioning water system it could be assumed that such a population will derive all the convenience and health benefits from the system that are normally associated with water supply.

Accepting service levels as a proxy for sector objectives can help formulate a logical format for sector analysis. The sector planning will then comprise six distinct steps as follows:

i) The assessment of present quantitative and qualitative service levels

ii) The setting of target service levels to be achieved by a given time

iii) The calculation of required resources for meeting targets

iv) Constraints emerging when requirements are compared with avalilable resources.

v) Suggested solutions to remove constraints. Foremost among these would be indications which projects deserve priority.

vi) The setting of investment priorities

The outline contains all the essential elements of sector planning, such as objectives, the feasibility of achieving them, and the emphasis on action through the preliminary identification of investments. The stress on present and targetted service levels guarantees that the sector planning retains the main purpose which is to supply the population with water and sewerage services, and does not deteriorate into abstract planning. The service situation of specific population strata, such as the urban and rural poor, can clearly be identified and measures to improve their lot proposed.

Present Service Levels

Although it may be agreed what the ideal water supply should look like, in the real world it is anything but simple to gauge service levels. The mere presence of a water supply system does not imply automatically that the population is enjoying satisfactory service. On the contrary, a defective public water supply may be a most effective way of spreading epidemics since it reaches each person. Unless the quality of the water supplied is superior to natural alternatives the population's health may suffer more than in the complete absence of a piped system. Similarly, if a water system is constructed with no attention to the safe disposal of the waste waters, the health situation may become worse than before.

It follows that an adequate description of service levels has to comprise estimates of the physical coverage of the community by the piping, as well as an evaluation of the quality of the water supplied. In between the two quantitative and qualitative facets of water supply is a series of other, less important factors, such as supply pressure, and hours of uninterrupted service. These can often be shown to influence the quality or safety of supply and therefore need not be analyzed in isolation notwithstanding their convenience aspects.

The physical coverage, or ease of access, comprises a wide range of types such as:

a) Individual house connection with multiple taps and fixtures;

b) Individual house connection with one tap outside the dwelling;

c) Public standposts serving more than one family. These encompass many different kinds, such as communal supply points that can be yard connections serving a few families, or standpipes serving thousands of people;

d) Truck or vendor delivery to door or distribution point;

e) Non-piped supplies relying on natural sources which may, or may not be subject to inspection and maintenance. Among such sources are wells, springs, surface streams, and rainwater collection.

Assuming identical levels of community education on how to use the different supplies, alternatives a) to e) roughly rank in order of safety of supply. An individual multi-tap connection with water <u>inside</u> the dwelling and with matching sanitary installations is the ideal. It is followed by those supplies which serve one family only since the risk of contamination from others outside the family is reduced. However, water that has to be carried and stored entails a risk of contamination.

This danger is much greater when water is drawn from a standpost and carried over considerable distances and stored in unsanitary ways. Truck or vendor delivery in turn can at times be safer than standpost supplies but the outside persons directly involved in the handling of the water entail an additional source of contamination. The variety of natural streams or wells, finally, common in rural areas, might be safer than public supplies but usually are not.

It is thus feasible to judge which is the better supply among different alternatives, but defining a minimum satisfactory level is far from easy. One might accept only individual house connections with water inside the house as satisfactory, but this ignores the fact that a majority of the world population are deprived of this service. Until everybody will receive individual connections inside their dwellings some definition of minimum standards of outside supply would be helpful. The most common definiton used is probable that of the World Health Organization where reasonable access is defined as within 200 m walking distance in urban areas, and in rural areas sufficiently close so that family members do not spend a disproportionate share of the day in fetching water. Supposedly, in rural areas this does not necessarily mean that a family draws its water from a piped system but could also include natural streams and dug wells supplying water of acceptable quality.

The supply types (A-E described above) have to be further narrowed to be useful in sector planning. It will generally only be worthwhile to discriminate between three classes of physical access to service, namely

i) The share of population with water <u>inside</u> the dwelling;

ii) The share of population with piped water <u>outside</u> the dwelling, notably through standpipes although not restricted to these;

iii) The share of population without piped water.

Even such a simplified classification must be intepreted with caution. Although most countries produce statistics on service levels, the quality of data does not permit any international comparison, and at times not even a basis for establishing trends within a country itself. For instance, in the service level statistics published by the World Health Organization in 1970 and in 1975 there are countries reporting complete coverage in urban and rural areas when the situation is known to be much different. Such distortions may be the result of well intentioned interpretations of definitions, or statistics may have been used for political purposes. In other instances highly unconventional definitions may be employed. There are examples where the mere existence of a public water system, although deficient, is construed to mean the entire population is well served whenever there are no alternative supplies.

The upshot is that international comparisons between service levels should be treated with much caution. Variations between countries are much larger than can be explained by their different levels of economic development and priority of goals, and there are invariably quirks distorting the results. Besides, it is difficult to understand the purpose of such international evaluations since global strategies to tackle the problems are unlikely to follow. Making national service level data for different time periods comparable would be worth while, however, since it would provide a firm basis for measuring progress.

A word of caution is in place when measuring total population and population segments. Population statistics are not as reliable as would be desirable in developing countries, and it is often better to define service coverage in terms of houses served in relation to the total number of houses. Housing data can be obtained from tax registers, from the records of other public services (electricity, telephones and so on), and from aerial photography and permit a cross-check and greater reliability. Moreover, it is easy to determine whether a certain house has water inside the house or not, or whether it is within a certain maximum distance from a piped water supply.

Qualitative Service Levels

The quality of water is an even more elusive concept than quantitative service levels. Quality may mean whether service is interrupted or not, or rather if the probability for such interruptions is high, it may mean the per capita supply of water, or pressures at distribution points, but foremost it describes the quality of the water itself.

Water quality standards are conveniently divided into three groups. The first are those relating to substances and organisms which if present in water consumed by man or animal may cause physiological damage, illness and even death. The second group of standards includes those which concern substances and characteristics damaging to the water system installations, or making the water unsuitable for commercial and industrial processes. The third group finally describes substances which make the water unattractive for cooking, drinking, washing, and recreation. Among the latter are those that give taste, odor and the like to the water, or that generally render it unattractive in appearance.

The first group of standards affecting man's health is of most interest to sector planners. Setting normative standards in this field necessarily involves striking a balance between perfection and what is economically feasible. It also becomes important to understand the limits of standards to make water safe. No standards, however rigorous, can produce safe water if operations are sloppy and quality control is deficient or lacking.

Deciding upon the second group of standards related to damaging substances such as corrosive elements or excessive hardness, is simpler as it can be analyzed as a least-cost problem. The added costs of improving the water quality have to be weighed against the savings in the form of less corrosion or whatever savings there may be.

The third group of esthetic standards might be set in accordance with what the local consumers are willing to accept, or in relation to their willingness to pay for a better-looking or tastier water. Standards that do not constitute health hazards can be treated flexibly both when setting national norms, and when designing projects. Though it may be costly to treat waters to reduce serious taste problems or high colors, the processes required to meet the first group of standards relating to health often go a long way in making the water clear, taste or odorless. Expending large sums just to make water look better is debatable in the context of developing countries where there are many competing demands upon scarce investment funds. The danger of transferring blindly standards from developed countries that are in a position to pay for the associated higher treatment costs is ill-advised and reflect poor priorities. A country about to adopt a set of standards, such as the WHO Drinking Water Standards, should instead state clearly that they are for guidance only and need not dictate design if found extravagant in individual cases.

DRINKING WATER STANDARDS

Comparison

CHEMICAL, PHYSICAL AND RADIOLOGICAL STANDARDS	WHO Recommended Standards (International, 3rd Edition)	European Standards 1970 Edition	Japan (1968)	India (1973)	India Recommended (1975)	Tanzania (Temporary 1974)	USSR 1973 (Gost 2874-73)	Israel (1974)	Germany (1975)	Poland	Sweden (1969)	Bulgaria (Quoted in Tanzanian summary)	USA 1975 Interim (1) USA 1962 (2)	Thailand	Canada	Korea	Australia - Criteria	Quatar	Philippines (1963)	France
Radioactivity, α activity β activity	3 pCi/l 30 pCi/l	3-10 pCi/l 80-100 pCi/l		10.9 10.8	3 pCi/l 30 pCi/l		1.2x13e)γ x10-10c/l	3 pCi/l					3 pCi/l 10 pCi/l				3 pCi/l 30 pCi/l			
pH	6.5-9.2		5.8-8.6	6.5-9.2	6.5-9.2	6.5-9.2	6.5-8.5	6.5-9.5		6.5-9.0	6.0-8.0	6.5-8.5		6.5-8.5	6.5-8.3		6.5-8.5		6.5-9.2	
Total hardness (meq/l) 1 meq/l = 50 mg/l as $CaCo_3$	2-10	2-10	6	12	12	12	10			7		9		6	10	6	10			6
Chlorides (as Cl)	600 mg/l	600	200	1000	1000	800	300	600		215	25/250	250	250$^{(2)}$	330	250	150	600	250	600	250
Depending on temperature, Fluoride (as F)	0.6-1.7 mg/l	0.7-1.7	0.8	2.0	1.5	8.0	0.7-1.5	1.4-1.7	1.5	1.0	1.5	0.7-1.0	1.4-2.4$^{(1)}$	1-1.5	1.2-1.4	1.0	1.5	1.6	1-1.5	1.0
Nitrate (as NO_3)	45 mg/l	100	45	50	45	100	45	90	90		30	30	45$^{(1)}$	45	45	45	45		50	44
Copper (as Cu)	1.5 mg/l	.05-3 for new pipe	.20	3.0	1.5	3.0	1.0	1.4		1.0	1.0*	0.2	1.0$^{(1)}$	1.0	1.0	1.0	0.3	0.3	1.5	1.0
Iron (as Fe)	1 mg/l	0.3	0.3	1.0	1.0	1.0	0.3	1.0		0.3	0.2	0.2	0.3$^{(2)}$	0.5	0.3	0.3	0.3	0.3	1.0	0.2
Manganese (as Mn)	0.5 mg/l	0.05	0.3	0.5	0.5	0.5	0.1			0.1	0.05	0.1	0.05$^{(2)}$	0.3	0.05	0.3	0.1	0.3	0.5	0.1
Zinc (as Zn)	15 mg/l	5.0	1.0	15.0	15.0		5.0	15.0	2.0	5.0	5.0	3.0	5.0$^{(2)}$	15.0	5.0	1.0	5.0	15.0	15.0	
Magnesium (as Mg)	150 mg/l	30 or up to 125 if 250 mg/l SO_4		150	150			150				50		125	150		150	125	150	125
Sulfate (as SO_4)	400 mg/l	250		400	400	600	500	400	240	150	25/250	250	Being studied	250	500	200	250	250	400	250
Phenolic compounds (as phenol) (mg/l)		.001	.005	.002	.002	.002		.002		17.0		.001		.001	.002	.005	.001	.001	.001	0
Color (platinum-cobalt scale)	50 units		5°			50	20	50	20		10	15		20	15	2	15	20		
Turbidity (T.u.)	25 T.u.		2°			30 T.u.	1.5 mg/l	25 T.u.	1 mg/l silica scale			30 T.u.	1-5 T.u.$^{(1)}$	5	5	2	5	5		
Taste	Should be unobjectionable		not to be abnormal			not objectionable	2 units	not objectionable						not objectionable	not objectionable	none	not objectionable			
Odor	"		"			"	"	"	3°			2		"	4 T.O.N.	none	"			
Arsenic (as As)	.05 mg/l	0.05	0.05	0.2	0.05	0.05	0.05	0.05	0.04	0.05	.01/.05	0.05	0.05$^{(1)}$	0.05	0.05	0.05	0.05		0.2	0.05
Cadmium (as Cd)	.01 mg/l	0.01	0.01		0.01	0.05		0.01	0.006		0.01	0.05	0.01$^{(1)}$		0.01		0.05		0.01	
Cyanide (as Cn)	.05 mg/l	0.05	0	0.01	0.05	0.20		0.05	0.05		.01/.2	0.01	0.01$^{(2)}$	0.2	0.2		0.2		0.01	
Lead (as Pb)	0.1 mg/l	0.1	0.1	0.1	0.1	0.1	0.1	0.05	0.04	0.1	.02/.05	0.10	0.05$^{(1)}$	0.05	0.05	0.1	0.05	0.1	0.1	0.1
Mercury (as Hg)	001 mg/l		0		.001			0.01	.004		.001/.005		.002$^{(1)}$				.002			
Selenium (as Se)	.01 mg/l	0.01		0.05	0.01	0.05	.001	0.01	.008		.01/.05	0.05	0.01$^{(1)}$	0.01	0.01		0.01		0.05	0.05
Polycyclic aromatic hydrocarbons	.0002 mg/l	.0002			.0002				.00025											
Chromium	0.05 mg/l	0.05	4 0.05	0.05	0.05	0.05		0.05	0.05		0.02	0.05	0.05$^{(1)}$	0.05	0.05	0.05	0.05	0.05	0.05	
Beryllium							.0002													
Molybdenum (mg/l)							.5													
Strontium							2.0													
Barium								1							1		1		1	

BACTERIOLOGICAL STANDARDS

WHO Standards, 3rd ed.	1. Water entering distribution system: Chlorinated or otherwise disinfected supplies - 0/100 ml; non-disinfected supplies E. coli 0/100 ml; coliform 3/100 ml occasionally. 2. Water in distribution system: 95% of samples in a year - 0/100 ml coliform; E. coli - 0/100 in all samples; no sample greater than 10 coliform/100 ml; coliform not detectable in 100 ml of any two successive samples. 3. Individual or small community supplies: less than 10/100 ml coliform; 0/100 ml E. coli in repeated samples.
European Standards (1970)	E. coli - 0/100 ml Coliform - 95% of samples - 0/100 ml. No sample to exceed 10/100 ml. No successive samples to be positive
Japan (1968)	Coliform - not to be detected
India (1973)	Coliform - 0-1.0/100 ml permissive 10-100/100 ml excessive but tolerated in absence of alternative, better source 8-10/100 ml acceptable only if not in successive samples 10% of monthly samples can exceed 1/100 ml
India (1975)	E. coli - 0/100 ml Coliform - 10/100 ml in any sample, but not detectable in 100 ml of any two consecutive samples or more than 50% of samples collected for the year.
Tanzania (1974)	Non-chlorinated piped supplies: 0/100 ml coliform - classified as excellent; 1-3/100 ml coliform - classified as satisfactory; 4-10/100 ml coliform - classified as suspicious; 10/100 ml coliform - classified as unsatisfactory; one or more E. coli/100 ml classified as unsatisfactory. Other supplies: WHO Standards to be aimed at.
USSR (1973)	Coliform not more than 3/litre on membrane filters Coli litre with enriched media not less than 300
Israel (1974)	Faecal coli - 0/100 ml Coliform - not more than 2/100 ml
Germany (1975)	
Poland	For systems serving at least 50,000 people - coli titre not lower than 100(coli index 10/1) For systems serving less than 50,000 people - coli titre not lower than 50 (coli index 20/1)
Sweden (1969)	
Bulgaria	
USA (1975 (1)) (1962 (2))	Coliform shall not be present in (a) more than 60% of the portions in any month; (b) five portions in more than one sample when less than five are examined/month; or (c) five portions in more than 20% of the samples when five or more samples examined/month.
Thailand	Coliform - 2.2/100 ml E. coli - 0/100 ml
Canada	Coliforms - Acceptable - at least 85% of the samples in any 30-day period to be negative. None of samples positive should have MPN greater than 4/100 ml. Maximum permissible - at least 70% of samples in any 30-day period to be negative. None of the positive samples should have MPN greater than 10/100 ml.
Korea	
Australia	Coliforms - 0/100 ml in at least 95% of samples for the year. No sample to contain more than 10/100 ml. Coliforms not to be detected in any two consecutive 100 ml samples. Faecal coliforms - 0/100 ml
Quatar	Coliforms 0/100 ml if present in two successive 100 ml samples, gives grounds for rejection of supply.
Philippines (196	Coliforms - Not more than 10% of 10 ml portions examined shall be positive in any month. Three or more positive 10 ml portions shall not be allowed in two consecutive samples; in more than one sample per month when less than 20 samples examined; or in more than 5% of the samples when 20 are examined per month.
France	E. coli - 0/100 ml Strep. faecalis - 0/50 ml

Sewerage Service Levels

The safe disposal of the waters used entails health and esthetic benefits in itself and has a bearing upon water consumption. Without adequate drainage a household will not be able to consume more than moderate amounts. Although this does not mean that water and sewerage have to be provided simultaneouly, it does imply that they have to be analyzed as a whole. Another example of their integrated nature is where the provision of water to a town may actually worsen the health situation in the absence of any control of the effluentes. Disease may spread not only, as a result of direct contact with effluents but also indirectly through mosquitoes whose larvae breed in open drains.

Adequate disposal need not be synonymous with water-borne evacuation, or sewerage. Depending upon a large number of factors, such as per capita water use, housing density, climate, soil permeability, and slope, different systems can be selected. Alternatives to sewers are for instance septic tanks, vault storage and periodical collection, different types of latrines, and night-soil collection.

It is the safe disposal of excreta that commands most attention because of its health risks. Although the Western world has opted for water-borne evacuation of sanitary sewage developing countries may be better off avoiding the large investment costs of water-borne systems. Much research is presently being carried out under World Bank auspices which should show whether the elaborate night-soil collection system in large cities in the Far East are cost-competitive with water-borne evacuation.

In cases where a sewerage system is already in place it may be of two main types, a separate kind where household sewage is separated from storm-water drainage, and a combined one where the network has dual purposes. Which system is more economical will depend upon local factors and past investments keeping in mind the added treatment costs that result from combined systems. The bulk of urban areas in developing countries are still far away from any treatment of sewage and may therefore lose sight of this aspect. The control of water consumption is also worth mentioning in this context as lower quantities will mean lower waste disposal and treatment costs.

The Setting of Service Level Targets

Cynics may argue that target-setting has too often been abused for political purposes to be taken seriously any longer. Notwithstanding such unkept promises for the future the fact remains that no forward planning is possible without goals that form the basis for the feasibility study of the sector. It is after all when comparing available resources with requirements to achieve different targets that the structural weaknesses of the sector appear. The objectives selected will have to be realistic, however, less they discourage serious analysis.

Officially proclaimed and widely publicized sector targets fulfill other important functions. They may command the imagination of leaders and constituents alike and rally them to greater efforts. They also make institutions and political leaders accountable and oblige them to provide the financial and human resources to make plans come true. Targets have the additional virtue of focusing on the ultimate purpose of sector development, viz to supply the population with safe water and adequate disposal. They can help overcome the fascination with a dam or a treatment plant and instead address the more relevant question whether more people actually will receive service as a result.

It is in this light that the proclamation of the 1976 Habitat conference in Vancouver should be seen. The conference on human settlements adopted a seemingly unrealistic resolution calling for the entire urban and rural population of the world to receive water and adequate disposal by the year 1990. From the onset the goals were scoffed at as being politically motivated and irresponsible. Nevertheless, these targets may lead to greater determination in the sector development in many countries that have up till now been content without any targets whatsoever.

Those setting targets should be willing to analyze their consequences and decide whether they are reasonable or not. For example, one country in Africa set out to provide its entire population with safe water within the period of some 10 years and should be commended for its ambitious goals but might have done well to consider whether their achievement is worth devoting an inordinate share of scarce public funds for this purpose. There should indeed be a willingness to modify targets if they are shown by circumstances to be unrealistic or too costly.

In practice, such an iterative process is required when elaborating the sector plan. A set of goals in terms of physical and qualitative service levels are chosen and their implications are studied. If the targets are shown to unduly strain the public budget, new targets will have to be fixed and the process repeated until the appropriate balance between what is feasible and desirable is struck.

Whether the sector during its early stages of development should concentrate on quantitative or qualitative targets is hard to say. It is easier to select a goal to provide a certain amount of water per capita by a certain date, but some minimum requirements regarding water quality are also called for. One compromise may be to stipulate that all waters should be disinfected but not necessarily fully treated. Qualitative targets are at any rate not effective unless the infrastructure to monitor and enforce them is there. In the absence of such quality control, standards should be sufficiently flexible to give designers and operators of water works some latitude in weighing economy against the desirable. Failure to set reasonable standards may in "soft" states, where law enforcement is lax, lead to the complete absence of applied standards.

Feasibility of Achieving Targets

Achieving the selected targets will have implications in many areas. It may be necessary to undertake an inventory of water resources and draw up water balance tables to ensure that required water quantities and qualities will be available. Human resources have to be mobilized to execute plans and operate facilities once comissioned. To this end an inventory of manpower by required skills might be undertaken and training programs launched. Existing human resources will have to function in the context of institutions and conceivably the efficiency of such institutions could be augmented through reorganizations, internally or externally. Adequate funding has to be assured for the works and will have to be the object of a separate analysis. In cases where the sector plan calls for expanded construction the sufficient amounts of construction materials and construction capacity may not be there when needed, and it might require a survey of the construction industry to assess the situation. The list could be longer but experience shows that there are three areas which have to be studied routinely to gauge the feasibility of any sector plan. These three are financial aspects, manpower aspects, and institutional aspects. They are the weakest as a rule in developing countries and removing them as constraints will go a long way in speeding up the implementation of the sector plan.

Financial Aspects

Insufficient financial resources are invariably cited as a common cause for the water supply sector's relative lack of progress resources. Sector staff themselves often cite lack of money as the main bottleneck to more rapid development, ignoring the more important one of insufficient human resources.

Saying that the bottleneck is financing is too simplistic and frequently erroneous. It is simplistic because a bigger problem is the lack of skilled staff, who could drum up the financial revenue through a more active commercialization of operations. Similarly it can be argued that improving operations and maintenance at insignificant costs can often contribute much more to improved quantitative and qualitative service levels than fresh investments. The argument is erroneous where it can be shown that better planning could have avoided the construction of a few "white elephants" thus freeing funds for more productive investments. The greater danger in using insufficient financing as a scapegoat for slow sector progress is the failure to acknowledge the sector's own responsibility for generating its investment funds. After all the water supply and sewerage sector is revenue-producing in contrast to most other social sectors and in some countries has become nearly financially autonomous. This characteristic offers much hope for the future and needs be emphasized at every opportunity.

The conviction that the sector cannot develop properly while relying on budgeted funds that are not recuperated form the beneficiaries is what has characterized World Bank lending to the sector. The argument has been succinctly expressed by a previous Bank president, Mr. Eugene Black:

"The Bank has been laboring this point for a very long time. We have held that it is dangerous for a developing country to be sentimental or practically expendient about things like railroads and power plants;" and urban water supply, he might have added, "that policies based on these attitudes only create an intolerable drain on the savings which are the lifeblood of every country's future prosperity. We have said that adequate utility rates are especially important in a country where there is no organized capital market. By 'adequeate'rates we have meant rates which enable utilities not only to cover the real cost of their services, but also to retain out of earnings, substantial sums each year to help finance the expansion which inevitably will be needed to sustain future growth. And we have made no distinction in advocating adequate rates between privately-owned and publicly-owned utilities."

At first sight; application of the principle expounded by Mr. Black and called here the "sound utility" approach seems to ignore the disproportionate numbers of poor people needing water service and their inability to pay high prices for water. However, in numerous cities where water systems are financed out of budgeted funds and where revenues collected from water sales do not even pay for operations, it is apparent today that the poor people are the first to suffer. It is in cities which have poorly-operated and badly-managed water systems where the poor are without water. The city which establishes a tariff structure for water that takes into account the type of service provided and the amount of water used, will be able to distribute cost equitably among all its people.

The sector cannot expect to get released form its financial straits until the water and sewerage authorities themselves shoulder the responsibility of raising more revenue themselves through a stronger tariff policy.

External financing can not make up for insufficient domestic funding but will remain marginal as up till now. Recent surveys by the World Health Organization and the World Bank show that only some 10% of water supply and sewerage sector investments have come from external sources. The external assistance amounts to even less of the sector's total financial requirements given the fact that in many countries not even operating and maintenance expenditures are met by revenues.

Sector investments are rather low in developing countries. Typically a fraction of 1 US$ per capita is invested each year. More developed countries such as in Latin-America invest more, or in the range from US$ 1 to 11 per capita. For those populous nations with lagging service levels, annual average investments in relation to total population were in the order of 0.2 US$ per capita in the early 70's. These estimates may ignore some additional investments. It is clear that given population growth in the order of 2% and with per capita investments per additional served person of around US$100 each for water supply and sewerage, many countries will need centuries to achieve complete physical and qualitative sector coverage. At the same time, demonstration effects from developed countries, partly transmitted through national staff trained in developed countries, have rapidly raised sector ambitions. Much frustration has resulted. It is not always easy to accept the fact that sector progress is not a foregone conclusion and that service levels may periodically fall during warfare and unrest . In this context it seems surprising that the World Health Organization in its survey of service coverage in developing countries reports steadily and rather rapidly increasing service levels.

Failure to require the sector to generate its own funds has other negative effects. Authorities accustomed to depend upon grant financing frequently believe such funds to be free, and overdimensioned works result. With no pressure to recuperate funds financial management will often suffer and financial statistics that could be used for better planning are not produced timely if at all. In contrast, with clear commitments to make the water sector financially self-sufficient better investment planning, more rapid and economic construction, and more reliable operations and maintenance could be expected.

Manpower Aspects

A large number of studies on water supply and sewerage development have been unanimous in identifying scarcity of skilled staff as the most common and serious obstacle to more rapid and efficient sector progress. The diagnosis is undoubtedly correct since in turn it spills over into deficient planning, project execution, and most importantly, deficient operations and maintenance of existing facilities. The findings are not unique to the water supply sector either: the transformation of human resources to change with changing circumstances, be they social, cultural, economic or technical, is the very essence of development.

The scarcity of suitable staff is evident in most developing countries at all levels. Where there are no acute scarcities in numbers, it is easy to see where existing staff could be made more productive. Potential productivity increases are indicated by the fact that in the United States there are some 3 staff for each 1,000 water supply connections whereas in developing countries a more representative figure is 9 staff per 1,000 water supply connections. Were the comparison to include the quality of services offered the differences would be even more striking.

There are exceptions to the general picture of scarce skilled staff. India, for instance, has a large pool of skilled and unskilled technical manpower which is underutilized, but it does suffer from a relative scarcity of skilled financial management which could mobilize the financial resources to operate and expand water supply services. The more typical developing country is short of manpower at the upper and middle layers of the employement hierarchy, while it has abundant unskilled manpower at the base.

The negative effects of lacking management skills are easily noticed. Investment planning becomes deficient and the tangible evidence may be "white elephant" projects utilized to a fraction of their capacity. It can be countered that such mishaps are not uncommon in developed countries such as the United States, but they stand out more in developing countries where excess capacity is not seldom found alongside the absence of service for large population groups. Developing countries can less afford such misallocation of scarce investment funds.

Another consequence of inadequate technical staff is the misdirected use of highly capital intensive technology for water supply and sewerage works where labor is abundant and capital is scarce. Staff responsible for the design and investment decisions may habe been trained in developing countries and adopted the technology developed for the cost conditions in those countries. It is understandable then that technical solutions are transferred wholesale since it requires considerable professional judgement and experience to adapt a process for local cost conditions. The aggressive selling of sophisticated equipment, supported at times by generous bilateral financing, add to the difficulties.

The absence or insufficiency of financial management is striking in the field of water supply. Financial reporting is unsuited to information needs and financial staff may at times be inept at capturing what financial resources there are. There are examples where the lowest-income population are paying more in absolute amounts for small quantities of water from water vendors than more affluent groups are paying for plentiful household supply through individual connections. It is unfortunate that water vendors should show more financial talent and flair for entreprenuerism than financial managers. Instead a typical complaint from financial staff is that the company is receiving insufficient funding for investments and operations. The consequences of scarce skilled middle-leves staff show up in other ways. Most serious are low standards of operations and maintenance which may put existing facilities out of operation. Not only overly sophisticated gadgets become inoperative due to the lack of spare-parts but also relatively simple apparatus deteriorates rapidly due to the absence of preventive maintenance. The fact that so few water supply systems in developing countries can be characterized as safe is largely due to deficient operations. The compoments are all there, treatment plants, distribution works and so on, only the product is not safe for human consumption.

Training Programs

Sector planning should address the typical problem of inadequate manpower and propose corrective measures, if for no other reason that it is unlikely that any other institution or planning process will analyze and make recommendations on the problem of lacking human resources. The water sector, with its characteristics of local water systems, is invariably fragmented. Though each local body feels the problems of attracting and retaining qualified staff, it may be unwilling or unable to launch training programmes or offer incentives to overcome the difficulties.

There is a natural reluctance to invest in staff by training them, only to lose them to better paying employers. Such attrition from sector institutions can either be to other sector bodies, or to employers whose activities are unrelated to the water supply and sewerage sector. It is the second kind of staff mobility that represents a real loss to the sector, although not for the country.

Staff scarcity or inadequacies are corrected through the implementation of training programmes. These are simple enough in theory. An inventory is made sector-wide of the human resources available by categories and skill, and is then compared with the requirements in the future. The evident shortcomings will thereafter have to be overcome by training programmes. Such training can be of the on-the-job type within the institutions themselves or at academic institutions. In the case of extensive on-the job training the strong points of different sector institutions can be used to send staff between different institutions. One company may be especially proficient in metering, another in the commercialization of water services, and so on and can then direct staff from other companies.

It is curious to note that only in few developing countries have comprehensive training programmes, been implemented. To a degree this can be explained by underestimated training needs, to a degree by the institutional fragmentation of the sector.

A pious solution invariably proposed to improve the staffing situation is that staff be better compensated so that they will be attracted to and stay in the sector. This is no panacea if not matched by training programmes and institutional reform to boost staff productivity. At any rate, improved staff compensation in one part of the public sector cannot take place in isolation from the rest of the public administration, and it may not be politically acceptable to introduce across-the-board raises. Besides, staff quantity and quality rarely go together and in the choice between restricting staff numbers while raising salaries, and status quo, staff will frequently prefer a larger number of staff, although less well remunerated.

Institutional Aspects

It has been said that good staff can perform well under almost any institutional setup, whereas the best institutional organization charts, filled by insufficiently trained or plainly incompetent staff can never be effective. There is much truth in the statement but it is clear that inappropriate institutional arrangements waste what is most scarce in the first place, viz. human resources. It may be that the observation can help explain why there are such different institutional arrangements in the water sector in different countries, each functioning about as well, or as badly as the others.

Sector institutions can fittingly be analyzed from two aspects. The first is the simple sector institutional configuration the second is within the institutions themselves. The first describes how the sector as a whole is organized, the second describes how each of the institutuons functions internally.

Sector Configuration

The water supply and sewerage sector by its nature is more local than other public utilities such as power and telecommunications where transmission and interconnection is the essence.

This caracteristic can explain why the sector is often fragmented, and why there are real advantages in decentralizing many functions. Operations and maintenance, and construction could well be decentralized to one city or a group of villages. In this fashion local interests can be given maximum incentive to work and administrative overhead is reduced.

Other functions may be better off centralized, either because of their nature or because they require special skills which are not available at the local level. Obvious examples are sectoral planning, financial planning, and technical design of complicated works. Rules for the proper mix of decentralization vs. centralization cannot be generalized, though, since the manpower situation and administrative traditions will vary from country to country. Where local staff is available to perform tasks competently, they should certainly be given the authority to do so.

A related question is which functions should be kept within the public sector, or whether such tasks as design, construction, supervision and construction should be the responsibility of the private sector, subject to competitive procurement. At an extreme in some countries the entire water sector is operated by private interests under concessions. Here again, there are no easy and general recommendations but country circumstances have to determine the suitable distribution between public and private interests. The one factor that would seem to speak in favor of private contractors is their greater elasticity to changed levels of construction. This goes in both directions. During slack periods staff can be laid off easier within the private sector compared to the public sector which only seems able to grow. Another element favoring design by outside consultants is the public sector's greater difficulty to remunerate staff which makes it hard to retain the most competent staff. Rather than lose them to other sectors it is better to offer them employment opportunities within sector-related institutions.

Analysis of the Sector Institutions Themselves

The institutions themselves can best be understood and analyzed from the view-points of decision - making, including delegation of responsibility, and of information flow, comprising the adequate and timely generation, analysis and use of information as the basis for decision-making.

Water supply organizations like many of their sister organizations in the public sector both in developing and developed countries, invariably suffer from difficulties to decide, particularly as they grow older. This phenomenon which much slows down sector development can be explained by several factors. One factor may be lack of personnel within the organization to analyze the data base and make informed decisions. Another more prevalent factor may be organizational reluctance, "bureaucratic fear", to take any decisions at all in the fear that they may cause a chain of events which may negatively affect the decision-maker. This attitude is reinforced by the assymetric reward and punishments systems typical of bureaucracies where good decisions are not sufficiently rewarded whereas bad decisions invariably will negatiuely influence the decision-maker. Under the circumstances, dynamic behavior is not sufficiently rewarded and efforts to share responsibility with as many others as possible become the rational thing to do. In extreme cases the reluctance to make decisions for fear of antagonizing powerful interest groups may lead to the institution degenerating into a preparatory organization, where all decisions are ultimately taken by outside groups, notably those representing political interests. Such a degradation is deplorable since decisions taken under such procedures often ignore the technical, economic or financial feasibility of investments planned.

Pursued "successfully" by the staff. the game of not making any decisions will lead to bloated organizations which eventually survive themselves. As such institutions grow older, it becomes increasingly difficult to rejuvenate them by replacing staff. If anything, improductive staff, known as "dead wood" are often protected by misdirected labor legislation which makes it prohibitively expensive from the institution's viewpoint to dismiss them. For most organizations the process of aging takes about a generation, a span of maybe thirty years. With gross mismanagement the process can be accelerated. Since it is well nigh impossible to reverse such a trend, the practical response is to create new organizations to do the job where existing bodies have failed. Inevitably, the new organizations grow arteriosclerotic and over the years a number of institutions duplicating efforts become the end result.

It is against this realistic backdrop that institutional improvements have to be proposed and implemented. The decline of an organization is not a priori irreversible, although in all instances is it more difficult and time-consuming to build up a good institution than to ruin it. The latter can actually be achieved with a few appointments of managers bent on pursuing paths in conflict with the interests of the institution.

Any rehabilitation is best guided by simple rules and there is no need to intellectualize. One sound rule to check and reverse the growth of dead wood is to quite arbitrarily define and implement a rate of annual shrinkage, for instance that absolute numbers should decline by a certain percentage each year. Productivity increases of remaining staff are best achieved by forming specially pampered units within the overall structure, unrestricted by the cumbersome bureaucracy so as to attract good staff and make decisions. Managing in this way with common sense does not require complex administrative and management studies. Organizational efficiency is after all more related to sound management principles than organizational structure. The latter is however often mistaken for sound administration. It should instead be clearly understood that a good manager with a reasonable information system, some financial autonomy, and constantly working at training and upgrading his staff can alone make or break an institution.

Sector Investment Priorities

The analysis and setting of investment priorities, with the tentative identification of projects, are the true punchline of the study. Supposedly the investment opportunities are those that strike a compromise between what is most needed and what is feasible. A natural cue for setting sector priorities is the macro-plan with its broad priorities. However, most of the time it will not be specific enough to indicate which areas or geographical regions deserve particular attention. In the absence of such an integrated development plan water supply and sanitation investments should strive to:

(i) redress service level disparities, both between different provinces and between the urban and rural subsectors;

(ii) be guided by the health and economic situation in each area;

(iii) foster maximum investment efficiency, both in the short and long-term.

The first two criteria should lead to the formulation of geographical priorities whereas the third criterion will apply to the type of work to be executed in any part of the country. Commonly one will find that rural areas have both lower service levels and higher rates of water-related diseases and they would thus be a clear priority. Within the rural sector one might further sharpen the investment priorities by specifying that the agglomerated rural population should receive piped water and sanitation before the dispersed population. This makes sense since per capita costs drop with increasing agglomeration, at least in its early stages, and since the risk for epidemics rises with higher concentration. What is a problem of the health of an individual family among the dispersed rural population is transformed into one of public health when a community is formed and grows. Another reason for giving priority to agglomerations is the lesser risk of constructing a system only to later find the intended beneficiaries moving away. And in terms of organization it is of course easier to supply one thousand families living together in a village rather than trying to reach them scattered over a large area.

The health situation in different areas would seem to be an essential guide for selecting geographical priorities but in reality is seldom used. This is because statistics on water-related diseases are often absent and always deficient. They may not be available by geographical region and often suffer from underreporting. Part of the explanation is that doctors are consulted only when the disease has taken on serious proportions, part is that medical doctors may not have been sufficiently trained in public health. Morbidity of water-related diseases is thus likely to suffer from relatively higher underreporting that mortality. Mortality is also underreported however and, even when certified by a medical doctor, only the ultimate cause of death may be registered, say as heart failure, when the original cause has been a sanitation or water-related disease such as cholera.

Efficiency criteria for setting priorities will center around cost-efficiency and attempt to remove the most serious bottlenecks. Cost efficiency considerations will typically evolve into rules on maximum per capita investment costs for projects. On occasions massive metering campaigns may be suggested since saving water by controlling wastage is frequently cheaper than producing additional quantities. At other times one may discover that the sector has systematically over-invested in production, frequently compounded by applying uneconomically long design periods, to the detriment of distribution works. A natural investment priority would then be distribution works to redress the imbalance.

CASE STUDY THREE - QUANTITATIVE WATER SERVICE LEVELS

Background: A South-Asian country for its public investment plan wants to etimate investment requirements in the water supply and sanitation sector. To obtain firm estimates of needs which could be linked with its investment plans, it wishes to use a recent housing census. This method is considered more reliable than estimates of population served since population figures are projections based on censuses more than 10 years old. In order to specify which sub-sector should receive more attention in the investment budget service levels should clearly differentiate between urban and rural areas.

Analysis: The estimated physical service levels for the different sub-sectors are shown in the table below. That part of the rural population living on estates growing cash crops, has been shown separately since they form agglomerated communities which lend themselves well for piped water systems.

Physical Water Supply Service Coverage

	Percentage of Housing Units with Respective Type of Service			
	Urban	Rural	Estate	Total
Piped Water				
1. Inside Housing Unit	16	1	5	4
2. Outside Unit, within Premises	10	1	48	8
3. Outside Premises	19	3	22	8
Sub-total Piped Supplies	45	5	75	20
Well Water				
4. Private well	19	31	2	26
5. Shared well	32	51	13	43
Sub-total Well Supplies	51	82	15	69
Other Sources, Rivers, etc	4	13	10	11
Total	100	100	100	100

The share of the total population lacking a public water system altogether is around 10% and shows surprisingly small variations between the different sub-sectors. The shares of the urban and estate populations with piped water however, are much higher than in rural areas. The latter rely almost exclusively on wells for their supply. The circumstances reflect the dispersion of the rural population which makes piped systems expensive, and the fact that water is readily available in most of the country and rural areas have ready alternatives. A tentative investment strategy based on cost efficiency and health hazards might be to concentrate on well programs for those entirely lacking a system, and thereafter supply more of the urban and estate populations with piped water.

The definition of what is urban and rural populations is worth mentioning. In the country studied the definition comprises administrative elements as well as minimum population density requirements. For investment planning the latter definition is more fruitful since it may be used to estimate average investment per house, or per capita. In other countries there are definitions based upon minimum community size to differentiate between urban and rural areas. Apart from not giving population densities, such cut-off criteria urban and rural populations vary between different countries. In some countries urban communities are those with more than 200 inhabitants, in others with more than 2,500 and in others still, above 20,000 inhabitants. It is therefore not very promising to undertake international comparisons based on such definitions.

Summarizing, a useful definition of urban and rural areas should say something about the cost efficiencies of establishing piped water systems. To this end the rural sub-sector will often have to be further detailed, between those living in agglomerated rural communities, and those being dispersed.

CASE STUDY FOUR - SERVICE LEVELS AND ECONOMIC DEVELOPMENT

Backround: In Country F the water supply authorities are seeking support to augment annual investments since they feel that service levels are low in relation to the country's economic development. In order to strengthen their argument in the discussions on the investment budget, the water supply authorities have prepared supporting data. These are shown in the adjoining table that compares water supply and sewerage service levels in ten countries with their respective per capita gross national product (GNP) and annual investments.

Analysis: The ten countries are all from the same continent as country F with a similar history. In the table their rankings of per capita GNP, per capita annual investments, urbanization, share of the total population with piped water inside their dwellings, and share of dwellings sewered have been calculated. The comparison excludes the population with easy access to piped water and with individual excreta disposal schemes, such as septic tanks and latrines. Their exclusion is motivated since such data are often ambiguous and incomplete.

The table shows that there is a very strong correlation between a country's economic development as measured by per capita GNP and service levels. Correlation is likewise good between the share of a country's total population that is urban and the shares of dwellings with piped water inside and with sewerage. Allowing for the fact that all the economic, urbanization and service level variables are somewhat imprecise the correlation between their rankings is very good indeed with the exception of countries D, F and I. The two latter have lower and higher service levels, respectively, than would be expected given their level of economic development and urbanization.

Water supply and sewerage service levels in country F do lag economic progress. The explanation may not be so much low per capita investments as a slow start of sector investments. The first water supply works were only initiated some 20 years ago and given the time required to create the manpower and institutional base it is not surprising that country F's service levels trail its economic growth.

COMPARISON BETWEEN SERVICE LEVELS, URBANIZATION AND ECONOMIC RESOURCES

Country	Per capita GNP US$	Annual per capita sector investments, US$	Urban Population %	Share of population with inside water	Share of population with sewerage	Ranking of Country: Per capita GNP	Ranking of Country: Per capita investments	Ranking of Country: Urban Population	Ranking of Country: Inside Piped Water	Ranking of Country: Inside sewerage	Ranking of Country: Sum of rankings
A	1,730	4.4	82%	53%	27%	1	3	2	2	2	10
B	1,450	2.6	83%	67%	63%	2	5	1	1	1	10
C	1,110	11.0	59%	51%	27%	3	1	3	3	3	13
D	790	1.5	38%	18%	10%	4	9	7	7	8	35
E	770	6.0	41%	29%	23%	5	2	5	4	4	20
F	760	2.0	38%	12%	4%	6	6	8	8	9	37
G	570	1.7	40%	21%	15%	7	7	6	6	5	31
H	540	3.2	42%	12%	12%	8	4	4	9	7	32
I	450	1.6	35%	27%	15%	9	8	9	5	6	37
J	230	0.3	24%	5%	-	10	10	10	10	10	50

CASE STUDY FIVE - SECTOR FINANCIAL ANALYSIS

Background: A medium-sized country has set targets for its water supply and sanitation services. Overall the goals aspire to raise the share of total population with piped water from some 37% to around 54% during the course of five years, and with sewerage and sanitation from 22% to 50%. A financial feasibility study has been ordered to find out whether the sums budgeted for the purpose by the Ministry of Planning are sufficient, and whether financing plans are realistic.

Analysis:

Rough estimates of the required capital costs during the years 2-6 were calculated by applying recent estimates of per capita investment costs to the number of additional conusmers to be supplied with water and or sewerage. The detailed calculations are shown in the adjoining table.

To reach the established service goals some 177 million monetary units would have to be invested during years 2-6. Some 121 million monetary units would be necessary for water supply and 56 million monetary units for sewerage and sanitation.

Financial Constraints

Investments of the magnitude of 180 million monetary units during the five years period are very unlikely. Although the Government's financial situation is good and can attract external loans, the sector has been unable to qualify for a sufficient level of foreign financing because of a limited capacity to prepare and implement projects. Financial constraints are therefore an outgrowth of other sector problems. For this and other reasons, it is probable that no more than half of the estimated 177 million will actually be forthcoming, and the set goals will consequently not be attained.

During the preceding five-year period, only some 53 million monetary units (in current prices) were invested, of which 16 million came from external sources and 37 million from internal sources. With the historical trend in mind, the sector entities in an investment survey expect investments of only about 67 million during the next 5-year period, over half of which, 35 million is to be financed by external lenders and 32 million by internal sources. This low level of internal financing is attributed to the absence of both a rigorous tariff policy and large central budgetary transfers.

PRESENT AND TARGETTED SERVICE LEVELS AND FINANCIAL REQUIREMENTS

	URBAN WATER SUPPLY			RURAL WATER SUPPLY	TOTAL WATER SUPPLY	URBAN SEWERAGE			RURAL SANITATION	TOTAL SEWERAGE AND SANITATION
	Metropolitan Area	Other Urban	Total			Metropolitan Area	Other Urban	Total		
Population Year 1 (thousands)	860	1,130	1,990	3,370	5,360	860	1,130	1,990	3,370	5,360
Estimated Annual Growth Rate (percentage)	5.0	2.9	3.8	1.8	2.5	5.0	2.9	3.8	1.8	2.5
Population Served Year 1 (thousands)	(6/conn)	(5/conn)	(5.5/conn)							
Through House Connections	440	430	870	80	950	350	160		—	
Through Other Public Systems	320	260	580	430	1,010	60	--	60	570	630
Subtotal	760	690	1,450	510	1,960	410	160	570	570	1,140
Population Served (Percentage)										
Through House Connections	51	38	44	2	18	41	14	26	—	10
Through Other Public Systems	37	23	29	13	19	7	—	3	17	12
Subtotal	88	61	73	15	37	48	14	29	17	22
Total Population Year 6	1,150	1,340	2,490	3,760	6,250	1,150	1,340	2,490	3,760	6,250
Percentage Population Served According to Targets										
Through House Connections	70	65	67	15	18	n.a.	n.a.	n.a.	—	n.a.
Through Other Public Systems	20	15	17	18	19	n.a.	n.a.	n.a.	50	n.a.
Subtotal	90	80	84	33	37	70	33	50	50	50
Target Number of Population Served (thousands)										
Through House Connections	800	870	1,670	560	2,230	n.a.	n.a.	n.a.	—	n.a.
Through Other Public Systems	230	200	430	680	1,110	n.a.	n.a.	n.a.	1,880	n.a.
Subtotal	1,030	1,070	2,100	1,240	3,340	800	450	1,250	1,880	3,130
Additional Population to be Served										
Through House Connections	360	440	n.a.	480	n.a.	n.a.	n.a.	n.a.	—	n.a.
Through Other Public Systems	--	--	n.a.	250	n.a.	n.a.	n.a.	n.a.	1,310	n.a.
Subtotal	360	440	n.a.	730	n.a.	390	290	n.a.	1,310	n.a.
Per Capita Investment Cost, Year 3 prices										
Through House Connections	70	70	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Through Other Public Systems	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Subtotal	70	70	n.a.	60	n.a.	80	40	n.a.	2	n.a.
Required Total Investments Years 2-6	25	31	56	44	100	31	12	43	3	46
Rehabilitation Works Million Monetary Units	6	10	16	5	21	10	—	10	—	10
GRAND TOTAL REQUIRED INVESTMENTS	31	41	72	49	121	41	12	53	3	56

TOTAL REQUIRED INVESTMENTS YEARS 2-6
TO ACHIEVE TARGETS 177 MILLION MONETARY UNITS

Comparison between financial target requirements and current investment programmings over next 5-year period.

	Ministry of Planning	Sector Institutions	Target Needs
Water Supply			
Metropolitan Area	31	37	31
Other Urban	20	10	41
Subtotal Urban	51	47	72
Rural	33	9	49
TOTAL WATER SUPPLY	84	56	121
Sewerage and Sanitation			
Metropolitan Area	31	10	41
Other Urban	-	1	12
Subtotal Urban	31	10	53
Rural	-	-	3
TOTAL SEWERAGE & SANITATION	31	11	56
GRAND TOTAL WATER SUPPLY AND SEWERAGE	115	67	177
Financing of Grand Total			
Internal	35	32	n.a.
External	80	35	n.a.
TOTAL	114	67	177

In contrast to the forecasts of sector agencies the Ministry of Planning in its budget has allocated some 114 million during the next 5-year period which shows that it is considerably more optimistic than the sector entities themselves. A closer scrutiny, however, reveals that the Ministry of Planning foresees only 34 million from internal sources and an overwhelming 80 million provided by external lenders. If the letter is not forthcoming, the investments actually executed will drop to the sector entities more modest estimates.

The table below illustrates the large discrepancies between what funds would be required to reach the sector targets, and what the Ministry of Planning, and the sector institutions themselves, respectively believe will actually be invested.

Intrasectoral Investment Allocation

In addition to the problem of insufficient investments is that of the imbalance of past and planned investments for the area and other subsectors. The following table shows the intrasectoral allocation for water and sewerage works during the past and projected 5-year periods using the institutions' estimated investments.

WATER INVESTMENTS

	Distribution of Sector Water Investments, %		Annual Per Capita Water Investment	
	Past 5 years	Next 5 years	Past 5 years	Next 5 Years
Metropolitan Area	76	72	6.8	6.7
Other Urban Areas	10	10	0.7	0.8
Rural Areas	14	18	0.3	0.5
Total	100	100	1.3	1.7

1/ Annual average investments divided by total population of the middle of the period.

As can be seen planned and executed investments favor the metropolitan area. For water supply, it received, and will continue to receive, some ten times as much investment per capita than the rest of the country; the imbalance is less for sewerage although the rural sector is at a disadvantage.

Financial Recommendations

The existing financial constraints may be eased by the following three complementary measures: greater external borrowing; increased national contributions through tariffs or budgetary transfers; and more economical design criteria.

External Assistance

The Ministry of Planning and the various sector institutions disagree on how much external assistance may be attracted. The Ministry and the institutions alike project more or less the same amount from internal resources for their respective programs -- 34 million and 32 million. They differ, however, on external financing, the Ministry expecting 80 million and the institutions foreseeing 35 million. The institutions appear far more realistic since only 16 million in external assistance was received during the preceding five years. It is unlikely that more than 35 million could be disbursed during the next period considering the weakness of many sector institutions and the time needed to process and disburse new commitments. Projects not already identified are unlikely to produce much disbursement during the rest of the decade.

If the institutions are to achieve even 35 million in external disbursements, more active efforts to attract and diversify external assistance are necessary. In the past, one external lender contributed 98% of all external assistance. It may not be able to assume this burden in the future and it would seem advisable for the authorities to actively try to interest other multilateral and bilateral lenders, or donors for water supply and sewerage projects. This action will necessarily require improved project preparation at both the central and local levels where potential projects exist but go unprepared.

Increased National Contribution

National contributions to water and sewerage works may be increased by a more active tariff policy in addition to greater budgetary transfers.

Tariff Policies

It is recommended that tariff rates be adjusted to cover operation and maintenance costs, debt service and, where possible, to generate some funds for future investments. Present rates are usually insufficient to cover operation and maintenance costs. Even in the Metropolitan area, where consumers have a greater ability to pay, revenues have not covered current costs. In other urban areas revenues cannot cover current costs, and in the rural areas, water consumption is not metered, revenues will likely cover operations and maintenance costs.

Budgetary Transfer

Larger budgetary transfers, at least partly in the form of loans, seem advisable. The Government's capital budget for the next four years seems inadequate, particularly considering the social importance of water. The Ministry of Planning projects that the central budgetary capital cost contribution will be largely unchanged from the preceding period. This means substantially lower real contributions after taking inflation into account. The share of water and sewerage works in total public sector investments is thus projected to decrease from 5.8% during 1970-75 to 5.1%.

Design Criteria

More economical designs might also reduce the sector's financial constraint. Some simple maximum unit per capita investment costs should be applied to weed out the least cost-efficient investments. Furthermore, investment needs are favored throughout the country to the detriment of maintenance and operations. Instead of the uneconomically long design periods one might apply maximum period of 12 years, corresponding to the economic optimum for a real discount rate of 10% and an economy of scale factor of around 0.65. These shorter periods, apart from their economic optimality, would help stretch funds considerably. Designing works for 12 instead of 24 years for instance, would allow investments to annually serve a population 55 per cent larger over the medium term. This would be achieved by designing for less capacity, thereby lowering the per capita investment cost and allowing a larger number of individual schemes to be undertaken.

CASE STUDY SIX - SECTOR MANPOWER DEVELOPMENT

Background: Country H has witnessed its public sector stagnate along with its entire economy. The national water and sanitation entity has been no exception and the toll on staff has been severe. Real salaries have been lowered with the result that the most qualified staff have left for the better-paying private sector or emigrated. Those that have stayed on are generally the older or less qualified staff. Some have taken up a second employment outside the sector entity with the result that their productivity in the water supply authority has dropped. With a view of reversing the negative trend it is decided to undertake a training program.

Analysis: The planning and execution of a training program is undertaken in four consecutive steps. The first step is to undertake an inventory of the number and kinds of personnel, at present and over the past year. The results of this survey is shown below for years 1, 4 and 8:

Year	1	4	8	1	4	8
Technical professionals	110	120	90	3%	2%	2%
Technicians	230	250	220	5%	5%	4%
Workers	2,600	3,690	3,500	60%	68%	70%
Sub-total technical staff	2,940	4,060	3,810	68%	75%	76%
Administrative staff	1,370	1,350	1,170	32%	25%	24%
Total	4,310	5,410	4,980	100%	100%	100%

As can be seen the number of technical professionals and technicians have dropped over the period except a temporary increase in year 4. At the same time the number of workers have increased. Where there were 24 workers for each technical professional in year 1, there are now 39. The number of middle level technicians that can actually transform the professionals' analysis into action has gone down both relatively and in absolute numbers and this scarcity may in the end be even more damaging to the organization. In other words, on average the staff has become less qualified with a lower proportion of professionals and technicians. At the same time those professionals that remain are not rejuvenated and are running the risk of not keeping up-to-date with technical, administrative and commercial progress.

The second step in planning the training is to estimate the gross requirements of the sector in the future. This could be done in two ways. One method would be to study in detail the number of staff that each operating and planned system and activity will require. Another would be to compare staff productivity in different countries' water supply and sanitation sectors to gain an approximate idea of country H's position. Such a comparison is shown in the adjoining table that comprises eighth countries. The staff productivity between them can be seen to vary from a ratio of 320 water supply and sewerage connections for each sector employee to a low of 60 per employee with the overall average being 120 connections per employee. The wide variations are not due only to differing staff productivity but also to the extent to which the entities themselves undertake construction and design. All the surveyed entities do handle operations and maintenance.

Judging from this crude comparison it would appear that country H at present has more than a sufficient number of employees but that its proportion of professionals and technicians is considerably lower than in other comparable countries. Since the number of connections can be expected to rise only slowly the numerical sufficiency will likely remain. The qualitative deficiencies are serious, however, and will require a large number of courses, scholarships and upgrading through on-the-job training.

The third step is to locate the possible suppliers of the different types of training. These can be found within the country and abroad. The national sources are existing university and vocational training institutes that generally only require better and more reliable funding of teaching staff plus for purchase of educational equipment in order to meet the needs. External sources are in this case sought first in nearby developing countries in order to minimize the brain-drain that will often arise when staff are sent on long-term scholarships to the most developed countries. On-the-job training is the preferred alternative for training abroad and can be facilitated by drawing upon the strength of different countries' water supply and sanitation entities. One entity can be especially experienced in metering, another in technical design, a third in preventive maintenance and so on, and by accommodating staff for training the know-how can be effectively spread.

The fourth and final step is the actual implementation of the training program which extends over several years and should be continuous. In order to safeguard a proper funding it is decided to establish a rotating training fund for the sector. The inflow to this fund is arranged by levying a training tax on the entire payroll in the country, both in the private and the public sectors. In this way the public sector does not lose, at least financially when its employees leave for the better-paying private sector.

TABLE SECTOR MANPOWER PRODUCTIVITY AND DISTRIBUTION

Country	Number of Staff								No. of house connections water and sewerage	Staff productivity connections per staff
	Professionals		Sub-professionals		Unskilled		Total			
A	1,000	4%	6,400	26%	17,000	70%	24,400	100%	2,800,000	120
B	60	10%	200	32%	360	58%	620	100%	200,000	320
C	170	6%	780	30%	1,710	64%	2,660	100%	280,000	110
D	90	7%	460	34%	830	59%	1,380	100%	260,000	190
E	40	8%	80	16%	370	76%	490	100%	30,000	60
F	50	7%	130	17%	580	76%	760	100%	240,000	310
G	70	7%	360	37%	550	56%	980	100%	110,000	110
H	120	2%	290	6%	4,600	92%	5,000	100%	500,000	100
Total	1,600	4%	8,700	24%	26,000	72%	36,300	100%	4,420,000	120

CASE STUDY SEVEN-SECTOR TOPOLOGY ANALYSIS

Background: A country, small in population and area has set ambitious targets to raise service levels both in urban and rural areas for water supply as well as for sewerage. One bottleneck that might prevent the targets from being achieved is the institutional set-up with a multitude of institutions with overlapping or conflicting authorities. It is decided to analyze the sector's institutional arrangements in order to suggest a new division of responsibilities.

Analysis: It is of major interest to see which existing organizations may be suitable to execute and support the investment plan. The diagnosis therefore separates the various steps of the investment cycle, starting from sector planning, leading over into project generation and selection, continuing with the design, the construction of works and ending with the operations and maintenance of the facilities. All institutions are mapped according to these functions, and to their area of authority. The table below gives the result

Sector Institutions Listed According to Functions

Function	Metropolitan Area		Other Urban Areas	Rural Areas	
	Water	Sewerage	Water and Sewerage	Water	Sanitatio
Sector Planing	MinPlan		Min Plan	MinPlan	MinPlan
Proj. Generation	Inst A	Inst B	1)Municipalities 2)Inst C	Inst D	Inst E
Proj.Selection	Inst A	Inst B	Inst F	Inst D	Inst E
Proj.Design	1) Inst A 2) Inst G	Inst B	Inst F	Inst D	Inst E
Proj.Execution	1) Inst A 2) Inst G	Inst B	Inst C	Inst D	Inst E
Proj.Supervis.	1) Inst A 2) Inst G	Inst B	1) Inst C 2) Inst F	Inst D	Inst E
Operations and Maintenance	1) Inst A 2) Inst H	Inst B	Municipalities	1)Inst D 2)Local Communitie	1)Inst E

The sector topography is highly illuminating. The country's poverty is contrasted by the plethora of sector institutions, where eight different bodies, not counting the Ministry of Planning and local communities and municipalities are involved. Operations and maintenance are invariably the duty of the communities themselves.

There are both duplication and fragmentation of sector responsibility. Thus in the metropolitan area there are four institutions active in various stages of project development. Apart from the implied squandering of scarce qualified manpower and higher overhead, communications and coordination are made difficult. In other urban areas and in the rural sector there is also fragmentation but less serious.

Another violation of universally accepted management principles is the separation in the metropolitan area of water supply and sewerage services. Their integrated nature argues strongly for managing them together, for reasons of better investment coordination, and because sewerage has a more difficult time to become financially self-sufficient unless supported by revenue from water supply services.

Another useful principle would be to keep all functions from project generation through operations and maintenance under one roof. In this way there is maximum feed-back from operations to the selection and design staff. Negative and positive reactions to made designs are brought out and improvements can be made in subsequent designs. This sound rule is not followed in the case of "Other Urban Areas" where project selection and design and supervision of construction have been taken over by another institution than the ones handling project execution and operations and maintenance.

Although each institution would have to be studied in some detail before making any far-reaching reorganizations in the sector, it would seem reasonable to simplify the sector to have one institution responsible for all aspects of water supply and sewerage in the metropolitan area, another one for remaining urban areas although the different municipalities might as before be in charge of operations and maintenance, and one or two instituions responsible for water supply and sanitation, respectively in the rural sector. The number of different bodies could then be brought down from the present eight to three or four with ensuing savings in overhead, better coordination and more efficient utilization of staff.

CASE STUDY EIGHT - CHOICE OF SEWERAGE SECTOR ORGANIZATION

Background: In a medium-sized African country the production and distribution of water are the responsibility of an autonomous National Water Board created some ten years ago. The creation of the Board replaced a fragmented water sector where each minicipality was responsible for all aspects of water and sewerage operations. The Board improved planning and implementation of works, thus accelerating the provision of water to individual houses, particularly in the small urban centers and semi-rural areas by supplying all settlements having 500 inhabitants or more. The remaining rural population, comprising some 30% of total population, live in isolated dwellings which cannot readily be served by public water distributions systems.

The service situation in sewerage is less encouraging. The municipalities retained control over sewerage operations at the time of the sector reorganization but have not managed the systems well with the result that sewer systems are incomplete, overloaded and badly maintained, if at all. This situation has come about because the local bodies lack the funds and the trained personnel to provide the neccessary service. There are only some 25 trained technicians and workers in the country having the necessary skills and 20 of these are employed in the capital city. The lack of a clear division of responsibility among the ministries, the municipalities and other national agencies active in the sewerage sector have resulted in an absence of decision-making for sewerage at the national level.

To remedy the unsatisfactory service in the sewerage sector and to match the higher water supply sercice levels, expanded investments are planned for sewerage. The question has arisen what kind of institution should be entrusted with carrying out the investment programme and ensure adequate operations and maintenance of the works.

Analysis: It is clear that the municipalities cannot be counted upon since the very reason for the sewerage sector's poor state has been their inability to expand and operate sewerage service. The severe scarcity of staff speaks in favor of a centralized organization where the few available staff could be fully utilized. The urgency of the investments is such that it is not possible to await the results of training programmes for the municipalities with a long gestation period. The previous success with the establishment of a Water Board also speaks in favor of an analogous solution for the sewerage sector.

It remains to be decided whether the Water Board should also be entrusted with sewerage, or whether a new agency should be created. The interdependency of the services speaks in favor of an institutional integration but the need to undertake the sewerage investment programme with undivided attention speaks for a separate sewerage body.

The latter argument proves decisive and a national, autonomous sewerage authority is established. It is given the task to plan, operate, maintain, and contruct all sewerage works within municipal limits and within tourism and industrial development towns. The Ministry of Health continues to exercise control over the quality of pollution control since it is felt that an outside body should be responsible for the monitoring.

CASE STUDY NINE - COMPREHENSIVE WATER SECTOR PLANNING

Background: A major federated country had experienced a series of years of rapid economic growth. Social services essential to the population's well-being had fallen behind, however, and water supply and sewerage were no exception. Only half the urban population had piped water supplies, in most cases of inadequate quality, and in rural areas the coverage was lower. Only a quarter of the urban residents had sewerage whereas practically none in rural areas had adequate sanitation. Sector investments had been undertaken in a piecemeal fashion and had not kept up with urban growth rates which were in the order of 5% per annum.

In order to attack the sector problems at the root it was decided to conduct a critical and comprehensive diagnosis of the difficulties and then set up new comprehensive planning and executional procedures which would resolve the immediate inadequacies and lay a solid foundation for the future.

Analysis: The main reasons for the sector's failure in the past to keep abreast of population growth were identified and it was established that:

i) Each community had attempted to resolve its problems on its own and this had led to the poorer communities falling further behind since they could not raise the financing for works. They were most of the time disadvantaged with regards to the allocation of scarce grant funds and could for reasons of financial weakness not borrow for investments.

ii) Institutional fragmentation made it difficult for the water companies or municipalities to attract and retain qualified staff. Employed competent staff could not be utilized to their full potential.

iii) The multitude of separate entities unduly raised operating cost since no efficiencies of scale were possible in the field of administration, and maintenance. Local pressures to increase the number of staff in each water entity caused operating costs to soar due to low productivity.

iv) Fragmented investment planning and construction prevented the sector to take advantage of scale efficiencies in design, procurement, including standardization, and lower construction costs by contracting for a large number of small projects at a time.

Objectives

Once the results of the diagnosis were known service level targets were set. In water supply it was decided to supply 80% of the total urban population within a 10-year period. In sewerage the goals to quadruple the served population.

Principles for Solution

Recognizing the weaknesses characterizing the sector previously a different approach was suggested based on three main principles:

i) The sector institutional fragmentation would be discontinued by establishing statewide companies to reduce the number of separate water entities from some 4,000 to 26.

ii) The introduction of a new financial policy tomake water and sewerage services financially autonomous over the 10-year period. Consumer charges would after the initial build-up period, during which they would be supported by federal and state grant funds, be required to cover operations and maintenance costs and generate a surplus sufficient for expansions. In order to sustain the poorer urban communities such financial self-sufficiency would be required at the level of the state-company and not of the community. The latter implied income transfers within the state so that wealthier communities would subsidize poorer ones.

iii) Integrated planning and execution of the required investments would be undertaken and in particular expected requirements in financial, human, and material resources would be analyzed and shortfalls amended through special programmes.

Detailed Solutions

In each state according to the institutional blue-print a state company was set up to plan, execute and operate the entire programme. These state companies received financing from the state and national budgets during the build-up stage and were under the supervision of a central, national entity which ensured that the programme objectives were followed in each state, and which also channelled the national financing.

To identify financial, human, and material requirements in each state the following sequence was applied:

a) Evaluation of the stock of existing goods and services, and conversion of these into monetary units of constant value, allowing for depreciation;

b) Evaluation of the demand, at present and throughout the period considered, for the goods and services necessary to meet the requirements of at least 80 per cent of the urban population;

c) Estimate of the present deficit, and quantification of the financial, human, and material resources, needed not only to eliminate the deficit but also to keep supply and demand balanced throughout the period;

d) Programming the investments needed in the period in order to balance the supply and demand for goods and services as soon as possible;

e) Schedule of priorities for the order in which the requirements of each urban agglomeration are to be met, in order to eliminate the deficiencies as rapidly as possible.

The initial financial resources to operate and build up the capacity to supply 80% of the urban population were provided by the national and state budgets in the form of mostly grants. However, the tariff policy at the consumer level implied that investments would be recuperated in real terms statewide. Accordingly, after the initial 10-year period the state companies were expected to be financially autonomous and not have to recur to any additional grant financing since the 80% served at that stage were expected to generate the funds to cover all current costs, and a surplus to expand the systems to keep abreast of population growth and gradually connect the remaining 20% not served initially.

Human resources were proven inadequate in numbers and skills at the onset of the programme and shortages grew worse during the execution. To correct for this a comprehensive training programme was set up to train staff at different levels, from company managers to skilled workers. A continuous technical assistance programme to help weaker state companies was established at the same time.

The scale of the investments required stepped up construction material needs. To ensure that no scarcities would appear the following steps were taken:

a) Programming of investments to avoid marked irregularity in work schedules and consequently in the demand for materials;

b) A detailed survey of the demand for materials and the distribution of that demand throughout the period under consideration;

c) Opening lines of credit for companies willing to expand production of the materials required for implementing the Plan;

d) Financing the purchase of materials, with delivery spaced out over 12 months, to permit better programming by producers and a consequent drop in production costs;

e) Standardization of applicable materials, with a view to reducing stocks and the cost of maintenance and replacement.

CASE STUDY TEN - THE SETTING OF INVESTMENT PRIORITIES

Background: A large federal republic has commissioned a study of its water supply and sanitation sector. The sector investment priorities to be fixed should be analyzed from two aspects: which geographical regions deserve priority, and which type of investments should be favored in any one system. Geographical priorities could be guided for instance by particularly low service levels in certain states or regions. System specific investment priorities might be motivated by particular imbalances and needs on a national level. For the setting of geographical priorities use should be made of a recently prepared National Urban Development Plan which is quite specific as to priority regions.

In this plan different population strata and regions have been analyzed, and ten regions have been identified as of priority since they present favorable economic development potential, having underexploited natural resources and being well suited to absorb more population. These ten zones are called conurbaciones or urban growth areas.

Analysis: Geographical Priorities

Since public investment programs will be coordinated to include the full range of directly productive, infrastructure, and social investments, the ten urban growth areas obviously deserve priority for water supply and sanitation investments as well.

A complementary method for selecting geographical priority areas would be to explore which states have service levels substantially below the national average. By studying service level variations between states it can be seen that 20 out of 30 states have lower water supply coverage than the national average.

Combining the service level priorities with those of the National Urban Development Plan one finds that there are 11 states that can be designated as top geographical priority since they appear both in the Urban Development Plan and have lower-than-average service levels.

System-Specific Investment Priorities

Complementing the geographical priority areas are a series of system specific investments which deserve parallel priority. The related criteria have been elaborated against the background of the following observed deficiencies:

(i) inadequate or absent water disinfection leading to frequently unsafe water;

(ii) inadequate or absent water metering leading to wasteful uneconomic consumption;

(iii) insufficient distribution capacity;

(iv) inadequate sanitation facilities; and

(v) insufficient trained staff to operate and maintain the separate systems.

All the enumerated deficiencies combine resulting in unsafe and wasteful water and sanitation service in a large share of localities. In one state it was found that out of some 70 systems operated none supplied water continuously, and no waters received disinfection. The situation in other urban localities of comparable size is not likely to be strikingly better, and in rural areas disinfection is seldom practiced. In addition, lack of effective metering causes excessive and wasteful consumption frequently leading to intermittent service. Further, lack of sanitation programs may lead to groundwater contamination, which in turn may contaminate the water distribution system through groundwater infiltration since service pressure is zero. Instead of improving community health, such a deficient system may actually worsen it. A compounding factor is inadequately trained operators. Symptomatically preventive maintenance is nowhere carried out.

Judging from an analysis of data for some 740 systems it seems that there are certain components of the individual systems that have been favored in the past, and others, principally distribution works, that have been relatively starved for investments. By comparing the present installed capacities for the three main components production, storage, and distribution with the projected requirements in 5 years it was found that 130 systems needed more production capacity, 250 systems more reservoir capacity, and practically all 740 systems more distribution capacity. It follows that by concentrating on distribution investments one could increase the share of population served without having to make additional increases in production and storage capacity in a large number of systems. Furthermore, it is likely that extended metering would further reduce the number of systems where production and storage investments will be required.

The explanations for the existing excess capacity in production, and, to a lesser degree in storage, are many. One is the need to build some measure of excess capacity into the system components since there are economies of scale associated with water supply investments. Another possibly more serious and interesting reason, is that the systems have been designed and constructed in the past by production biased staff, partially neglecting the distribution of the water. This bias has been compounded by the fact that there have been federal funds available to construct the production and reservoir capacity but insufficient funding for distribution works. Where local bodies are in charge of operations, including network extensions, it is easy to understand that financial weakness has prevented them from undertaking such needed works. A third possible reason is excessive design parameters for production investments, with per capita supplies around 300 lcd and design periods of around 20 years.

National Distribution Program

It is clear that a nationwide crash program to boost distribution capacity is urgent to boost connection rates in already constructed systems. On average, some 66% of the populations in these 740 towns and cities are presently connected and the medium-term goal should be to connect 100%. Such a National Distribution Program would likely require stepped-up efforts in marketing water supply services to induce the unserved population to connect. Such marketing would have to include health education and financing on terms compatible with the income levels of connecting households.

National Metering Program

Both distribution and disinfection programs would have to be complemented by a National Metering Program to help balance demand against existing supplies. In a water-scarce country with increasing marginal water costs, controlling excess consumption is the cheapest fashion of de facto increasing supply. A National Metering Program would thus be in support of programs for Distribution and Disinfection as well as enabling the water supply sector to approach financial self-sufficiency. It would have to comprise a broad spectrum of activities besides the mere installation of meters and reading them. Before undertaking any meter installation in a given community, a connection census should be made so as to determine the real number of connections, and the state of water meters. If metering is shown to be economically justified, meters should be installed. Likewise, readings, billings and collections routines would have to be elaborated or improved. In other words, it might be better to talk in terms of a National Program for Consumption Efficiency rather than for Metering only.

National Disinfection Program

Around 70% of the water systems lack disinfection equipment altogether and a share of the remainder is periodically inoperative due to supply problems of disinfectants and breakdowns. It would seem natural to launch a National Disinfection Program to provide disinfection for each water system. Such a program would entail a relatively insignificant cost but its importance merits a special effort.

National Sanitation Program

Excreta disposal appears to have received scant attention in the past and no Government agency seems to be actively involved in latrine programs. Low sewerage connection rates and unsafe water supplies have in many cases produced health hazards. One way to remove these, would be to launch a National Sanitation Program, consisting of the construction of latrines and other systems for safe excreta disposal in conjunction with vigorous campaigns to make the population aware of the importance of proper sanitation. The Ministry of Health would seem a natural candidate to assume the responsibility for such a Sanitation Program through its extended network of local health services, and because of the obvious interaction with health education.

The National Training Program

A National Training Program continues to be vitally needed. To increase its adequacy it might have to be better coordinated with investment programs, notably the four National Programs mentioned above. Moreover, instead of concentrating on training staff in middle or management positions as until now, the National Training Program should be directed primarily at the lowest level, that of operators and maintenance personnel.

PROJECT PLANNING

Introduction

Project planning concerns identifiable investments with an explicit purpose, or projects. The analysis becomes more penetrating and thorough than during sector planning since the focus is narrowed. The projects may be defined in space, time, or in purpose. A typical project may be the provision of water supply and sewerage to one city. Alternatively it can be limited in time to finance a certain share of a sector investment program during a given time period. Finally, the project can be defined to achieve a certain purpose, such as to improve water metering and associated commercial practices for a country's entire water sector.

It seems then that a project can mean almost anything provided it involves investments of a magnitude justifying special analysis and preparation. The emphasis on investment volume roughly separates a project from technical assistance that involves less money. This does not preclude large technical assistance schemes being part of projects and analysed as other components.

Another characteristic about projects is the framework in which they are ideally planned and executed, the project cycle. Its first step is the identification where the purpose and approximate boundaries in time, space and amounts are defined. Following the identification there is usually a period of project preparation where additional data are collected and analyzed. Depending upon the complexity of the envisaged works, different studies such as pre-feasibility, feasibility and even detailed design are prepared. The next step is the project appraisal where the prepared project is further analyzed in its technical, economic, financial and institutional aspects. The appraisal fixes the project boundaries and recommends whether to execute the project investments depending upon whether they are feasible or not. Assuming thereafter that financing has been arranged with posible legal ramifications, project execution can start under proper project supervision. The latter should ensure that the original project purpose guides the works and that funds are invested with maximum efficiency. Finally, upon the completion of the investments and after operations and maintenance experience has been gathered, a project evaluation is carried out to learn from the project. The added experience is then fed back into the relevant stage of the next project cycle to improve future work.

Going through the whole project cycle is time-consuming given the number of studies and the construction which may often meet unexpected difficulties. From the first identification through the project evaluation it may take as much as 10 years, at times less. It is vital to make efforts to reduce the time, particularly from the identification to the initiation of construction. After all in the project cycle the emphasis should be on execution and there comes a point when the costs of generating and analyzing additional data are not matched by better decisions.

For a deepened understanding of project lending it is useful to compare it to programme lending. The distinction between the two is the same as between project planning and sector planning. Whereas project lending clearly identifies the investments, the programme lending does not. The project lending is more forward looking as the planning cycle starts early and is geared to generate project investments. Programme lending on the other hand will finance investments generated routinely by the executing institution, and the role of the lender is more passive.

PROJECT IDENTIFICATION

General

The identification of projects should ideally be tentatively made as part of the sector planning so as to better fit the sector development strategy. Furthermore, since a prime aim of the sector planning is to identify service levels the project identification can take advantages of any disparities and tailor the investments to dovetail with disadvantaged population groups. A project should not only increase service levels, however, but also reach other objectives such as institution building and assist in the training of staff. Since such objectives are another sector concern it is natural to let the sector study generate the project.

There are other ways in which projects are identified. In case a city has undertaken investments further works usually are identified and a project can be formulated. In other instances special interest groups lobby via the political system to have their concerns satisfied, and a project is born.

Whichever way a project has been identified it has to satisfy a few fundamental conditions. It has to be in a sector of the economy which has a recognized priority in the Government's development strategy. Secondly, it has to be technically and economically feasible, i.e. its costs should not exceed expected benefits. Thirdly, it has to be financially viable, both in terms of its financing plan and the future recuperation of capital and current costs. Fourthly, since the project investments have to be planned, executed and subsequently operated and maintained by a competent institution, the institutional arrangements have to be explored.

In addition to the above economic, technical, financial, and institutional aspects there are other practical or incidental considerations. It may be desirable to have a certain minimum size investment program since there is considerable administrative inertia associated with obtaining financing and administrative approval of investments, especially if external financing is involved.

Economic Aspects of Project Identification

At the early stages of the project cycle where the project is identified the economic analysis cannot be sophisticated since good and pertinent data may be scarce. Nevertheless it is of essence that economic analysis play a role as early as possible when investments are still undetermined and consequently all costs are variable.

The economic analysis should lay down the objectives of the investments proposed, either by defining who will be the beneficiaries or in which geographical areas the works should be undertaken. Basic as this may sound, it is not uncommon to find projects where the ultimate beneficiaries from the project investments do not correspond to those most in need.

Economics should further indicate how to attain set objectives most economically. At times, the project may not even be needed to achieve them. An example would be when there is more water wasted in a city through absence of metering and low tariffs than will be supplied by the proposed project. The obvious solution would instead be to control consumption and cancel the project. In other instances the project objectives may be attained cheaper and very differently than proposed. The search for alternative project solutions is indeed one of the basic tasks of economic analysis.

Bottle-neck Analysis

In order to determine precisely what works are required the economic analysis should decide which components of the existing water system should have their capacity augmented. The analyst will have to proceed in two steps: identify where capacity has to be increased, and how much the increase should be. Wherever a project involves construction from scratch, only the second problem is relevant. A common situation would be where water supply system has become insufficient to satisfy demand. The analyst then proceeds to analyze the system broken down into its various components, such as catchment, transmission, treatment and so on. The capacity of each component is compared to the estimated demands at given years and needed works are scheduled so that bottle-necks are eliminated in the sequence they materialize. Over a long time period practically all components will require additional capacity, over the medium-term it may be sufficient to consider only a few. As a result the timing of each component addition will heavily influence the cost of the project. Exactly how much the capacity of each component should be augmented is a matter of least-cost analysis based on discounted value analysis. It will be fully discussed under the section of project appraisal.

The end result of such a bottle-neck analysis will be a continuous investment plan where capacity is gradually augmented to satisfy the demand. Projects are for reasons of financing often conceived in terms of investment tranches spanning a limited time period, say four years. The bottle-neck analysis will then decide which investments are needed during a given time period. One would estimate when project investments can start on account of necessary lead time with project preparation and appraisal and on the basis of the lead and execution period see which components need extension.

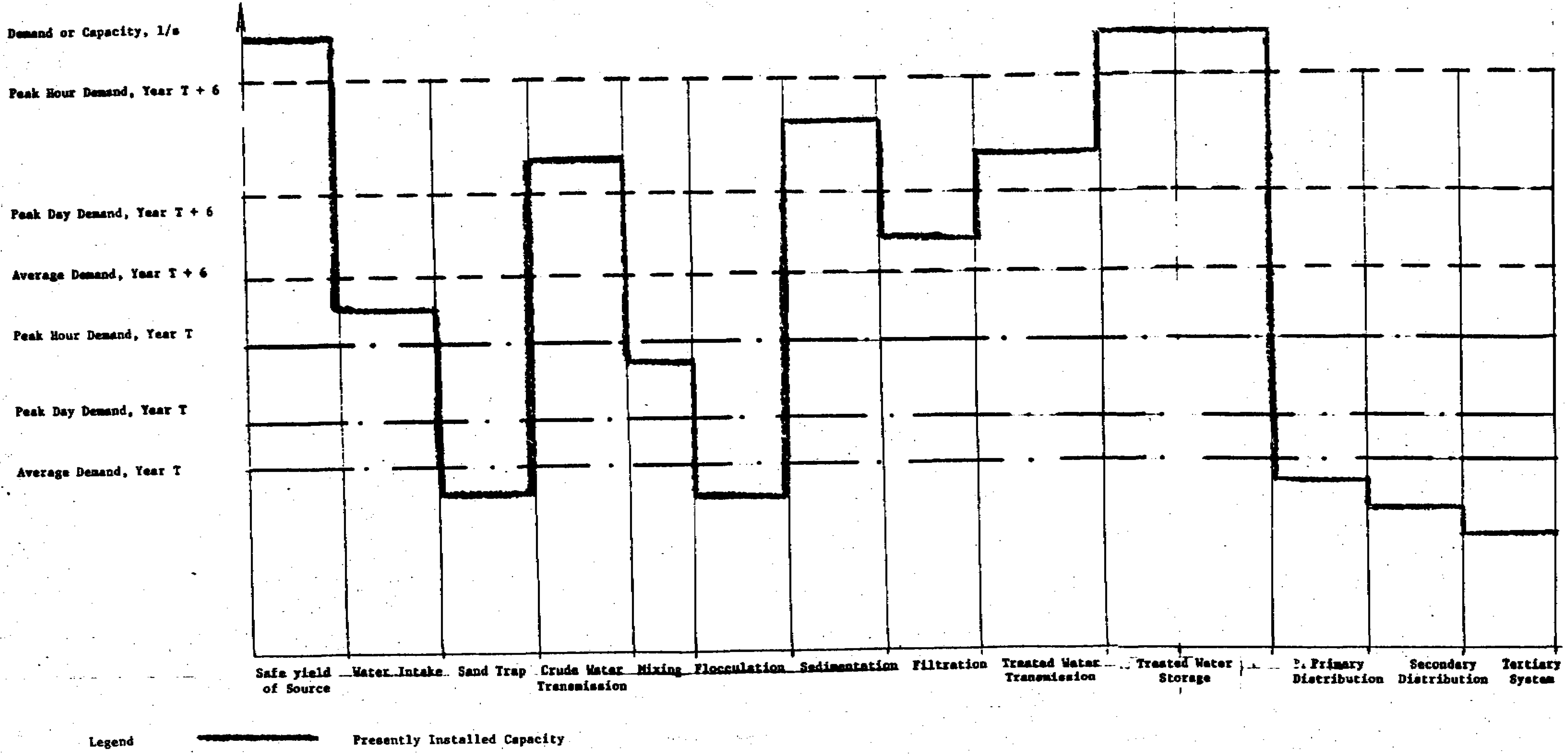
The figure on the adjoining page shows the application of bottle-neck analysis. The cut-off year has been chosen as six years from the time of the project identification, corresponding to two years from identification to initiation of works, and a four-year construction period.

From the study of the figure it follows that the following components need more capacity immediately to meet demand: the sand trap, the flocculation in the treatment plant, and the primary, secondary and tertiary water distribution networks. Within a six-year horizon the capacity of the water intake, the mixing in the treatment plant, and the filters will prove insufficient. Remaining components are likely to be sufficient to meet demand during the next six years. Incidentally, a situation where all system components have the same capacity is unlikely since, this is generally not economical. Each component should rather be designed on the basis of its respective efficiency of scale and other circumstances, and differing design periods are the result. The point is worth remembering when designing a system for a locality without a system. It will <u>not</u> be optimal to design all the components for the same capacity. Certain works with significant efficiencies of scale such as intake works may be designed at once for the safe yield of the stream while works that are easily staged such as wells should be designed for shorter periods.

<u>Sector-wide Bottle-neck Analysis</u>

The same bottle-neck analysis used for individual projects to determine the timing of capacity additions can be applied to sector-wide project identification. This requires a competent planning institution that is able to analyze the component capacities in a large number of systems. The sector investment program should in a given year include only the priority works in each individual system so as to remove the respective bottle-necks. The resulting increase in system capacity over the entire sector will be larger than had the same funds been invested in a few systems only. The application sector-wide would then imply one system receiving funds to construct a service reservoir only, another to upgrade its treatment plant, a third to lay a transmission line and so on. It should be a minimum requirement that a national planning agency keep a data bank on the capacity of the different water systems and on the components so as to permit such sector-wide analysis.

BOTTLE NECK ANALYSIS OF A TYPICAL SURFACE WATER SYSTEM



The most frequently encountered bottle-neck may be time or restrictions in its use. Many times system capacity can be substantially increased by adding shifts, for instance a night shift for pumping. At times labor legislation forbids night shifts or demands exorbitant compensation on such work. This is paradoxical in developing countries with abundant labor and scarce investment funds.

Other Sector-wide Identification Criteria

At times data may not be available in a near future to permit bottleneck analysis and the initial project selection will be based on other criteria.

One such simple criterion is the per capita investment cost, defined as investments per additional consumer served as a result of the contemplated project. This is obviously a crude way of selecting projects but can at least eliminate those projects with obvious overinvestments. The measurement can be further refined by separating those investments which serve to improve quality of supply to already connected consumers from those that aim primarily at connecting additional consumers.

Another common rule-of-thumb for comparing the merits of different sub-projects sector-wide is the cost per unit additional supply. This methods simply divides the present-value sum of investment and operating costs by the additional capacity supplied by the sub-project. A frequent application is for comparing different bulk water schemes.

Another criterion ranking alternative water schemes is the unit cost per water produced. This method is the most exact one and can best be expressed as an average incremental unit cost (AIC). For the purposes of project identification the calculation of the average incremental unit cost (AIC) is too time-consuming, however, and necessary data may not exist. A more practical measure is the annuitized investment costs of the respective schemes added by the estimated operating costs, the sum of which is divided by the volume of water produced.

Comparison between the Selection Criteria

The three criteria for selecting a project for further preparation have their strong and weak points. The quickest way is the criterion of costs per unit of additional capacity. Its use is not recommended, however, since it does not take into account the rate at which demand catches up with the added capacity. It therefore ignores the time dimension which is most important for the economy of investments. Blindly applied this method will favor those subprojects which add the most capacity since there are economies of scale for water supply investments.

The second measure of per capita investment costs is correct in focussing upon the ultimate user but similarly fails to take into account differing periods of excess capacity. In order to weed out clearly exaggerated investments its use is justified, and it also says something about the feasibility of recuperating the investments costs from the beneficiaries.

The third measure, the various types of costs per cubic meter, may theoretically be the most attractive but should be combined with an analysis showing how many more people will enjoy water supply as a result of the works proposed. Conceivably the scheme promising the cheapest water might supply only a large industry whereas one with higher unit costs would focus on connecting additional consumers.

At the project identification data are often scarce, and the best one can do is to calculate the cost per additional consumer. Where population estimates are unreliable one is better off relating the proposed investment costs to the additional number of houses served under the project.

Technical Aspects of Project Identification

The technology of water supply and waste-water disposal has been relatively static as compared to many others. There will therefore be few doubts about whether a certain method is technically feasible since it has been tried in many other localities all over the world. Instead, the technical uncertainty will focus on whether there will be sufficient water quantities available and whether it can be treated to an acceptable quality. Neither of these aspects is primarily technical but economical. The technologies are known and it is a matter of how much they could cost.

The choice between different technology arises foremost in the field of water treatment. It is of essence to have a good understanding of the qualities and peculiarities of the waters to be treated. Failure to do so may lead to adopting standard designs ill-suited to the water in question. Typically, such designs may originate in developed countries because the design engineer might have been trained there and because that is where the manufacturers of the treatment equipment are located. The combined result is treatment plants containing at the same time unnecessary and missing components. Highly developed technology is synonymous with a more mechanized process both when constructing and operating the works. In turn more skilled staff is needed to operate the works who are likely not available in the developing country. Besides, capital-intensive processes make little sense where unskilled labor is abundant and where capital is scarce.

The statistics on which the designer bases his projections and technical solutions, are often so unreliable that the risk of making wrong decisions is great. Under the circumstances flexible planning is imperative and if possible, investments should be gradual instead of lumpy. This would tend to favor ground-water systems over surface-water systems. Accordingly several developing countries e.g., Brazil,* clearly indicate that the feasibility of groundwater should be explored first of all. Unfortunately, hydrological data are frequently weak and the planner anxious to minimize risks will rather choose the surface water solution since there is no doubt about its existence.

Where existing systems need expansion the bottle-neck analysis is highly relevant particularly if components can be upgraded using technological advances. A case in point is filter upgrading in older treatment plants where the conversion of filter media may lead to dramatic increases in filtration rates.

Financial Aspects of Project Identification

The rudimentary financial analysis at the identification stresses two questions: to what degree can the investments be recuperated from the beneficiaries, and what kind of financing is available?

The cost-recovery cannot be analyzed well until some socio-economic study has been conducted in the community to be served. Since it is not possible to await such a study estimates of market wages or legal minimum wage rates are often used instead. Some share of total gross family income is assumed for water services, and existing tariff levels are examined. In many Latin American countries households are considered able to pay up to one day's gross earnings each month towards water and sewerage services. By deducting the expected average operating costs per household from the gross revenue a rough estimate of the gross surplus per household is obtained. This surplus can be used for servicing debts that could finance part of the works. For instance, if the feasible tariff burden each year would be $20 and the operating costs 10, the annual surplus annually is $10. The debt that could be serviced would then be around $100 per household assuming a capital recovery factor of 0.10. The approximate project cost would be the sum of any grant financing available plus the number of households times the servicable debt. In addition some households earn more than the legal minimum wage and the project cost could be increased further.

Feasible Financing Plans

Investment funds come from three main sources, viz. grants, borrowings, and contributions from the beneficiaries of the works.

There is an inverse relationship between the availability of each source and its cost. Grant funds are free but are scarce and unreliable. Relying excessively upon them is hazardous since project execution may be delayed with resulting cost increases. Grants are nevertheless a traditional way for financing water sector investments in a large number of countries, both developing and developed.

Borrowings are more expensive but more plentiful and reliable once water and sewerage operations have a sound financial basis guaranteeing debt service. To this end lenders demand extensive project preparation and institutional improvements.

Contributions from beneficiaries are appealing in several ways. It is fair that the beneficiaries should pay something for the service, and experience has shown that consumers who have contributed towards the building of a system are likely to feel more responsible for the upkeep and operation of the works. The point is especially relevant in rural water supply where beneficiaries are required to contribute in cash or in kind towards system construction

Institutional Aspects of Project Identification

Institutional aspects are fundamental, and the existence or probability of a competent institution will often determine whether there will be a project or not. Institutional matters have almost invariably been part of the sector analysis but will have to be further studied at the project identification.

One concern is whether the institution executing the project will have the ability to prepare it adequately. Accordingly, the planning and design departments of the designated institution have to be evaluated, and the finance department as well. The finding is often that there is a need to bring them together and integrate technical, financial and economical aspects.

A second obvious area for scrutiny is the institution's ability either to construct the proposed works itself, or supervise outside contractors. Its capacity to plan, monitor and influence the rate and quality of construction has to be proven. For the purpose of monitoring critical path method analysis or simple bar charts may be employed.

The third field for query is the institutional capacity to operate and maintain works. Wherever possible during the identification information should be gathered through field inspection of the condition of existing facilities. Such visits are most illuminating and frequently influence investment priorities to direct more funds towards training of staff and rehabilitation of inoperable facilities.

Practical Considerations for Project Identification

Each project identified and selected will have to pass many subsequent tests of a technical, financial, economical and institutional nature and as a consequence some will drop out. At the same time there is considerable inertia in bringing together all the pieces that make the project, such as financing and administrative approval. For this reason one should err on the generous side during the early stages of the project cycle and keep a large number of projects identified and prepared so as to be able to select and finance them at relatively short notice. The corresponding cost is surely less than that of foregoing funds that suddenly become available to the sector. The best argument for financing is a well-prepared project, and the situation where financing seeks sound projects is as frequent, as where good projects seek financing.

CASE STUDY ELEVEN - BOTTLE-NECK ANALYSIS OF TWO WATER SUPPLY SYSTEMS

Background: The water supplies in two towns are insufficient to keep up with demand and corrective investments are decided. Works are expected to be initiated in two years time and a construction period of four years is planned. Determine through bottle-neck analysis what investments will be necessary during the next six years, and the approximate sequence in which they should be effected.

Analysis: The capacity of the different components in each of the water systems in towns A and B were estimated and compared with the forecast demand in six years' time. Each comparison is shown below:

Town A	Installed Capacity in Year X	Forecast Demand in Year X + 6
Intake	23 l/s	12 l/s
Sand Trap	23 l/s	12 l/s
Raw Water Pumping, 11 hours' Pumping	10 l/s	12 l/s
Treatment	15 l/s	12 l/s
Storage	230 m^3	310 m^3
Secondary Distribution	12,500 m	20,000 m
Individual Service Connections	850	1,200
Water Meters	490	1,100

Town B	Installed Capacity in Year X	Forecast Demand in Year X + 6
Well Capacity, 16 Hours Operation	40 l/s	60 l/s
Transmission Line	50 l/s	60 l/s
Booster Pumping, 17 Hours Operation	30 l/s	60 l/s
Treatment	No chlorination	Chlorination
Storage	400 m^3	900 m^3
Secondary Distribution, Network length	20,000 m	80,000 m
Individual Service Connections	1100	5400
Water Meters,	600	5000

The necessary investments in order of urgency in each of the two towns A and B follow immediately from the comparison and are shown below:

Investments and Priority in Town A

1. Water meters
2. Individual Connections
3. Secondary Distribution
4. Storage
5. Pumping more hours

Investments and Priority in Town B

1. Water meters
2. Chlorination
3. Storage
4. Booster Pumping
5. Pumping Wells more hours
6. Secondary Distribution
7. Individual Connections
8. Transmission Line

The order of priority of works is at times difficult to determine since there are different construction periods for different components, and varying procurement periods for different types of equipment and civil works. The optimal phasing is best studied in bar diagrams or in Critical Path diagrams. What is of major interest is to avoid those components in a project tranche that are not necessary. For instance, in town A there is no need whatsoever to expand the intake and sand trap.

CASE STUDY TWELVE - LONG-TERM BOTTLE-NECK ANALYSIS OF A WATER SYSTEM

Background: A city has requested financing for its investment plan over the next 15 years. Its financial situation is precarious, however, and investments should be kept at a minimum. A loan covering part of the investment costs over the next five years is contemplated. Which should be the investments during this period?

Analysis: The consumption during the next 25 years was compared with the capacities of intake and well capacity, of transmission capacity, and of storage capacity as shown below:

Water System Capacity and Proposed Expansion Path

Year	Estimated Consumption ($1000m^3$/day)	Intake Capacity as % of consumption	Transmission Capacity as % of consumption	Storage Capacity as % of consumption
- 2	410	100%	117%	61%
- 1	440	100%	109%	59%
0	500	108%	96%	52%
1	520	107%	96%	74%
2	550	105%	131%	84%
3	570	107%	126%	95%
4	590	108%	130%	92%
5	610	105%	154%	88%
6	640	133%	148%	84%
7	600	129%	142%	88%
8	690	123%	136%	91%
9	720	118%	131%	88%
14	880	112%	107%	n.a.
19	1,090	110%	110%	n.a.
24	1,270	106%	125%	n.a.

Expressing the main components of the system as a percentage of the estimated average consumption shows how well investments are timed with respect to needs. It can be observed that the intake and well capacity follow smoothly the expected demand growth with capacity being a maximum of 133% of demand in year 6 when a major surface water scheme is to be commissioned. Transmission increases are more lumpy and it is not obvious why the increase from 130% to a high 154% in year 5 is needed. This increase could probably be postponed to keep excess capacity smaller. Storage capacity ranges from 52 to 95% in the period and some savings may be possible. Storage related to hourly demand fluctuations might be in the order of 20%. Anything above could be explained by three factors, viz. the desire to have distributed storage capacity over the entire service area to permit separate pressure or service zones; the desire to build excess capacity into additions to take advantage of efficiencies of scale and finally the need for a reserve in case of failure in the transmission line or intake. The first two of these justifications lend themselves to rigorous analysis whereas reserve requirements are more subjective. In the absence of statistics on past breakdowns no firm analysis is possible. It would appear that storage capacity could be decreased in relation to forecast demand, and some of the contemplated storage investments could be delayed until after the financially difficult 5-year period, years 1-5. The financial pressure upon the water company could be eased by postponing the second transmission line and storage additions until later years.

CASE STUDY THIRTEEN - THE PER CAPITA INVESTMENT CRITERION

Background: A sector investment program includes a large number of sub-projects in urban and rural areas. In three towns the goal is complete coverage through house connections in five years time. These goals seem exaggerated considering that minor towns and the rural sector have much lower service coverage. The planning authority has requested additional information to make a decision.

Analysis: The respective water supply investment costs and additional populations to be connected as a result are shown in the table below:

Calculation of Per Capita Investment Costs

	Town A	Town B	Town C
Present Population in Millions	0.56	0.46	0.34
Percentage served through house connections	33%	71%	43%
Percentage served from standposts	28%	14%	1%
Percentage served from other sources	39%	15%	54%
Design Population in Millions	0.78	0.49	0.40
Percentage served through house connections	100%	100%	100%
Percentage served from standposts	-	-	-
Percentage served from other sources	-	-	-
Additional population served under the project in millions	0.60	0.16	0.25
Related water investment in millions monetary units	78	72	60
Implied per capita water investment level monetary units	130	450	240

The investments in town B seem exaggerated and should be pared at least to levels for the other towns all the more since hydrological and topographical conditions are very similar.

CASE STUDY FOURTEEN - COST PER ADDITIONAL SUPPLY FOR RANKING ALTERNATIVES

Background: A large city has been mining groundwater for a long period and the consequences have become increasingly serious. The sub-soil has subsided and depressions have damaged buildings and underground water and sewerage systems. Competing demands from agriculture have forced the city to consider constructing a bulk-water scheme and bring in water from adjacent basins to stop mining and supply future demand. At present the city is consuming 40 m^3/sec of which some 15 m^3/sec is mined from the aquifer. The city has to select one of four bulk water schemes and wants to make a preliminary selection on the basis of total discounted costs per additional supply unit.

Analysis: Pertinent data for discounted investment and operating costs are shown in the Table below which also gives the total cost per additional m^3/sec:

Ranking of Bulk-water Schemes

No of Scheme	Additional Supply	Capital Cost Sum	Operating Cost Sum	Total	Unit Cost
1	7 m^3/sec	2,870	1,100	3,970	570
2	11 m^3/sec	3,690	1,600	5,090	460
3	35 m^3/sec	7,000	9,000	16,000	460
4	24 m^3/sec	6,000	7,000	13,000	530

Total costs per m^3/sec of additional capacity for the four schemes are estimated at 570, 460, 460 and 530 million monetary units respectively. On the basis of the data the city concluded that scheme 2 and 3 were equivalent, and scheme No 3 was selected since it provided more water.

This conclusion is erroneous, however, and it is important to understand why. It ignores the different schemes'total capacities. Unless the demand deficit is so large that the entire capacity is utilized at once after completion of each scheme, there will be excess capacity in each sub-project over varying time periods. Dividing by the entire capacity increase in m^3/s assumes implicitly that the capacity in each scheme will be fully utilized for the first day and onwards. In the example above the assumption may be correct for the two smaller schemes providing 7 and 11 m^3/sec since there is a demand deficit from the onset in the order of 15 m^3/sec of overexploitation which should at least partly be discontinued. For the two larger schemes with 35 and 24 m^3/sec several years of excess capacity is likely. This fundamental difference is ignored and schemes 3 and 4 can not be automatically compared with schemes 1 and 2. In contrast to the conclusion reached scheme No 2 seems more attractive. Before it is selected it should be confirmed that there are no cheaper ways of increasing supplies such as controlling demand through metering. The reported damages to construction need be quantified to see whether they exceed the costs of bringing water from adjacent basins. Conceivably it could be cheaper to pay the damages due to mining, as the sub-soil might consolidate when drained and thus reduce losses.

The latter argument does not resolve the risk in using up nonreplenishable resources. Inter-basin transfers are also not risk-free since competing demands may later develop to claim the waters in their own basin. In case this materialized the city importing water would be saddled with a huge infrastructure built to transfer water which does not exist.

CASE STUDY FIFTEEN - UNIT PRODUCTION COSTS TO RANK SCHEMES

Background: A city's water supply system is approaching capacity and additional raw water capacity is needed. The choice is between two alternative surface water schemes, A and B. The gravity system A would capture waters of good quality but further away than the proposed intake of system B. The latter scheme requires higher treatment costs and pumping. Show which scheme is preferable.

Analysis: The use of the unit cost or comparing different schemes is only permissible if the investment phasings and excess capacities are similar. For instance, the comparison between a ground water scheme that can be easily staged to follow the demand growth closely, and between a bulky, surface water system often has to involve present-value techniques.

In the example above systems A and B are similar in size. System A would be able to produce 4 m^3/sec with an initial investment cost of 4000 million monetary units and subsequent operating costs of 0.5 m.u. per cubic meter, whereas system B would yield 3 m^3/sec with an initial investment cost of 2,100 million monetary units and operating costs of 1.0 m.u. per m^3.

The unit cost of scheme A is then approximately the annuitized capital cost per m^3 plus the operating costs per m^3. Assuming a discount rate of 10% and a useful life of the facilities of 50 years, the total annuitized cost would be 400 million which amounts to around 3.2 monetary units per cubic meter. Total unit costs of scheme A would consequently be around 3.7 monetary units.

The annuitized capital cost of scheme B is analogously 210 million m.u. and the unit cost per m^3 is 2.3 monetary units. Total unit costs for scheme B are 3.3 m.u. per m^3.

The conclusion is clear. System B is recommended for further study and eventual execution since its unit costs are lower, and its total capacity is lower implying less excess capacity.

PROJECT APPRAISAL

General

Supported by the additional information and analysis generated under the project preparation the planner can appraise the investment project. The appraisal is the final step before works are executed and therefore carries much weight.

In a way it is a repetition of the project identification but goes deeper. There is the technical assessment to ensure that the works presented are feasible and represent a sensible compromise between what is desirable and affordable.

The proposed investments are analyzed from the economic point-of-view to make sure expected benefits exceed costs. The answer is provided by the cost/benefit analysis which comprises the three steps, cost analysis, benefit analysis, and the cost/benefit comparison.

Some economic costs and benefits are not reflected by monetary transactions or are not captured by the institution in charge of the construction and operation of the project works. Accordingly separate financial analysis is needed to ascertain there will be funding of the works during their construction, and revenue to defray current expenditure and service debts during the operations.

Finally, institutional arrangements have to be studied and at times corrected so that project construction and operations will not suffer.

In addition, there are other angles to the proposed investment project, for instance of a legal nature, but the four above are fundamental. In the following sections the economic and financial aspects will be discussed and exemplified to degree that is judged practical for water supply and sewerage projects. Technical aspects will not be touched upon for their complexity which is outside the scope of this work. Likewise institutional analysis is excluded since its essential sides have already been discussed under the section on sector planning.

Cost/Benefit Analysis in the General Case

The economic analysis at the appraisal is largely synonymous with cost/ benefit analysis. The concept is nothing difficult, since it is just a comparison between benefits and costs, but in practice both theoretical difficulties and measurement problems make the comparison imprecise.

For the actual calculations the cost/benefit analysis can be separated into three steps which are:

(i) The identification of economic costs;
(ii) The identification of economic benefits;
(iii) The comparison between economic costs and benefits;

The first of these steps, the cost analysis, can further be broken down into three well defined operations to [illegible]

(i) The identification of the overt, financial costs of the project;

(ii) The conversion of the overt market-place costs into economic costs plus the quantification of any other costs not reflected by money transactions;

(iii) The conversion of economic costs incurred at different points in time to one common unit, the so-called present-value cost.

The three-step cost analysis is parallelled by a three-step benefit analysis with analogous steps. Although the terminology used may appear a bit abstract illustrations from actual project work will be used to make it more tangible. The roundabout way is necessary for testing whether a project is profitable or not. Financial revenue cannot simply be compared with costs to construct and operate the project works since economics and finance are two entirely different concepts. Whereas finance only deals with recorded money transactions economics goes deeper and is concerned with the actual resources that are produced and consumed in the processes catering to needs of men. These processes may or may not be recorded in monetary transactions and even when they are, the prices registered may not correspond to their value or costs as perceived by economics. The distinction between economics and finance can thus be stated: Whereas the general economic problem is to use scarce available resources to maximize human welfare, the financial problem is only to record the associated transactions where the economic scarcities are reflected by prices.

Step One of Cost Analysis - Identifying Financial Costs

Inasmuch as the marketplace registers the scarce resources through their prices, it is a good place to start identifying them there. The financial costs of the project are whatever money that has to be injected into the market to construct and operate the project and achieve its objectives. Since the focus is on the projects' contribution, the relevant financial costs are the difference between the situation with the project and without it.

Several clarifications are in order here. The with/without rule usually corresponds to the chronological sequence after/before the project but the two should not be confused. The latter rule is automatic and non-reflective whereas the with/without criterion requires determining what costs are a direct result of undertaking the project. It is commonplace that costs that are incurred after the project are not at all related to it, as they would have been incurred at any rate. Logically they should not be included among the project costs.

Another problem is where in the marketplace financial costs are best found. Water supply and sanitation services happen to be revenue-producing and the place to look are the financial statements of the entity constructing and operating the facilities. Such financial statements may be misleading, however. The investment cost of a project may not appear on the profit-and-loss statement as could innocently be expected but will have to be obtained by comparing different periods' balance sheets. What may appear on the profit-and-loss statement as a cost of the facilities is depreciation, but this is only a book-keeping transaction which does not reflect the money actually invested in the project facilities. To determine economic costs one will rather have to identify the book-keeping entries in the year when the resources were actually committed or used up for the project purpose. The distinction that financial analysis makes between capital costs and current costs is less interesting for economic purposes. The financial distinction is connected with time with capital costs denoting the goods or services producing benefits over a longer time period, and current costs being those for daily operations and maintenance.

The search for financial costs has to be extended outside the constructing and operating entity since it may well be that other bodies will bear project costs. This refers to the construction as well as the operations. What has been discussed under external diseconomies in the section of Macroeconomic Planning is relevant to the project level as well.

Step Two of Cost Analysis - Conversion of Financial Costs into Economic Costs

Fundamental for the understanding of cost/benefit analysis is the distinction between an economic cost and a financial cost. As mentioned financial costs are simply what happens to be considered an appropriate financial payment or book-keeping entry (e.g., depreciation) to account for the use of resources for a given purpose. In contrast, economics is concerned with the best use of scarce resources to increase human welfare. It is then natural to define an economic cost of employing scarce resources for a given purpose as the losses in welfare incurred by committing the resources for the project purpose. Alternatively the definition may be: Economic costs are those benefits foregone by using scarce resources for a given purpose.

Resources stand for anything that can increase human welfare, or satisfy human needs. They can be goods and services as measured by manhours worked, oil burnt, machines deployed and so on. Had a workman not been committed to achieving project objectives, he might have worked elsewhere and produced for instance a car which would have made its owner feel better off. Or the laborer employed might have been a nurse giving help to sick people to increase their welfare.

Economic costs of a project can either be measured in terms of quantities of resources foregone or, more practically, by the prices these quantities command in the market. The assumption is then that the price reflects the benefits since a rational consumer could be expected to pay a price for a product up to the benefits of the same product. Money becomes the measuring-rod for resources.

There may be a divergence between financial costs and economic costs due to market imperfections. Such imperfections denote how much financial prices diverge from the true scarcity values of resources and may arise because of regulations or because consumers have insufficient information of the true scarcities and may not be able to bargain well. Even in a perfect market where prices accurately reflect the relative scarcities, goods and services would have to be adjusted for external economies, unless these were included in the prices charged.

Sunk Costs

A classic example of the distinction between finance and economics are sunk costs. These represent resources that are used up and cannot be influenced by the economic planner at the time of economic analysis and decision-making. For instance, a surface water supply system may be constructed and it is later discovered that a groundwater system can be constructed to produce water at total costs lower than the operating costs of the surface water system. The ground-water system should under the circumstances be constructed and the surface water supply shut down, at least on grounds of economic costs. It does not matter that there may still be large debts left to be paid off for the surface water system. Those investment costs are a thing of the past, the manhours are already expended and cannot be recreated, the concrete has been poured into the forms and cannot be retrieved.

Sunk costs show that financial analysis is looking backwards and economic analysis forward since it considers what the best action is at the moment of decision given the resources available.

Another example of sunk costs is the distinction between technical and economic life-times of machines. A factory may have invested in a new set of machines five years ago and could operate them for another 15 years. Technology advances, however, and a new machine is developed which can produce the same output at total capital and current costs less than the operating costs of the old machines. Obviously the new machine should be bought and the old ones scrapped since they will require more resources in the future than the new machine. Technological progress have reduced their economic life-time to a fraction of the technical life-time. They may still appear in the company's books as assets, and there may still be repayments of loans contracted to buy them, but economically they are not viable.

Transfer Payments

The example on machine obsolescence included a financial cost with no equivalent economic cost, namely interest payments on debts. Whatever the charges shown in the company's books, and whatever the money paid to lenders, no additional economic resources are used when a transaction is registered or made, and the economic cost is zero.

Depreciation charges are close in nature to debt service and as already mentioned are mere internal book-keeping entries and do not show what the economic costs are.

Any publicly imposed cost such as taxes, and import duties that a company has to pay in the course of its operations has no directly equivalent cost in the economic sense although they are financial burdens. To the extent that such public levies stand for use of resources in the public sector doing the tasks for which the company itself would have to hire people, the charges are economic costs and should be charged. Such a decision involves a farreaching investigation involving the whole economy. To the extent that taxes levied distort the true scarcity prices the prevalent market prices have to be corrected for them.

Externalities

Externalities on the cost side are external diseconomies which arise as a consequence of the project but which are felt and borne by others. Common examples would be pollution affecting downstream populations, or worsened navigation or fishing downstream after part of surface stream has been captured for water supply.

Different kinds of ecological damage belong to this category for which prices are usually not charged to the entity causing the damage.

Labor Costs

Labor costs are an important share of investment outlay and one area where there are often wide divergences between financial and economic costs. The financial cost of employing a workman is obviously the going market rate which is determined as a result of negotiations or by edict by the authorities. At the same time that laborers are employed at these rates, it is commonplace to find widespread open and hidden unemployment. An unskilled worker who would lose his job would have to join their ranks or engage in less productive tasks. In case he becomes permanently unemployed he is likely not to produce anything and consequently the economic cost of employing him is zero, since this is the value of his output if not hired. Logically then, in situations of large un-or underemployment the financial cost of unskilled labor should be subtracted from the total projects cost to arrive at the proper economic cost.

The common-sense observation that it does not cost the economy anything to mobilize an unemployed person's time lies behind the drive for labor-intensive technologies which are not new. For such technologies to have an appreciable impact, market forces would have to be allowed to influence wage rates more. The situation where strong labor unions exert upward pressure on wages in the face of unemployment does not make sense, and the establishment of minimum wage rates under the circumstances price marginal workers out of the market. Advocating subsidies to firms employing labor-intensive technologies is somewhat theoretical since the fiscal systems in developing countries are unable to raise the required revenue.

Costs for skilled labor are different since these categories may be much in demand. Conceivably, there is a wide gap between private and public sector wages for skilled labor, it may even be that economic costs exceed financial costs. The latter would then have to be adjusted upwards keeping in mind the fringe benefits that public sector employees in many cases are entitled to.

Foreign Exchange

Scarce foreign exchange often hampers the economic development of a country and are invariably subject to exchange controls combined with allocation procedures. Prevailing exchange rates are thus distorted from true scarcities and the economic analysis will have to convert the foreign exchange component based on the official rate into one that accurately reflects scarcities. For the calculations it should be kept in mind that the foreignexchange component of a project is not only the direct share of imported goods and services but also the indirect one. The latter comprises goods and services imported to produce the domestic component of investment costs. An illustration would be machinery imported for national factories.

The choices of a proper shadow exchange rate can vary. At times it is taken to be the black-market rate, or the rate at free trading abroad. At times more elaborate analysis is attempted to decide upon the correct rate, but it is uncertain the improved precision is commensurate with the extra effort involved.

Price Controls and Subsidies

At times a government finds it necessary to deliberately intervene in the market and fix prices, either by edict or by providing subsidies. The case is analogous to taxes, and market prices have to be adjusted. One example would be underpriced energy and oil in the aftermath of rapid price changes on the international market, another would be the fixing of utility rates such as electricity tariffs.

Step Three - The Dimension of Time and Discounting

After the necessary analysis and conversions out-lined in the two steps above, one is left with a string of economic costs to be incurred in different years. Different projects may have identical sums of current economic costs with very different cost profiles in time. In one case most of the cost may be incurred during the early years, for instance for heavy construction, whereas in another the costs may fall mainly at the end of the time-period. The economic costs of these two streams are not equivalent because of the time dimension of money, loosely paraphrased by the expression "time is money. Another popular interpretation is given by "a dollar today is worth more than a dollar tomorrow." The implication is that costs or benefits incurred in the future should be reduced by some proportion to arrive at their value today. It also implies that the present-value is smaller the later the payment is effectuated.

Classical economic theory provides more explicit reasons than the above intuitive observations. It argues that the reduction of money expected at a future date - discounting - is reasonable on two accounts. On the supply side of money, ultimately the consumers, one can observe that they demand some form of compensation in return for postponing the consumption by saving. Even if a consumer were absolutely confident of receiving his postponed consumption in the future, he would still demand some interest. Most individuals act according to this criterion although one could construe that some take such a pleasure in the mere act of saving that the postponement is a reward in itself. They are surely a minority, however.

On the demand side there are those who are willing to pay some form of compensation for using the saved funds. They may be willing to do so since they know how to make money grow. There are indeed many examples from nature of this growth such as in tree planting, in wheat production to mention a few.

Following the theory, since there is a supply of capital from the consumers and a demand for it from producers a market is mutually beneficial, and the market will agree upon an interest rate at which all the savings supplied would be borrowed. This balancing interest rate is argued to be the appropriate discount rate which indicates by how much the present-value of money decreases each year.

Another justification for discounting is the unrelenting technological progress which makes it likely that future production costs will be lower than today's. To reflect this decrease of real costs future costs should be discounted. The immediate consequence for water supply design is that one should not try to satisfy too distant consumption since it is likely that one could supply it cheaper later by taking advantage of advances in technology. Rapid technological progress should imply high discount rates and short design periods.

In practice, the nice economic theory is not helpful to the economic analyst who wants to select a discount rate by monitoring interest rates in the capital markets. Capital markets happen to be among the most manipulated and distorted and at times do not exist at all. Interest rates are simply fixed arbitrarily as they would be in Soviet-type planned economies. Whereever rates do exist they may be multiple and it is far from obvious which is the opportunity cost of capital to be used for discounting.

In developing countries there are many circumstances that speak in favor of using higher discount rates than in developed countries where it is easier to identify them in the capital markets. In the developing world low income levels and skewed income distribution are the rule. Now, for the poor the mere staying alive till tomorrow or next year is all-important and they will therefore be most unwilling to forego present consumption. They would then be expected to demand high compensation in the form of interest which implies that high discount rates are appropriate. The case is applicable when a water supply system is constructed for a poor neighborhood where part of the investment funds are raised in the form of consumer contributions.

Another characteristic of developing countries is their scarcity of development capital exemplified by capital imports from more developed countries. Supposedly, this would justify the use of higher discount rates in developing countries than in developed ones. It is debatable whether this point is valid, though. In developing countries the lack of infrastructure and stability would seem to make investments yield a lower return than in more developed countries where there is a tradition of economic development. The existence of high interest rates in developing countries may not be a reflection of the productivity of investments but of less productive activities such as real estate speculation.

Present-Value Analysis

Before discussing the empirical determination of appropriate discount rates their use may be illustrated. For the time being the discount rate can be defined as the annual interest rate at which future receipts or outlays decrease in value. Thus, if one were told in year 0 that one would receive the sum of money s_1 in year 1 and the discount rate was " i " % the value of s_1 in present terms would be $s_1 \frac{1}{(1 + i)}$. Similarly, if the sum s_2 were promised for year 2 the present-value would be $s_2 \frac{1}{(1 + i)^2}$, and generally the sum s_n to be received in "n" years would have a present-value of $s_n \frac{1}{(1 + i)^n}$. The present-value sum of all these would then be $\sum_{t=1}^{n} s_t \frac{1}{(1+i)}^{t}$

The factors with which the expected sums are multiplied with are called present-value factors and are tabulated for different interest rates. An extract from such a table for an interest rate of 10% is shown on the adjoining side.

A few examples could illustrate the use of discount tables in economic analysis:

Example 1 Assuming that the appropriate discount rate is 10% in constant money, is $100 to be received in five years preferable to $150 in 10 years time?

PRESENT WORTH OF 1 What $1 due in the future is worth today	PRESENT WORTH OF 1 PER PERIOD What $1 payable periodically is worth today	PARTIAL PAYMENT Annuity worth $1 today Periodic payment necessary to pay off a loan of $1	PERIODS
.909	.909	1.100	1
.826	1.734	.576	2
.751	2.487	.402	3
.683	3.170	.315	4
.621	3.791	.264	5
.564	4.355	.230	6
.513	4.868	.205	7
.467	5.335	.187	8
.424	5.759	.174	9
.386	6.145	.163	10
.350	6.495	.154	11
.319	6.814	.147	12
.290	7.103	.141	13
.263	7.367	.136	14
.239	7.606	.131	15
.218	7.824	.128	16
.198	8.022	.125	17
.180	8.201	.122	18
.164	8.365	.120	19
.149	8.514	.117	20
.135	8.649	.116	21
.123	8.772	.114	22
.112	8.883	.113	23
.102	8.985	.111	24
.092	9.077	.110	25
.084	9.161	.109	26
.076	9.237	.108	27
.069	9.307	.107	28
.063	9.370	.107	29
.057	9.427	.106	30
.052	9.479	.105	31
.047	9.526	.105	32
.043	9.569	.104	33
.039	9.609	.104	34
.036	9.644	.104	35
.032	9.677	.103	36
.029	9.706	.103	37
.027	9.733	.103	38
.024	9.757	.102	39
.022	9.779	.102	40
.020	9.799	.102	41
.018	9.817	.102	42
.017	9.834	.102	43
.015	9.849	.102	44
.014	9.863	.101	45
.012	9.875	.101	46
.011	9.887	.101	47
.010	9.897	.101	48
.009	9.906	.101	49
.009	9.915	.101	50
.008	9.923	.101	51
.007	9.930	.101	52
.006	9.936	.101	53
.006	9.942	.101	54
.005	9.947	.101	55
.005	9.952	.100	56
.004	9.956	.100	57
.004	9.960	.100	58
.004	9.964	.100	59
.003	9.967	.100	60

Answer: The discount table indicates that for a discount rate of 10% each dollar receivable in five years is worth 0.621 in dollars of today, and each dollar receivable in 10 years time is worth 0.386. Consequently the 100 dollars in year five are worth 62.1 dollars today, and the 150 dollars in year 10 are worth 57.9 dollars today. Clearly the preferred alternative is 100 dollars in five years time.

Example 2 Assuming that 10% is the proper discount rate in constant money, what would be the present value of receiving 100 dollars during each of years 11 to 30?

Answer: The present value of receiving 1 dollar during each of the years 1 to 30 is according to the table 9.427 dollars, and consequently the value of 100 dollars during each of the years would be 942.7 dollars. From the same table the value of receiving 1 dollar during each of the years 1 to 10 is shown to be 6.145 and consequently the value of 100 dollars during each of the years 1 to 10 would be 614.5 dollars. It follows by subtraction that 100 dollars receivable during each ot the years 11 to 30 are worth 328.2 dollars today.

Example 3 Assuming that a discount rate of 10% in constant money is applicable, what would be the annuitized capital costs of a pipeline that costs 2 million dollars to construct and is estimated to last for 20 years?.

Answer: The annuitized capital cost of an investment, or its annuity, is the annual constant payment necessary to pay back the investment over its lifetime at the given interest rate. It is routinely applied when annual loan payments are calculated.

In the example the necessary period as payment is obtained by multiplying the investment cost by the capital recovery factor (CRF) corresponding to 10% and 20 years. The relevant CFR is 0.117 and consequently the total annual sum is 234,000 dollars. In order to obtain the total annual costs of the pipeline one would have to add the operations and maintenance costs.

As shown in the illustrative calculations above it is important when choosing the appropriate discount rate to separate inflationary changes from real interest rates. All the examples referred to the discount rate of 10% in constant prices or volume terms. Had the annual receivable amounts of 100 dollars, for instance, been in current money one would have had to apply a discount rate equal to (1+i)x(1+j), where "i" is the discount rate in constant money and "j" the inflation rate.

institutions, and parks as public. In some developing countries water delivered to hotels and tourism facilities is recorded separately as tourism consumption. The classification is made by the utilities to permit differential rates for the different users. At times it is controversial in which category a user will fall, since rates can differ widely.

Generally, water consumption is expressed in average volume (liters per gallons) per capita and day. The tables below give reported average consumption for various cities and towns in different countries:

Another observation is that it is often not necessary to continue summing present-values for a large number of years except when later years' receipt or outlays are relatively large in comparison to earlier years. In judging where to truncate, the number of significant figures in the data should be taken into account since it certainly is not meaningful to continue the present-value calculations beyond a point of the last significant figure.

Empirical Determination of Discount Rates

The determination of discount rates in a macro-economic context has been tried in several instances. The different methods try to measure the opportunity cost of capital either from the productivity side by the returns on capital employed, or by studying the capital markets. A few of these empirical studies will be discussed, more to show the possible ways to determine the opportunity cost of capital (OCC) than to recommend specific values.

The Incremental Capital/Output Ratio Approach

According to macro-economic theory growth could be explained by two components, viz. the return on capital/investments added (which is the opportunity cost of capital, OCC, although not strictly on the margin) and the result of adding more labor. The relation could be written:

IOCR = OCC + (ILCRxMPL) where IOCR = incremental output/capital ratio which is the inverse of the ICOR, or the incremental capital/output ratio
ILCR = incremental labor/capital ratio
MPL = marginal product of labor

This approach has been used for Yugoslavia, a country which is intermediate between developed and developing countries and possesses excellent macroeconomic statistics.

For the actual calculations the gross personal income was substituted for the marginal product of labor and the effect of technical progress was appropriated to capital by deleting an explicit term from the macro-economic production function. The latter introduced a systematic upward bias of OCC. The data employed produced estimates of OCC ranging from 9 to 29% depending upon which province was studied. The variations are clearly enormous and it is difficult to say which is the correct rate to use.

Cobb/Douglas' Production Function Approach

The Cobb/Douglas' type of function explains volume growth by growth in capital and labor, and the general function would be $P = A.K^aL^b$ where P = production value minus depreciation.

K = the sum of fixed assets and "circulating capital"
L = input of labor
A = constant
a = the marginal productivity of capital, or OCC
b = the marginal productivity of labor

The calculations for Yugoslavia produced estimates of OCC ranging from 2 to 10% in less-developed regions and from 10 to 17% in developed regions. The national average was calculated to be 13%.

Financial Rate-of-Return Approach

The third approach, less satisfactory theoretically than the previous two, approximated the opportunity cost of capital by

OCC = P/(FA + WK) where P Profits in survey firms
FA Fixed Assets net of depreciation
WK Working Capital

The Yugoslav data were again used producing an estimate of the national opportunity cost-of-capital of 7%.

Capital-Markets Approach

In perfect capital markets the going interest rate would be equal to the opportunity cost-of-capital. Most capital markets are far from perfect but the United States market is more competitive than most and could be used to estimate OCC. Although estimated rates find application to the US strictly speaking, the fact that it is a relatively open market for other countries makes the US rates interesting for other countries as well.

In their book "Water Supply, Economics, Technology and Policy" Hirshleifer/de Haven/Milliman calculate the OCC on the basis of financing practices and costs of privately owned utilities to be in the order of 10% in constant prices, i.e., after adjustments for inflationary effects. Other investigations have tried to estimate the opportunity cost-of-capital for public sector projects as a weighted average between the prevailing return on investments in the private sector, and between the lending rates for consumer loans, such as for mortgages or car purchases. The rationale would be that the public sector finances its investments out of tax revenue coming from the business sector and from private individuals. A detailed calculation along these lines by Milliman in 1969 produced an estimate of 7%.

Conclusions on the Choice of Discount Rates

The empirical studies discussed above are unanimous in one respect, that the opportunity cost-of-capital for discounting is an elusive concept which is difficult to estimate in a reliable way. Consequently, it is impossible to state with certainty which rate should be used in each individual case. The practice has evolved to apply a discount rate of 10% in constant money and such a rate has at least not been disapproved by the empirical investigations. Some estimates are indeed close to the 10% figure which would seem suitable for further use. The fact that higher discount rates may be applicable in developing countries would speak against the use of lower discount rates than 10%.

BENEFIT ANALYSIS

General

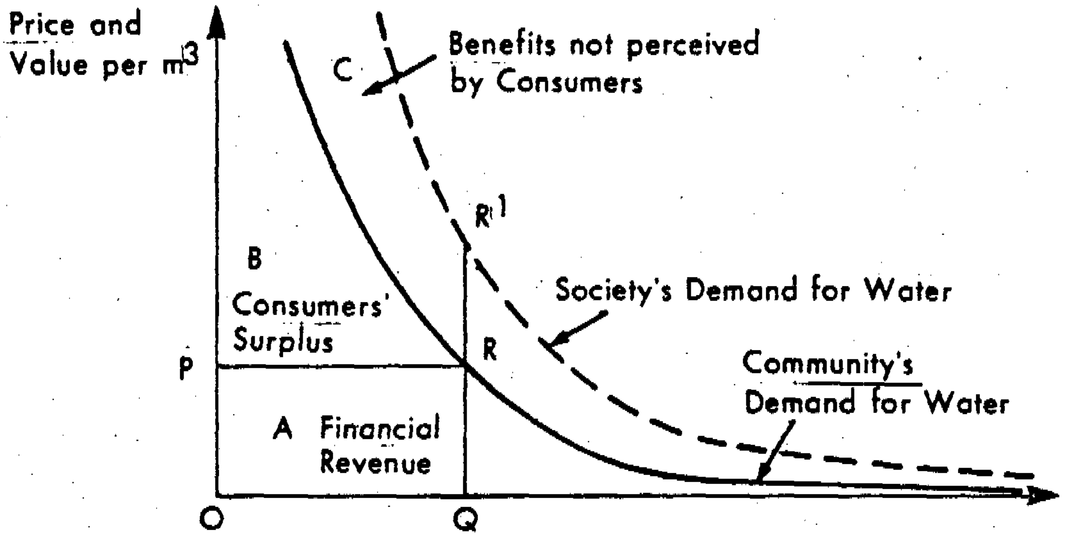
Benefit analysis is concerned with the very need for the project and aims at quantifying the economic benefits that measure the increase in human welfare made possible by the project. For a water supply project these benefits are derived from the consumption of the water supplied during the lifetime of the facilities. The fact that benefits will be spread over a large number of years requires the application of present-value technique to sum them up before they can be compared with the present-value cost sum.

Graphical Representation of Benefits

Physiological and convenience needs cause consumers to demand water. Such water demand is no different in principle than that for cars, books and any other goods or service. Accordingly, the water demand curve will have the general shape as shown in the Figure below:

Figure Community's and Society's Demands for Water

FIGURE Community's and Society's Demands for Water



The demand curve relates the prices consumers are willing to pay for varying quantities for water. Price and value per cubic meter are measured on the vertical axis and the quantity consumed per unit of time on the horizontal axis. The demand curve slopes downward from left to right reflecting the assumption that consumers will buy more water if it is cheaper. The few first units of water consumed will be worth much since they are necessary for survival. Subsequent quantities will be worth less and less since the consumer will have increasingly less use for the water. He will use water according to some priority order such as drinking, personal hygiene, cooking, cleaning, garden watering, car wash and street cleaning and so on.

In the graph the lower solid curve, labeled community's demand for water is the sum of all individual consumer's demand. For example, it shows that at price P the aggregate consumer demand will be Q m^3 of water per day. At lower prices the community will request more, at higher, less. The financial revenues collected from the water sales are given by the area of rectangle OQRP since the price is OP and the quantity OQ. It is this area A that constitutes the financial benefits of a water supply project.

Area B, lying above the line PR, between the vertical axis and the demand curve, is the area of consumers' surplus. The summation of area B shows what the consumers would be willing to pay if the producer would exact from them the price representing the total benefits from each quantity of water consumed. Such price discrimination is not put into system in most systems. In mixed delivery systems with vendors, and tank trucks alongside a public system with individual service connections consumers do pay varying amounts for the same quantity of water.

The broken curve, labeled Society's Demand for Water, relates the value society at large places on the consumption of different amounts of water. It lies above and to the right of the community demand for water, indicating that society values consumption of good water more than the consumers themselves. Thus the area C represents benefits from the consumption of water that the consumers do not perceive. Such benefits are different kinds of externalities are fore most health benefits. Benefits due to improved equity cannot be shown on the graph since they are not directly related to the total volume of water consumed but to its distribution.

Price Elasticity of Water Demand

Empirical determination of the shape of the water demand curve is problematic since one can only observe what quantity is consumed at a particular price. This amounts to just one point on the demand curve. In theory one could obtain a number of points by varying the price and registering the quantities consumed at each price, but this is not feasible in practice. Some limited information can be gained from tariff changes and the demand response. On the basis of these the price elasticity can be calculated which measures the slope of the demand curve in the vicinity of the point of observation. The price elasticity is defined as the relative change in water demand divided by the relative change in water price.

The elasticity is usually denoted by "e" and thus we have

$$e_{point} = \frac{\frac{\Delta Q}{Q}}{\frac{\Delta P}{P}}$$

The elasticity above is called point elasticity since the relative changes are calculated in relation to one point (Q,P) on the curve. Where the price or demand changes are large another elasticity measure, arc elasticity, is preferable. It relates the absolute changes in quantity and price to Q_1+Q_2 and P_1+P_2, respectively and where the indices denote the situation before and after the tariff change. The arc elasticity is thus written.

$$e_{arc} = \frac{\frac{Q_1 - Q_2}{Q_1 + Q_2}}{\frac{P_1 - P_2}{P_1 + P_2}}$$

Elasticities can be calculated with respect not only to price changes but also with respect to income changes in which case consumer income is substituted for water price.

The elasticity value provides important information about the demand curves' steepness. If the elasticity is zero, demand is said to be completely inelastic and no matter what the tariff is, consumers will continue consuming the same quantity of water. As long as the absolute value of the elasticity is less than unity, demand is said to be inelastic, while absolute values above unity imply that demand is elastic. Empirical studies seem to indicate that demand is relatively inelastic although not completely. This would seem logical in view of the relative difficulty to reduce consumption of a vital product. The studies also seem to show that larger per capita consumptions are associated with higher elasticity values. This finding is also reasonable since it means that there is relatively more non-essential consumption such as car washing, garden watering and so on which can be reduced.

Benefit Measurement One - Water Prices

The demand curve provides the potentially best way of estimating benefits from water supply projects. It relates the benefits consumers derive from each quantity of water, since the price is a proxy for the perceived increase in welfare derived from the water consumption.

However, in reality the direct measurement of benefits from the demand curve has proven inpracticable since only fragmentary information is available of the shape over large consumption and price intervals. Even if a demand curve could be reliably determined there would be theoretical difficulties in quantifying the benefits. This is because income varies much and some of the poorer consumers may not be able to indicate their demand since they are not connected to the system. Under the circumstances, should all the consumption be valued at the highest price that wealthy consumers are willing to pay under the assumption that everybody would consume as they, given the same financial possibilities? Or should the consumption be valued at the average price since this is manifestly what they are willing to pay?

Besides these empirical and theoretical difficulties there are others. Unless price discrimination is practiced the consumers' surplus cannot be measured. Then there are the various externalities that the consumers are not well aware of and consequently not willing to pay for.

Concluding then, data and methodological difficulties prevent the direct measurement of benefits from a demand curve. Notwithstanding, it is possible to at least obtain a "floor" estimate of the minimum benefits by equating them with the financial revenue. This may be sufficient to justify the project in which case there is no real need to go any further.

Benefit Measurement Two - Property Values

Instead of attempting to quantify benefits from water supply or sewerage and then sum up their discounted values, one could in theory let the consumer himself do the job. It can be surmised that a buyer, choosing between two properties, one with and another without water supply, would indeed perform such a mental operation. The quantification of water benefits would then boil down to statistically determining for a large number of equivalent properties how much higher those with water supply are assessed compared to those without.

As nice as the theory sounds, such empirical studies have failed due to the statistical difficulties to separate the effect of water supply from other factors. Theoretical objections similar to those raised against the basis of water prices apply here too. Moreover, it is doubtful whether there exist property buyers of such rationality and vision as to look into the future and perform the mental operations necessary.

The method with property value differentials can be used to justify investments in pollution control. An example would be where the project will eliminate pollution in a river. One would expect values of properties adjacent to the river, previously depressed due to the contamination, to rise to levels prevailing for properties in other areas of the city. The increase in property values can be taken to reflect precisely the discounted net benefits.

Another application of the methodology are drainage projects where land values will rise since flooding will cease. In larger cities with active real estate markets there are no difficulties to obtain up to date estimates for equivalent properties in areas unaffected by flooding and thus a relatively reliable benefit calculation can be made. In this kind of projects it is often the policy to recuperate part or all of the investments through betterment taxes which could provide a lower limit of the benefits if paid up.

Benefit Measurement Three - Health Benefits

Improved health is invariably used to justify investments in water supplies and waste water disposal, and it would seem natural to quantify the alleged benefits.

Consumers are willing to pay for water since they are aware of the general correlation between improved water and better health. However, they are most likely not so well informed that they can assign a value to the improved health, and certainly not the improved health of the whole community. The latter are higher because everybody is healthier and will not transmit disease to his neighbour as easily. Since consumers will lack good and precise information about health effects of better water (and sewerage) they cannot be asked to put a maximum value on health benefits.

Scientific studies are required to do that. These will have to be separated into two parts. First, it will be necessary to establish statistically a reliable quantitative relationship between improvements in water supply (and/or sewerage) and decreases in morbidity and mortality in water-related diseases. Second, assuming such a relationship can be established, it would be necessary to assign a monetary value to the decreases in morbidity and mortality to compare them with economic costs.

Some studies have been tried over the years to answer the first question. They have been surveyed (see for instance Saunders/Warford "Village Water Supplies") and invariably been found lacking in some respect. There do exist a number of studies which have indicated qualitative trends. For instance, two of these studies, one conducted in Kentucky in the US from 1954 to 1956[3/], and another conducted in Georgia in the US from 1949 to 1953[4/], reached rather similar conclusions regarding the prevalence rates for Shigella under varying sanitary conditions. In both cases, the findings indicate that the effectiveness of standposts to decrease the prevalence of Shigella is not particularly great and that it is not until the population receives water inside their dwellings that there are reasons to expect a large crop in the prevalence rate. These findings need be qualified. In the US hand-carried water represents very low socio-economic status which implies that for many reasons health conditions will not be good. It can be surmised that the low socio-economic status is associated with a low level of health education, which can be expected to lead to a higher prevalence rate of different diseases.

Although the findings of the two US studies are not readily transferable to other countries and other time periods, they do support the intuitive conclusion that once water is hand carried any distance from the distribution point, be it from a nearby courtyard or from far away, prevalence rates of different water related diseases will not be dramatically reduced at least of enteric infections. This is an interesting finding for choosing between house connection and public standpost systems.

The difficulties to quantify water health benefits are not hard to explain. Most of the water-related diseases, such as typhoid, shigella, infant diarrhea and others spread in more ways than through water. It becomes necessary to control statistically the other vectors in experiments as well as other health-related variables. Such studies will have to be set up as cross-sectional studies where a large number of communities, with water supply are compared with similar communities lacking piped water. Through factor-analysis one would hope to extricate the health impact of the water supply variable. In practice, in these cross-sectional studies other things are found never to be equal and the water impact cannot be isolated. Besides, the difficulties to accurately grade the quality of the water supply itself are considerable. Another way to tackle the problem would be to conduct time-series analysis of a town or more before and after the construction of a water supply system and observe the reduction in water-related diseases. The problem here is that although other factors are not given much time to vary and hence to distort the results, the improved water neither is given enough time to better the health of the population. There is accordingly no discernible health impact.

The answer out of the quandary is to combine the two types of study, and conduct a long-term longitudinal study for a large number of communities where all relevant factors would be under statistical control. Among the factors studied would be as a minimum the quantity and quality of supplies, levels of health and general education, water and sanitation related facilities, dietary, social, cultural, and economic factors, and even climatic and geographical variables. The list, which is not exhaustive, nevertheless gives an idea of the complexity of the required studies. Their cost could be expected to run into millions of dollars and require large numbers of qualified medical and statistical experts to build up health data from scratch. It is an open question whether the uncertain results are worth the costs involved. At any rate, even highly successful findings could not automatically be transferred to other parts of the world or even within the country itself.

The second step of assigning a monetary value to the reduced incidence of water-related diseases is not any easier. In a demographic situation typical of developing countries where a large share of the population is unemployed or underemployed, lives or labor-days saved may have low or even negative values from the hard-core economic point of view. The issue is partly ethical and depends upon whether one assigns a positive value to the consumption of economically unproductive persons or not. Certainly, if health benefits are claimed as the justification of a water project, it might appear contradictory to shadow-price unskilled labor at zero cost.

Concluding then, justifying water supply (and sewerage) projects on account of health benefits would not seem to be feasible due to the difficulties to establish firm quantitative relationships between improved water supplies (and sewerage) and lower morbidity and mortality rates, on one hand, and the problems of assigning objective monetary values to such health improvements.

Benefit Measurement Four - Cost Savings

Apart from appreciating health benefits from improved water, consumers request piped water for its added convenience. The greater ease of drawing water also stands for quantifiable cost savings which could be studied systematically. Theoretically, such an approach is less satisfactory since it will not tell what the direct benefits are, only that it is cheaper than another solution. It can indeed be argued that efforts to justify projects in terms of their cost savings are simply an exercise in least-cost design and do not come to grips with the real benefits.

Cost-saving studies where attempted, have focussed on the health impact of a water supply and tied to quantify the savings in curative health care. After all, investing in water supplies is a form of preventive health care. Intuitively, preventive health care would appear to be cheaper than curative but the difficulties to separate the health impact from improved water supply prevent such direct cost comparisons.

A second method would quantify the savings as compared to manual drawing and transportation of water from far away. Typical studies of this nature have measured the time savings. Again, in countries with underemployed or unemployed segments of the populations, the time savings may not be used very productively and the monetary value of saved hours would be negligible or low.

Ethical Justifications for Water Supply Projects

The difficulties to quantify water-related benefits have made rigorous cost/benefit analysis for water supply (and sewerage) projects dependent upon fortuitious circumstances where the project analyst would stumble upon figures that justify his proposed investments.

More generally, water supply investments are justified as being a good thing per se, and how good is less interesting. The argument, is at times to use water supply to redistribute income directly and indirectly. The "basic needs" development strategy for example includes good and safe water among the most basic needs, and lists it as a goal of economic development. By giving everybody access to safe water real income is equated at least in this respect. This kind of justification has to be taken seriously but also combined with appropriate least-cost analysis and proper financial policies, including levying tariffs. Otherwise it becomes impractical and a mere drain upon scarce investment funds.

COMPARING COSTS WITH BENEFITS

In the final step of cost/benefit analysis the sum of discounted costs are subtracted from the sum of dicounted benefits to yield net project benefits.

In case net project benefits are positive, a second test should be made to ensure that net benefits are as big or bigger than those from other mutually exclusive alternatives of achieving the project objectives. After an affirmative answer the project can be executed assuming there are no financial or administrative bottlenecks.

In case net benefits are negative, the project has obviously failed the first test for execution and its construction is now dependent upon whether non-quantifiable benefits can compensate for the negative net quantifiable benefits. One of the strong points of cost/benefit analysis based on net present values is that the decision maker is told exactly how much is lost in efficiency in order to attain non-quantifiable advantages, be they in the form of better income distribution or health.

Alternative Cost/Benefit Indices

In lieu of the net present value calculation a few other indices are at times calculated. One is the benefit/cost ratio which is simply the ratio between the sum of discounted benefits, and the sum of discounted costs of the project. Obviously a benefit cost ratio above unity implies positive net benefits. The second step of comparing the particular project benefit/cost ratio with that of mutually exclusive alternatives is less clear, however. The ratio fails to rank projects as the following example shows: A project with discounted benefits of 6 and costs of 3 has a net present value of 3 and a benefit/cost ratio of 2. Another project with benefits of 3 and costs of 1 has a net present value of 2 and a benefit/cost ratio of 3. Now, in a situation with no financial constraints the former project with the higher net present value should be executed in spite of its lower benefit/cost ratio. For reasons of such ambiguity and because benefit/cost ratios are not any clearer than net present values, their use should be discontinued.

Another common measure for project justification is the internal rate-of-return (IROR). The rate-of-return is the discount rate at which discounted costs and benefits are equal. It is also known as the "switching" value since at discount rates below the IROR the net present value is generally positive, and for values above generally negative. Once determined the IROR is compared with the opportunity cost of capital, IROR-values exceeding the opportunity cost of capital represent projects that should be accepted and viceversa.

The latter is not true in all cases, though. The calculation of the IROR amounts to solving an equation of a degree equalling the number of years of benefits and costs, and the roots to this equation may not exist or they may be multiple. This drawback and the fact that the internal rate of return is intuitively less understandable than the net present value makes it inferior to the method of net present values.

Cost/benefit Comparison for Water Supply and Sewerage Projects

The comparison of discounted costs and benefits is not feasible for water supply projects since only under exceptional circumstances benefits can be accurately gauged. A lower estimate for the economic benefits can usually be obtained, however, by inserting the financial revenue that the consumers pay for the service as a proxy for economic benefits. An example of the methodology is given below:

CASE STUDY SIXTEEN - NET PROJECT BENEFITS BASED ON FINANCIAL REVENUE

Background:

Economic benefits from water supply projects include among the following overlapping benefits to which it is difficult to assign monetary values: added convenience, higher work productivity, reduction in medical and hospitalization costs, increase in effective nutrition due to reduction of intestinal parasites (especially in children), and more equal access to services.

Neither of these benefits can be quantified at a cost that is reasonable, and in the economic justification of a water supply project can be based upon the incremental financial revenue related to the project output. Neither costs nor benefits that pertain predominantly to improved service for already connected population segments should be included.

Analysis: In the particular case below market prices were considered reasonably undistorted and no further adjustments of costs were justified. The table on the adjoining page shows incremental costs and financial revenue during a period of 30 years, being the estimated useful life of the project facilities.

Incremental rate of return for water, for 33 years
The rate of return is 12.5%
Sensitivity to 20% increase in investment
The rate of return is 10.7%
Sensitivity to 20% increase in investment, and 10% decrease in benefits
The rate of return is 9.33%

Since the net present value sum is positive at a discount rate of 10% the incremental project is justified. Alternatively, since the IROR is 12.5% or superior to an opportunity cost of capital of 10% it should be accepted.

Table Calculation of Project Net Value and Incremental Rate-of-Return
(Amounts in millions of monetary units)

Year	Total Costs + Other Revenues	Volume Sold	Average Revenues S/M3	Revenues	Net Benefit
1	-16.6	0.00	4.8	0.0	-16.6
2	-44.4	0.00	4.5	0.0	-44.4
3	-17.8	0.8	4.2	3.4	-14.4
4	- 2.5	1.5	4.7	6.7	4.5
5	2.0	2.1	4.8	9.9	11.9
6	1.2	2.5	4.7	11.7	12.9
7	- 0.9	3.0	4.7	13.8	12.9
8	- 2.2	3.2	4.7	15.2	13.0
9	- 4.0	3.2	4.7	15.2	11.2
10	- 4.0	3.2	4.7	15.2	11.2
11	- 4.0	3.2	4.7	15.2	11.2
12	- 4.0	3.2	4.7	15.2	11.2
13	- 4.0	3.2	4.7	15.2	11.2
14	- 4.0	3.2	4.7	15.2	11.2
15	- 4.0	3.2	4.7	15.2	11.2
16	- 4.0	3.2	4.7	15.2	11.2
17	- 4.0	3.2	4.7	15.2	11.2
18	- 4.0	3.2	4.7	15.2	11.2
19	- 4.0	3.2	4.7	15.2	11.2
20	- 4.0	3.2	4.7	15.2	11.2
21	- 4.0	3.2	4.7	15.2	11.2
22	- 4.0	3.2	4.7	15.2	11.2
23	- 4.0	3.2	4.7	15.2	11.2
24	- 4.0	3.2	4.7	15.2	11.2
25	- 4.0	3.2	4.7	15.2	11.2
26	- 4.0	3.2	4.7	15.2	11.2
27	- 4.0	3.2	4.7	15.2	11.2
28	- 4.0	3.2	4.7	15.2	11.2
29	- 4.0	3.2	4.7	15.2	11.2
30	- 4.0	3.2	4.7	15.2	11.2
31	- 4.0	3.2	4.7	15.2	11.2
32	- 4.0	3.2	4.7	15.2	11.2
33	- 4.0	3.2	4.7	15.2	11.2

Net present values at interest of

0.0%	261.
5.0%=	83.
10.0%=	17
20.0%=	-26

ALTERNATIVE OPTIMALITY ANALYSIS FOR WATER SUPPLY PROJECTS

The impracticality of determining water supply and sewerage benefits except under fortuitous circumstances prevents strict cost/benefit analysis. Instead of being able to say exactly how profitable investments are it is only possible to indicate the minimum social profitability. Under the circumstances, it is just as well to accept the limitations and restrict the project economic analysis of water supply and sewerage projects to what can be measured with accuracy and reliability. Project appraisal would then have to go through three steps which are:

Step one: Carrying out a careful demand forecast to ensure there is likely to be a demand for the project output. As will be further discussed under the section on demand forecasts such demand projections should take into account the impact of the price charged for water.

Step Two: Carrying out a least-cost analysis to ensure that the project will meet the objectives at the smallest sum of discounted investment and operating costs over its lifetime. Such analysis should consider the correct timing of new investments, their correct scale, and whether the selected technical solution is the best alternative.

Step Three: The sum of discounted project costs should therefore be compared to the sum of discounted project benefits which will in most cases be the incremental financial benefits. The tariffs selected should be guided by the long-run marginal cost approximated by the average incremental cost of water.

Comments on the Proposed Methodology

Before further discussion of the alternative methodology it might be useful to see what it does not attempt to achieve. The methodology takes a stand against the application of so called shadow-pricing analysis formats as exemplified by the Little-Mirlees and UNIDO manuals. These endeavour to put projects into a global context by using border prices for the project input and output and introduce macro-economic terminology into the project analysis.

Such sophisticated analysis is impractical for water-supply and sewerage projects and need not be attempted. Since benefits cannot be measured except under exceptional circumstances there is no point in refining the cost side of the analysis if the benefit side is guess-work or "floor" benefits. Efforts to this end will just give a false sense of precision. Shadow-pricing using border-prices disregards the fact taht water is not a tradeable product, and certainly not across borders. Where shadow-pricing assigns income redistribution benefits by way of introducing weights for project benefits to different income categories, the fact is obscured that income distribution aspects are necessarily subjective. Such efforts need not be attempted although the income redistribution impact of a project should by all means be taken into account as a qualitative consideration. Basically it is counter-productive to link project analysis with macro-economic analysis by requiring the former to question whether the economy in investing optimally or not. The attention is diverted from those aspects of project analysis which are much more basic to project success, namely demand forecasting, least-cost analysis, financial, and tariff analysis.

WATER DEMAND FORECASTING

Introduction

The importance of carefully projecting demand for water supply projects cannot be enough stressed. The entire design of the investment program depends upon the demand forecasts, on which also the financial projections are based. The latter in turn influence the size and timing of the works executed, as water sales are the major determinant of the internal cash generation. It is indeed superfluous to say that demand forecasts set the pace for investment plans and overall operations.

In contrast to the significance of realistic demand projections are the scant efforts by water supply planners to improve the methods of forecasting. Instead of studying the determinants of water demand, the concern has rather been to build projects ahead of time to meet future water requirements. For many years simplistic procedures have been used to estimate future urban water demand, where projected population have been multiplied by the current or projected per capita water use. This approach overlooks, among other things, the relationship between per capita water use and the price of water which cannot be neglected since future water sources invariably will be more expensive than present ones. It has also led to the frequently mistaken premise that additional supplies cost less than measures of economy.

Until recently water supply in developing countries has been primarily a municipal undertaking, of which most capital and operating costs have been financed by government funds. The lack of adequate demand forecasts has at times caused these municipal utilities to build oversized facilities which have become financial burdens to the community. Added to that is poor management which has made the utilities dependent on government financial assistance, with the consequences of having all policies dictated by the governments. Economic efficiency is so seldom achieved in the water supply sector that it is not unusual to find in many developing countries some of their cities with huge unused water facilities, while others are suffering acute water shortage. In all fairness it must be said that most national or municipal water entities do not provide incentives for efficient investment planning, while at the same time mistakes and failure to satisfy demand are punished.

Misdirected financing policies have encouraged the carefree impression that water is practically free and that there is no need to use it economically. As a result, the majority of investment planners have not been forced to make the best use of existing systems, perhaps unconsciously taking the view that their governments are obliged to supply urban water. The same concept is widely spread in developed countries as well. The predilection to think mainly in terms of additional supplies has been compounded by scarce reliable consumption data, and the combined effect in many instances has been projects constructed too soon and too big.

Consequences of inaccurate Demand Projections

The determination of the scale of a proposed system expansion and its timing depends upon the demand projections, which indicate whether or not the expansion is premature. In cases where a substantial supply back-log is evident, this risk and its related costs are small, as the incremental capacity is needed right away. The size of the proposed expansion will also be dependent upon the relevant discount rate and the economy of scale factor of the works in question.

Two types of costs are associated with basing the capacity increases upon erroneous demand forecasts. These costs can be illustrated by a case where the demand forecasts are off by three years. The first cost, wrong timing i.e., making the investment too early, is substantial and amounts to around 25% of the investment[1]. The second one, wrong scale, associated with using too long design periods, is less important as costs functions for water supply works are rather flat. An analysis of the investments with an economy scale factor of 0.65 and discount rate of 10% shows that the penalty cost of designing for a period of 11 years instead of the optimal 8 years say, would be only 2%. Thus the premature investment is far costlier than constructing for slightly longer design periods. The implication for demand forecasting is that the short-term demand projection is far more important than the long-term outlook.

On the financial side, overestimated demand over the short-term squeezed the utility in two ways. First, the utility will generate less cash to contribute to investments, as water sales fall short of the projections. Secondly, it will be saddled with an expansion program that may in fact not be needed for years. A times, it has been advocated to use two sets of demand projections, one more conservative for projecting the utility's financial situation, and a second with faster demand growth for scheduling and designing investments. This practice does nothing to avert the risks of premature and oversized investments and merely obscures the obvious importance of making accurate demand projections.

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[1] For illustrative purposes a discount rate of 10% has been used and it has been assumed that the investment is undertaken in year o as contrasted to the "correct" year 3. The cost is then given by the difference in present worth factors, i.e., 1.00-0.75.

While it is important to stress that planners should not advance investments prematurely in a situation without service backlog, one should also recognize that it is often difficult for them to resist the public pressure to plan ahead and invest with a margin of safety. However, the cost of these safety margins should be made explicit, and this is certainly essential when large and lumpy investments are projected. In such situations, it may prove more economical to start with a smaller program, though its costs may appear relatively high, before the large and costly capacity addition is undertaken. This is particularly recommended when the impact of a metering program and sharp tariff increases upon consumption is not yet known.

Projects can obviously not be successfully implemented when they entail unrealistic financial projections. The decision whether water supply to a given city should be increased or not, should rest upon a careful analysis of future demand and pricing policies considered optimum to promote the economic use of water. In contrast, projects have at least in the past on several occasions been approved and executed without explicitly forecasting demand and analyzing its determinants.

Water demand very often is typically not forecast on a continuing basis, and consumption and production data required for successful forecasting are not as readily available or reliable, as would be desired. In many developing countries water use is not metered, and only rough consumption estimates are available. Consequently, demand forecasting too often becomes production-oriented, while it should rightly be consumption-oriented. Benefits from additional urban water supply can be optimized only when investment planners take a marketing approach centered around the consumer and the need for ecomic use of a safe and reliable water supply. Such an approach should focus on the consumer, studying what his access to water services is and how much he might be willing or could afford to spend for different levels of service. After estimating the demand at different service levels the planner should design a system that will meet the consumers' expected demand. The ultimate goal would be to serve 100% of the population. In contrast, present water investment planners all too often put the cart before the horse as they concentrate on the technically more sophisticated production and transmission components to the detriment of the distribution components. As a result it is not uncommon to find cities with large excess production capacity while at the same time only a share of the population is served from the public system. Such cases point to misallocated investments.

Classes and Determinants of Urban Water Demand

Water consumed is ordinarily classified according to the type of activity for which it is used. Hence, water supplies to households is classified as domestic; that to commercial and industrial establishments as commercial or industrial; and that to schools, hospitals, government institutions, and parks as public. In some developing countries water delivered to hotels and tourism facilities is recorded separately as tourism consumption. The classification is made by the utilities to permit differential rates for the different users. At times it is controversial in which category a user will fall, since rates can differ widely.

Generally, water consumption is expressed in average volume (liters per gallons) per capita and day. The tables below give reported average consumption for various cities and towns in different countries:

Representative Average Demand Levels

Continent Country Town	Population of Town on 31.12.69 (thousand)	Water Consumption from Municipal water supply in 1969 l.c.d.		Maximum Demand as a Percentage of Average Demand
		Average	Maximum	
AFRICA				
Repubic of South Africa				
Cape Town	640	270	370	136%
NORTH AMERICA				
Canada				
Calgary	320	670	1,200	179%
Edmonton	430	370	700	189%
Hamilton	290	930	1,240	133%
London Ontario	210	420	740	177%
Montreal	1,460	650	910	141%
Ottawa	380	360	690	190%
Toronto (munic, agglom.)	2,050	600	1,010	170%
Vancouver	1,000	580	1,890	327%
U.S.A				
Boston	620	840	950	113%
Cincinnati	500	530	740	140%
Cleveland	810	700	1,100	157%
Dallas	910	340	450	133%
Detroit	1,570	640	950	150%
Philadelphia	2,030	710	930	131%
Grand Rapids (Mich.)	210	580	1,370	235%
Houston	1,210	500	710	142%
Indianapolis	680	500	700	140%
Kansas City	170	690	900	131%
Los Angeles	2,960	620	980	159%
Minneapolis	450	380	940	247%
Pittsburgh	600	500	600	120%
Portland, Oregon	380	460	960	310%
St. Louis	690	1,080	1,350	125%
SOUTH AMERICA				
Brazil				
Rio de Janeiro	4,500	300	600	200%
ASIA				
Japan				
Tokyo	8,980	470	560	118%
Yokohama	3,170	300	370	125%
Turkey				
Ankara	1,000	180	220	122%
Izmir	580	120	130	113%
EUROPE				
Austria				
Graz	250	210	240	113%
Salzburg	120	290	410	141%
Vienna	1,650	320	420	131%
Belgium				
Antwerp	230	170	210	113%
Brussels	1,280	140	160	111%
Ghent	150	100	300	300%
Liege	150	250	270	105%
Bulgaria				
Sofia	850	530	660	124%

Continent Country Town	Population of Town on 31.12.69 (thousand)	Water Consumption from Municipal water supply in 1969 l.c.d.		Maximum Demand as a Percentage of Average Demand
		Average	Maximum	
The Netherlands				
Amsterdam	830	200	260	134%
Breda	120	80	130	154%
Eindhoven	190	170	280	162%
Enschede	130	120	180	150%
The Hague	550	120	170	138%
Haarlem	170	120	170	148%
Hilversum	100	200	440	215%
Tilburg	150	200	300	145%
Utrecht	280	190	260	137%
Principality of Monaco				
Monaco	20	560	780	138%
German Federal Republic				
Augsburg	210	200	280	140%
Bremen	610	150	200	133%
Darmstadt	140	100	120	112%
Hamburg	1,820	200	290	143%
Hannover	520	220	310	145%
Mannheim	330	230	400	173%
Munich	1,330	270	390	144%
Nuremberg	480	220	370	168%
Stuttgart	620	220	340	151%
Wurzburg	120	250	490	201%
West Berlin				
Berlin West	2,130	220	410	184%
Norway				
Oslo	490	610	760	126%
Poland				
Bialystok	160	230	260	116%
Bielsko-Biala	170	390	490	126%
Bydom	190	190	230	120%
Chorzow	150	420	N.A.	N.A.
Gdansk	370	220	270	121%
Gliwice	170	190	200	106%
Katowice	300	190	N.A.	N.A.
Cracow	580	270	290	108%
Lublin	240	210	N.A.	N.A.
Lodz	750	200	220	110%
Poznan	460	230	300	131%
Radom	160	200	210	108%
Ruda Slaska	140	110	120	110%
Sosnowiec	140	170	200	115%
Szczecin	340	260	300	114%
Torun	130	220	240	109%
Walbrzych	130	240	270	111%
Warsaw	1,290	300	370	120%
Wroclaw	520	230	270	118%
Zabrze	200	150	N.A.	N.A.
Portugal				
Lisbon	840	200	280	140%
Oporto	350	80	100	127%
Switzerland				
Basel	210	480	800	166%
Bern	170	480	580	121%
Lausanne	140	470	720	155%
Zurich	430	420	600	143%
Sweden				
Goteborg	440	410	510	125%
Malmo	260	340	480	142%
Stockholm	760	450	610	136%
Hungary				
Budapest	2,000	330	440	136%
Miskolc	170	270	390	144%
Great Britain				
Birmingham	1,270	270	310	115%
Glasgow	980	420	460	109%
Leeds	510	250	300	120%
London	6,060	290	350	124%
Manchester	540	350	380	109%
Southampton	210	280	340	122%
Italy				
Bologna	80	280	340	120%
Genoa	840	390	430	110%
Modena	140	180	230	124%
Naples	1,280	250	290	116%
Padua	230	330	410	124%
Palermo	160	280	320	114%
Ravenna	70	140	140	100%
Rome	2,430	440	530	121%
U.S.S.R.				
Leningrad	3,000	520	610	116%
Minsk	570	270	-	N.A.
Tallinn	300	250	380	148%
Vilnius	240	220	230	107%
Czechoslovakia				
Ostrava	270	390	420	109%
Plzen	140	370	440	118%
Praha	1,160	220	240	108%
Denmark				
Aarhus	110	350	450	130%
Copenhagen	640	270	310	116%
France				
Bordeaux	270	330	480	144%
Brest	160	150	200	133%
Dijon	150	300	410	137%
Grenoble	160	410	470	115%
Limoges	130	250	350	137%
Le Havre	200	390	450	115%
Nancy	130	370	400	108%
Nantes	260	250	400	160%
Paris	2,580	320	400	125%
Reims	160	240	300	127%
Strasbourg	250	300	380	128%

Continent Country Town	Population of Town on 31.12.69 (thousand)	Water Consumption from Municipal water supply in 1969 l.c.d.		Maximum Demand as a Percentage of Average Demand
		Average	Maximum	
Europa/continental				
Finland				
Helsinki, 1974	500	430	540	125%
Turku, 1974	160	410	570	140%
Tampere, 1974	170	340	510	150%
Crece				
Athens 2,100	160	210	130%	
Ireland				
Dublin 600	240	260	106%	
Yugoslavia				
Belgrade	810	330	420	127%
Spain				
Barcelona	1,760	240	300	126%
Madrid	3,100	330	430	130%
Seville	620	300	420	130%
Toledo	400	590	880	149%
Valencia	600	200	250	105%
Valladolid	220	270	320	116%
Africa				
Ethiopia, Addis Ababa, 1975	1,100	35	40	114%
Malaw, Blantyre, 1975	210	160	240	150%
Somalia, Mogadishu, 1975	440	33	63	190%
Kenya, Nairobi, 1975	700	105	118	113%
Asia				
Singapore, 1976	N.A.	130	N.A.	N.A.
Singapore, domestic, 1976	N.A.	60	N.A.	N.A.
Malaysia, K.L., 1976	N.A.	360	N.A.	N.A.
K.L., domestic, 1976	N.A.	220	N.A.	N.A.
Thailand, Bangkok, 1976	N.A.	580	N.A.	N.A.
Jordan, Amman, 1969	480	34	N.A.	N.A.
Philippines 1975				
Baguio	N.A.	320	N.A.	N.A.
Cabanatuan	N.A.	260	N.A.	N.A.
Lipa	N.A.	220	N.A.	N.A.
Lucena	N.A.	390	N.A.	N.A.
San Fernando	N.A.	520	N.A.	N.A.
Tariac	N.A.	360	N.A.	N.A.
Pakistan, Lahore	N.A.	300	N.A.	N.A.
Nepal, Khatnandu	N.A.	130	160	123%
South America				
Brazil, Sao Paulo, 1969,	N.A.	210	N.A.	N.A.
Bolivia, 1969				
Potosi,	65	270	340	125%
Sucre	50	300	380	125%
Ecuador, Guayaquil, 1976	1,060	300	N.A.	N.A.
Nicaragua, Managua, 1976	480	250	N.A.	N.A.
Mexico				
Mexico City	8,020	360	N.A.	N.A.
Cd Victoria	100	380	N.A.	N.A.
Jalapa	160	430	N.A.	N.A.
Mexicali	300	400	N.A.	N.A.
Jamaica, Kingston	600	310	N.A.	N.A.
Panama, Panama and Colon	1,000	370	N.A.	N.A.
Colombia				
Bogota, 1976	3,700	210	N.A.	N.A.
Cali, 1973	1,100	260	N.A.	N.A.
Palmira, 1973	140	140	N.A.	N.A.
Tulua, 1973	90	140	N.A.	N.A.
Pereira, 1973	210	160	N.A.	N.A.
Neiva, 1973	120	210	N.A.	N.A.
Manizales, 1973	200	200	N.A.	N.A.
Armenia, 1973	160	190	N.A.	N.A.

As can be seen the average per capita consumption varies widely from one place to another. The wide variations are probably partly due to different definitions of average consumption but also domestic consumption depends on, among other things, the standard of living, climate, cost of water, metering, quality of water and availability of sewerage. Commercial and industrial consumption from the public system seems to be influenced primarily by the cost and quality of water, the ready availability of alternative sources, and the type of industry. As the cost of public water increases, industries can be expected to restrict their use of the public water supply and resort to private systems and other measures such as recirculation of cooling water, use of air for cooling, or use of water of lower quality.

An important share of water produced is not accounted-for. Though in nature not a consumption, this water use may be expressed in average volume per capita or as a percentage of total water production. It is termed unaccounted-for water which may mean many different things. At an extreme it is understood to be the difference between metered water production and metered water consumption. A second usage, apt to produce misunderstandings, equates water unaccounted-for with leaks in the distribution system. More commonly, unaccounted-for water is taken to be that amount of water not consumed through individual service connections, irrespective whether it is metered or not. In this sense it comprises leaks, consumption through unmetered public standpipes, water consumed in clandestine connections etc. This usage is close to a fourth one which defines water unaccounted-for as that which is not directly revenue-producing. The latterr may be useful for financial projections but should not be used for demand forecasts. Instead when projecting demand the best use of the term unaccounted-for water would seem to be that share of water produced that cannot readily be metered.

Irrespective of the definition used, it is essential to understand that in most cases the water unaccounted-for is to a large extent already being consumed although it is not recorded as water sales. It is therefore in general not possible to appreciably increase supply by decreasing the percentage of water unaccounted-for. More typically, a campaign to account for water will result in rapidly increasing water sales in the short term. This better administrative control over water consumption usually spills over into more economical use, thus lowering demand and freeing previously wasted water for the benefit of other consumers.

The same imprecise terminology is frequent when discussing consumption and supply. It may for instance be stated that a city's average consumption is 300 lcd and what is really menant is the average supply, including distribution losses. To avoid ambiguities it should be explicityly stated that water production refers to the metered water leaving the treatment plant. Unclear terminology is widespread with reference to service levels. An estimate of the population served should always separate consumers with individual service connections from those served through public standposts. This is not always done and creates much confusion and may at times glossly exaggerate the population unserved.

Impact of Tariff Changes on Demand

With a few notable exceptions, tariff changes either in level or structure have never been considered when in predicting future demand. Implicitly, water supply planners have assumed that water demand was completely price inelastic, that is, the quantity of water consumed would not vary when the price did. However, water usage will undoubtedly increase at lower prices and decrease at higher prices. Somewhat illogically, even those who claimed water demand to be price inelastic, did agree that demand is income elastic and that demand increases with the consumer's income.

One reason for the failure to take the elasticity of water demand into account, has been that the positive income elasticity and the negative price elasticity work against each other. In a situation with rising incomes and given the feeble efforts by many utilities over the world to recover costs through tariffs, the negative price elasticity has seldom been put to test. The matter is further complicated by frequently deficient metering. Another reason is that there has been a failure to distinguish between consumption per connection and total consumption. The former is relevant for judging elasticity, whereas the latter is likely to increase through the sheer population growth. Demand elasticity is particularly worth consideration in those projects, where metering is routinely introduced or improved, tariffs raised substantially to approach full cost recovery, and tariff schedules made more productive.

Evidence for the price-sensitivity of water demand is provided by a wide range of studies in different parts of the world. The salient results of these are shown in the table below:

EVIDENCE OF PRICE AND INCOME ELASTICITIES OF WATER DEMAND

	Calculated Average Elasticity	Tariff Increase in Current Prices	Average Monthly Consumption per Connection	No. of Connections	Observations
Price Elasticity					
Bogota, Colombia 1972/73	-0.44	6%	$50m^3$	270,000	Carefully metered system with good water supply. Elasticity *short-run* as time series analysis applied.
Bogota, Colombia 1974/75	-0.12	13%	$48m^3$	310,000	Ditto
Cartagena, Colombia 1973/74	-0.33	55%	$50m^3$	25,000	Data reliability rather good. Water service, rationed in parts though. Elasticity calculated is short-run.
Manizales, Colombia 1972/73	-0.60	80%	$60m^3$	24,000	Data reliability good. Reducation in consumption appears to be long-run.
Manizales, Colombia 1974/75	-0.18	41%	$42m^3$	25,000	Ditto
Medellin, Colombia 1973	-0.17	N.A.	N.A.	150,000	Ditto
41 Selected U.S. Study Areas, 1966	-0.23	N.A.	N.A.	N.A.	Cross-sectional study implying long-run elasticity.
Toronto, Canada 1972	-0.93	N.A.	N.A.	N.A.	Cross-sectional study implying long-run elasticity.
13 Communities, Georgia, U.S.A., 1967	-0.67	N.A.	N.A.	N.A.	Cross-sectional study implying long-run elasticity.
Penang Island, Malaysia	-0.15	N.A.	N.A.	N.A.	Time-series analysis implying short-run elasticity.
43 Systems in Utah, U.S.A. 1964	-0.77	N.A.	N.A.	N.A.	Cross-sectional study implying long-run elasticity.
One Standard Metropolitan Area, U.S.A.	-0.63	N.A.	N.A.	N.A.	Cross-sectional study implying long-run elasticity.
30 Cities in Africa, Asia and Latin America	-0.43	N.A.	N.A.	N.A.	Poor data reliability. Cross-sectional analysis implying long-run elasticity.
Yuma, Arizona, U.S.A.	-0.22	45%	N.A.	N.A.	Time-service analysis implying short-term elasticity.
Yuma, Arizona, U.S.A.	-0.33	48%	N.A.	N.A.	Time-series analysis implying short-term elasticity.
Kansas City, Mo., U.S.A.	-0.20	50%	N.A.	N.A.	Ditto
New Orleans, La. U.S.A.	-0.09	70%	N.A.	N.A.	Ditto
Average Unweighted Short-term Elasticity	-0.3 ====				
Average Co-weighted Long-run Elasticity	-0.6 ====				

It should be cautioned that several of the studies referred to in the table suffer from data and methodology weaknesses which diminish their validity. However, the reported price elasticities range from -0.1 to 0.9 in the shortrun with an unweighted average being -0.3. This means that for each 100% tariff increase, consumption could be expected to drop by about 30%.

The inmediate relative drop in per capita consumption divided by the relative tariff increase, or the short-term elasticity, is important for determining the proper timing of capital expenditures. By using the tariff effect, major capital outlays could be postponed or reduced by raising tariffs to reduce consumption. The associated savings can be substantial.

Assume, for instance, that demand is growing at some 6% annually and that a tariff increase of 100% is implemented over a short time before a major capacity addition. Applying conservatively a short-term price elasticity of -0.2, demand could be expected to drop by 20%. This would allow the planner to postpone the capacity addition by more than 3 years. Assuming the investment cost is US$40 million, the approximative savings would be US$10 million as given by the difference in present value factors at a discount rate of 10%. Demand varies not only with the average rate levels but also with tariffs progressivity and excess consumption levels. The same average tariff may be obtained from different tariff structures.

Of more interest for the long-term inverstment policy is the lasting reaction of the population to higher water tariffs. Aside from some scope for reducing water use inside the dwelling the population's major savings in water use can be achieved outside the house for yard watering, car washing, etc., and by repairing leaking plumbing faucets. Some studies of long-run elasticity of water demand in the United States, i.e., the permanent adjustment to higher tariffs, seem to indicate that it could be about -0.6, or higher than the short-run elasticity. Again, it must be cautioned that data and methodological difficulties make an indiscriminate use of elasticity values imprudent, and the long-run elasticities quoted only indicate the order of magnitude. The results of these studies also seem to indicate that water demand is much more elastic in humid than in arid climates. Another study of water demand in 38 cities in developing countries suggests a long-run price elasticity of -0.4. The latter study, however, is based on data so unreliable as to subtract much value from it.

Impact of Income Differences on Demand

Most of the studies on price elasticity of water demand have detected that the short-term elasticity of demand is more pronounced for higher income groups. The evidence is fully congruent with the economist's concept of a sloping demand curve where the first units consumed entail very high marginal benefits, after which these benefits fall off relatively fast as consumption increases. Two studies made in Bogotá and Cartagena, Colombia found that the lowest income groups' demand in many cases became completely price inelastic after several tariff increases. One could surmise that they had already economized on water use to such an extent that later tariff increases produced no further drop. This illustraates the wisdom in adopting a progressive tariff structure to help the poor afford a minimum water supply at a price lower than the marginal cost, but to penalize larger customers by charging them a much higher price to induce them to use water economically.

It has been argued that consumers are not price-sensitive until the water bill reaches a certain proportion of their total income. Such an assertion is not supported by the studies previously mentioned, and consumers seem to react to sharply increased water bills if obliged to pay for their consumption. It must be stressed that the income elasticity coefficients found in the literature are not very reliable, as income data are notoriously difficult to estimate. To give an idea of the expected relative growuth in water use divided by the relative income growth, or the income elasticity of water demand, reference is made to the four studies shown in the table below:

Income Elasticity of Water Demand	Calculated Elasticity	Observations
38 cities in Africa, Asia and Latin America	+0.33	Poor data reliability. Cross-sectional analysis implying long-run elasticity.
Penang Island, Malaysia	from 0 to +0.4	A cross-sectional analysis of 1,400 households implying long-run elasticity.
13 Communities, Georgia, U.S.A.	+0.33	Cross-sectional analysis implying long-run elasticity.
Selected U.S. Areas	+0.32	Cross-sectional analysis implying long-run elasticity.
Unweighted Average Long-run Income Elasticity	+0.3	

The data would seem to indicate that the income elasticity of demand is about 0.3 although it may not hold over very large income intervals. For the purposes of determining the optimal timing of investments the income elasticity probably does not matter very much, as per capita income changes can be expected to be small over a few years time.

Effect of Metering

Wherever sewerage is readily available, only metering can hold water usage within reasonable proportions. There has been much controversy over the need for metering. Some planners have come out against metering in systems with low capital costs and unlimited supply, but have neglected to balance the higher cost of treating increased sewage volumes. Several studies have proved that the installation of meters can substantially reduce water consumption and therefore wastewaters. For instance, a large study in the Netherlands in 1967 made a cross-sectional analysis of towns and cities with populations above 50,000 inhabitants in which it was found that per capita consumption levels were 40% lower in metered than in unmetered systems, although the relation did not hold for communally metered supplies where consumers did not feel any individual responsibility for holding down consumption. The figure of 40% lower per capita consumption is well supported by the studies in the table below:

Effect of Metering on usage

Punjab, India, 1976	For the socio-economically very similar cities Ludhiana and Jullundur, average monthly production excluding 40% water unaccounted-for was found to be 45 m^3 for Ludhiana which is well metered, and 69 m^3 for Jullundur which is practically unmetered. Metering extensively in Jullundur could be expected, ceteris paribus, to result in a drop of 33% in water consumed per connection.
Pueblo, Colorado	Metered residential consumers were consuming at rates 60% of those in unmetered areas. The introduction of metering could be expected to result, ceteris paribus, in a drop of 40% in water consumed by unmetered consumers.
Boulder, Colorado	The introduction of metering reduced residencial demand by 36%.
Lima, Peru	Overall consumption dropped 30% when metering was increased from 44% of service connected to 100%.
Bogotá, Colombia	Overall consumption dropped 54% when meter coverage grew from 8% to 68%.

Cali, Colombia	Overall consumption dropped 44% when meters were introduced on 80% of the service connections.
Honiara, British Solomon Islands	Overall consumption dropped 43% over a year's time when metering was introduced for 100% of the connections.
Average reduction after extensive metering	<u>40%</u>

The fact that a relatively small number of the customers account for the bulk of consumption has prompted some utilities to install meters for those customers only. For instance, in Panama City, Panama, 3% of the consumers use about 43% of the total volume of water distributed; the smallest consumers representing more than 80% of all customers use about 18% of the water. In the city of Tunis, Tunisia, about 2% of all customers consume 43% of the water distributed; the smallest users accounting for 85% in numbers consume 33% of the volume distributed. In Bogotá, Colombia, 30% of the customers consume 70% of the water distributed.

Consumption distributions may vary widely between cities depending upon whether industrial consumers are connected to the public system or not. Although metering in most cases in worth the investment and operating costs, some form of cost-benefit analysis should be made before metering. The cost of meters and their subsequent readings and maintenance costs should be weighed against the savings from producing less water and from postponing additional works. The additional savings of not having to collect and treat the saved wastewater should also be counted among the benefits.

Further imponderable costs would be the consumers' marginal benefits of the water saved but these are probably balanced by the important additional information that good metering provides. The decision whether to meter or not has to be periodically reexamined. It may well be that it is economically justified to meter before a major capital expansion is undertaken and equally justified to let metering slip once a large investment program with low marginal production costs has been completed.

Impact of Educational Campaigns

At times, utilities undertake propaganda campaigns to induce the population to save water, or alternatively, to use more water. Such campaigns may be quite effective. In the face of a persistent and severe drought in 1976/77 in California, the San Francisco Water Utilities launched a campaign to reduce water consumption, coupled with penalties, which in less than a year reduced per capita consumption more than 25 percent. A similar campaign in 1969 in Sao Paulo, Brazil, lowered the daily per capita consumption from 215 to

160 liters, or by more than 25 percent. Campaigns with similar success have been reported after droughts in Japan in 1972 and in Dublin in 1974. These figures illustrate the potential value of educational campaigns to influence water consumption.

Impact of Other Factors

Some investment planners have assume that the removal of water rationing will lead to higher consumption once the improvements become operational. In the city of Palmira, Colombia, it was found, however, that the population living in areas with intermittent water service consumed the same amount of water as the population living in areas well serviced. The explanation is rather simple. Consumers living in areas with good service are free to draw water at hours of the day most convenient to them, while those living in areas with rationing have to draw water at inconvenient hours at night and then store it. The introduction of good service could thus merely display inconvenient drawing to convenient hours, and the quantity of water consumed remains the same. It has even been argued that in situations of unpredictable water rationing, the rationed population actually may consume more water than those well served. Perhaps the explanation is that rationed consumers store great volumes of water in advance, and then flush it away when the supply comes on from the public system.

Some water supply planners have also argued that high pressure in the distribution system would result in increased consumption. There is no conclusive pro or con evidence, though ligically high pressure may generate leaks in the distribution system and increase consumption. In one instance, in Bogotá, Colombia, substantially increased service pressures did not, however, result in any significant consumption increased.

Similar findings that pressure variations have little effect upon consumption have been reported from the Netherlands. Bearing in mind that nature of the Netherlands, it is likely that pressures are lower to start with, giving smaller opportunities for reduction.

In a report from South Africa covering experiments in Johannesburg, a very good relationship between pressure and consumption was observed. In this case, three successive weeks' supply pressure to a zone was varied and the resulting consumption curves plotted. Demand increased or decreased significantly with the pressure and followed the relationship.

$Q = kh^x$
Q = flow in m^3/hour
k = a constant depending on the characteristics of orifice
h = pressure head in metres
x = a constant for the particular orifice.

Pressure wa demonstrated to follow this curve and it was shown that a rise of 60% in pressure caused a 30% increase in consumption. Tests were also carried out by restricting garden watering to a limited number of hours morning and evening. This saved 20% on consumption at peak demand. A 33% reduction in pressure could have produced the same result.

It would thus seem hazardous to predict exactly how pressure variations will influence demand in view of the conflicting results from the studies in Colombia, the Netherlands, and South Africa.

FORECASTING METHODS IN THEORY AND IN PRACTICE

Water demand depends upon the number of population served, personal income and its distribution, education, housing density, tariff levels, tariff structure and progressivity, connection fees, percentage metered levels, and the composition of connections by categories. There are other variables, which probably can be assumed constant for a given city such as seasonal demand, rainfall patterns, water availability from other sources, and design of sanitary appliances. The best mathematical approach under these circumstances is probably a multiple non-linar regression.

What may be theoretically ideal may not be the projection method in practice. Data are often of such poor quality or simply not available that it is doubtful whether such multiple regressions will produce firm results. Instead the methods will have to focus on the main determinants of demand and try to build up a data base with the most significant variables.

Over the following pages three methods will be discussed. Two of these, the "requirements method" and the "extrapolation method" are routinely used. In view of their weaknesses a third explanatory method is proposed which relates demand to the investment program, particularly to the number of house connections.

I. The Requirements Method

Future urban water demand in a community may be estimated by multiplying its current per capita consumption by the population forecast for specific dates. This method which has been used for many years to predict future water use is simple but shortsighted. It can be refined by adjusting the per capita consumption to anticipated changes in water use, or by projecting the different classes of consumption separately. Many designers usually assume that per capita water use is vegetative and thus increases with time. However, the growth of per capita use observed say in Europe or in the United States may not automatically apply to other countries.

Two important observations should be made on the requirements method. At best it can be applied with precision only to cities whose entire current population is already supplied with service pipes. Secondly, it ignores all economic aspects of urban water and rather assumes that water usage is independent from the price of water. It should also be noted that since the planner views future demand as a fixed volume of water which is to be supplied, the economic analysis of a water scheme is simply confined to a technical determination of the least cost supply.

The requirements method cannot be used successfully for cities of developing countries, where only part of the population has piped water. In those cities the current per capita consumption is distorted by the partial usage made by the population not directly connected to the system. Those unserved draw water from standposts and from neighbours, and as the percentage of population with house connections increases, the average per connection consumption would tend to decrease, since the newly connected population would only make a marginal increase of usage. Moreover, since additional consumers are in the low income categories with less usage than current customers, the average per capita consumption should drop further.

A main weakness of the requirements method is that the two key variables, per capita consumption and population, are difficult to estimate for communities of developing countries. Population census data are often fragmentary and where they do exist, they may be unreliable, either inflated for political reasons or distorted by poor survey techniques.

The margins of error both for population and for service levels may be considerable. There are cases where as much as a fourth of the estimated population failed to materialize after a careful population census was conducted. On the service level side there are examples where the demand forecasts assumed 70% of the population to be served from the public system, whereas subsequent information proved 95% to be the case. These examples illustrate the risks involved in using population as a variable in demand projections. A more reliable proxy for population would be the number of houses in a city multiplied by an average surveyed number of occupants. The population served through house connections could be given by the ratio between the number of house connections and the total number of houses constructed.

Forecasting the Demand of the Urban Poor

The supply of water to the urban poor based on a public standpost system would appear to be one case where the requirements method is applicable for lack of better alternatives. Such systems are generally not metered and all the water planner can do is to estimate the population through a small census and then apply an average consumption per inhabitant and day of say 20 liters. This basic needs supply might be supplemented by educational campaigns. These could be aimed at the women who usually draw the water so as to build up public pressure to upgrade the standpost system into one based on individual service connections.

II. The Extrapolation Method

This method simply consists of projecting past consumption trends to forecast future water demand, assuming that the factors which have influenced the recorded demand, will continue to have the same effects in the future. Usually, annual demand is projected in relation to the population served. The projection can be made graphically or mathematically by least square methods. On semi-log papers, plotting the population served "x" on the arithmetic scale and water use "y" on the logarithmic scale, usually gives a straight line represented by an equation in the form of:

$$y = ae^{bx}$$

where "a" and "b" are constant and "e" the base of natural logarithms.

The weaknesses concerning unrelible population and water use data apply to the extrapolation method. In addition, the major criticism that could be fgormulated against this method is tat it involves no attempts to understand why consumption is rising or falling. The extrapolation method implicitly assumes that past population and consumption trends will continue. However, as indicated earlier, price increases and extended metering can considerably alter the current trends.

At times the extrapolation method is complemented by a comparison with cities in other countries, or in the same country to see whether there are similarities in demand growth between them and the city for which demand should be forecast. Such inter-city comparisons are often not valid since the cities are dissimilar.

III. Explanatory Method Linking Demand to Connection Levels

This method focuses on the prime importance of the distribution system, notably the individual service connections, to influence demand. The method is a combination of the two preceding methods and offers the advantage of linking demand to the investment program. Medium-term water demand is projected as a function of the number of service pipes or house connections.

An analysis of historical records of water utilities in developing countries shows that there is a very good correlation between demand "x" and number of connections "y", and that the two can be correlated through an analytic function in the form of:

$$y = Ax^C + L$$

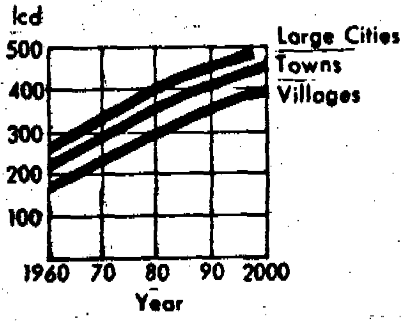
where A, C and L are constants. In general L is very small and can be neglected. The above equation when plotted in log scales is thus represented by a straight line which can be determined by the method of least square regression.

As in the case of the extrapolation method, the connection-related methods assume that past consumption trends will continue. However, while in the former the variates are not necessarily directly associated, the connection methods postulate mathematical functions which give the expected value of demand for a selected number of connections, (which the utility can control), and takes into account any effect that the price of water or charged consumer composition might have had in the past on consumption.

One of the limitations is that reliable historical data are needed to calculate the regression line. However, it is expected that as more empirical studies are undertaken for various cities and countries, it will be possible to establish typical values of the constants "A" and "C" for communities of comparable climatologic, economic and social conditions.

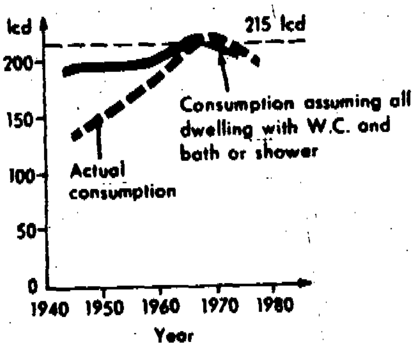
CASE STUDY SEVENTEEN - EFFECT OF TARIFF INCREASES IN SWEDEN

Background: In Sweden long-term projections for water demand projections were carried up to the year 2,000. Forecasts made assumed invariably rapid consumption increases such as illustrated in the figure below:



The projection shown was made in year 1965 and assumed the domestic consumption per capita to double between year 1960 and 2,000 and that the industrial consumption per capita would triple.

Analysis: The projections made in 1965 ignored the effect that price increases might have on consumption. The average tariff for water in 1976 was actually four times higher than in 1960, although only some 0.75 higher in constant money. What happened was also a saturation of water demand in each household since the sanitary standards could not rise much more. As a result of these two factors the per capita consumption actually peaked around 1970 and in some instances decreased continuously over some 10 years. The trend was noticeable both for domestic and for industrial consumption. The typical per capita domestic consumption in 1975 was around 205-225 lcd considerably lower than forecasts. The evolution of demand is shown below.



CASE STUDY EIGHTEEN - FORECAST OF WATER SALES IN TUNISIA

Background:

Volumes of potable water consumed in Tunisia have been recorded since 1958. However, these records are considered reliable only from 1966 after water meters were installed and a rigid water maintenance program was initiated. In 1966 water sales amounted to 52.1 million m^3 (Mm^3) with more than 55% of this volume for domestic usage. In that year about 40% of the urban population was served with service pipes resulting in a per capita annual consumption of 72.5 Mm^3. In 1966 some 720,000 people, most of them in Greater Tunis, were connected to the water supply systems.

In the years following 1966 the percentage of urban population with service pipes has been increasing rapidly. In 1975 about 1.6 million people or 62% of the urban population was connected to the networks. In that year 93.5 Mm^3 of potable water was consumed amounting to a per capita annual consumption of 56.8 Mm^3. The evolution of water sales in the last ten years is shown in the Table on the adjoining page. As can be seen in this table, the per capita consumption steadily decreased as the water supply systems reached increased percentages of the urban population. This decrease in the average consumption can be explained by the fact that low income consumers use less water than well-to-do customers. As the networks are generally first installed in high and medium income areas and are progressively extended into low income areas, the average per capita consumption would continue to decrease.

House Connections

The number of connections which were only 86,000 in 1966 also steadily increased to reach 242,000 in 1975, an increase of more than 181% over the 1966 level. During the same period, however, water sales increased by only 79% reflecting again the fact of higher population density and lower consumption in low income areas. The evolution of the connections is shown in the Table. The average annual consumption per connection continued to decline between 1966 and 1975. In 1966 it was about 606 m3; it decreased to 386 m3 in 1975. The average number of people served by each connection, which was about 8.4 in 1966 also declined to about 6.8 in 1975, reflecting the predominance of single-family dwellings in small lots in low income areas of the country.

During the period various tariff increases were implemented, which caused some reduction in demand. However, given the low percentage of urban population served, the assumed reduction is not believed to have had a great effect on the trend of water consumption observed between 1966 and 1975.

Analysis:

In forecasting water sales in the next 10 years it has been assumed that the percentage of urban population directly connected to the systems would increase from 62% in 1975 to about 83% in 1986. This would represent an overall increase of 21% similar to that accomplished between 1966 and 1975. Observing the past trend of water sales and population connected, a mathematical test of the historical data shows that if the population connected "x" is multiplied by a constant factor "A", water sales increased by the same factor raised at a constant power "n". The test also shows that the same property exists between the population connected and the number of connections, and between water sales and the number of connections. Observing further that for zero population connected, water sales and the number of connections should be nil, it becomes obvious that the relationships between the population connected, water sales and number of connections can be expressed by functions of the form $y = Ax^n$ which are represented by parabolic curves which, when plotted in log scales, are straight lines.

To predict future water sales, a mathematical model of water consumption vs population connected to the distribution network in Tunisia was developed. This model is expressed by the equation:

$$y = \frac{x^{0.66}}{1.44} \qquad (1)$$

where "x" is the population connected in thousands and "y" water sales in Mm^3/year. The constants "A" and "N" of the equation were determined by the method of least squares using the values observed for "x" and "y" between 1966 and 1975.

Similarly a mathematical model relating water sales to number of connections were derived from the observed data. This relationship is represented by the equation:

$$y = \frac{x^{2.11}}{58.4} \qquad (2)$$

where "x" represent water sales in Mm^3/year and "y" the number of connections in thousands. Both functions are graphically represented in the adjoining charts. As it can be observed on this graph, the correlation of the historical data is almost perfect.

Water sales can then be forecast for 1977 through 1985 by using the derived curves in chart 1. It is predicted that the sales would grow in the next decade at an average annual rate of 6%. This rate is projected assuming that 83% of the urban population would be connected to the systems by 1986. The growth would be slower if a lower percentage is to be reached by 1986. It should be noted that equations (1) and (2) are independent of time, and years are introduced in the Table only for estimating the number of house connections that the utility should execute every year to realize the predicted water sales.

Future Number of Connections

The relationship between population connected and number of connections in Tunisia is expressed by the equation:

$$y = \frac{x^{1.45}}{182.1} \quad \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_} (3)$$

where "x" is the population connected in thousands and "y" the number of connections in thousands. This relationship was derived following the same procedures used to develop the model for water sales. Equation (3) is graphically represented in chart 1. The predicted number of connections appears in the Table. Over the next five years it is expected that the number of connections will grow by about 36,000 until 1980, and then to 50,000 after that year.

The above equation give results which correlate remarkably. For instance, estimating the urban population connected to the network, equations (1) and (3) will give the expected water sales and number of connections. In a different approach, knowing the water sales, equation (2) will give the number of connections.

Trend of Per Capita Consumption

As stated earlier, as more consumers are being connected to the water network, the average per capita consumption would continue to decline. After the entire urban population is connected, the average per capita consumption will stabilize and probably start growing. The first evolution stage of the average per capita consumption "y" (in m3/year) may be related to the population connected "x" (in thousands) by an hyperbolic function in the form of $y = b + \frac{c}{x}$. Applying the method of least squares to the historical data, the above function is expressed in the form:

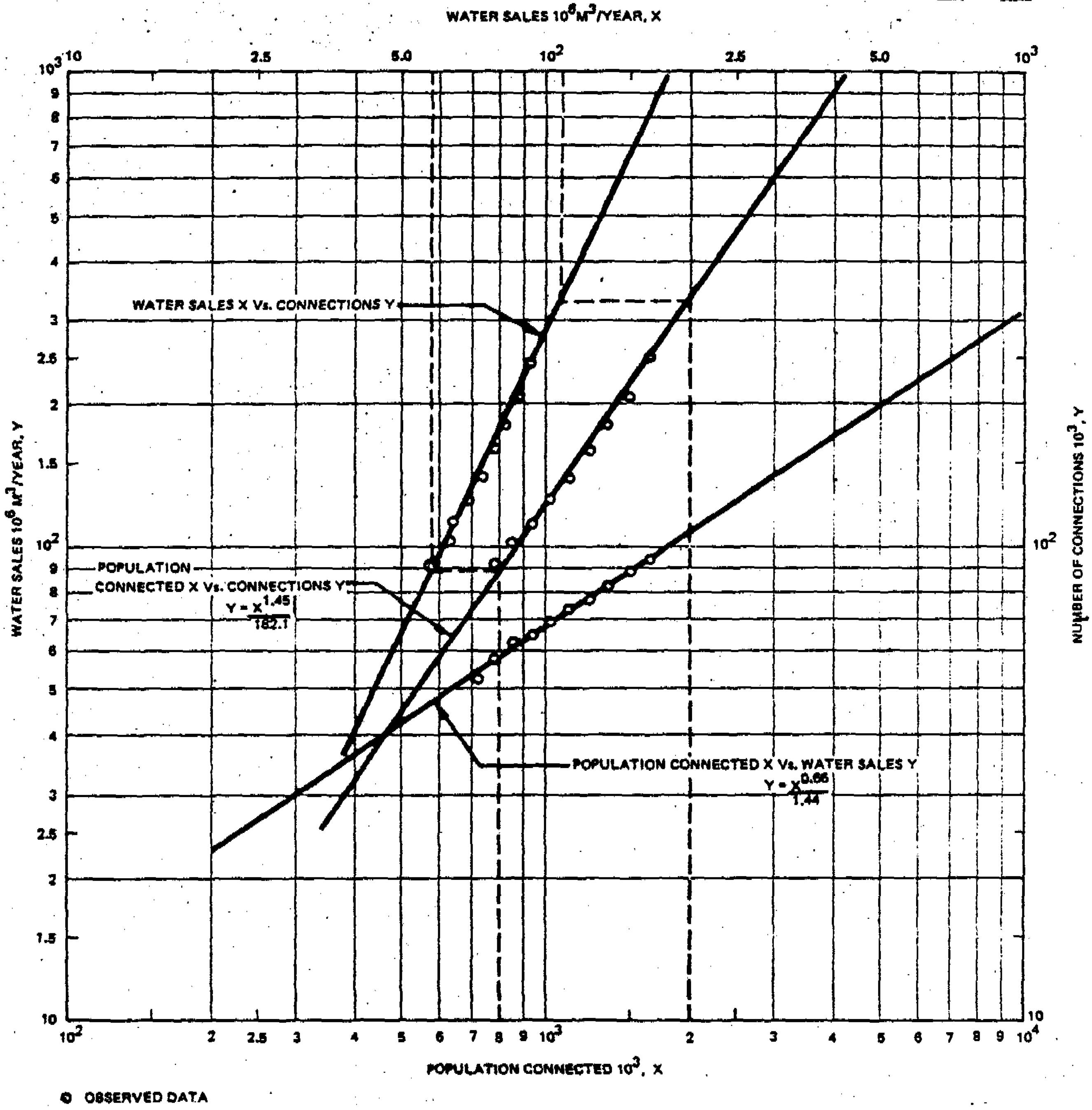
$$y = 39.7 + \frac{27.2}{x} \quad \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_} (4)$$

Equation (4) is represented graphically in Chart 2. It becomes a straight line when consumption "y" is plotted against the reciprocals (1/x) of the populations connected, using arithmetic scales for both variables. As the percentage of urban population connected to the water systems keeps increasing, the average per capita consumption tends towards a minimum value of 110 liters/day which is considered realistic.

TUNISIA

GRADIENT OF WATER CONSUMPTION

CHART 1

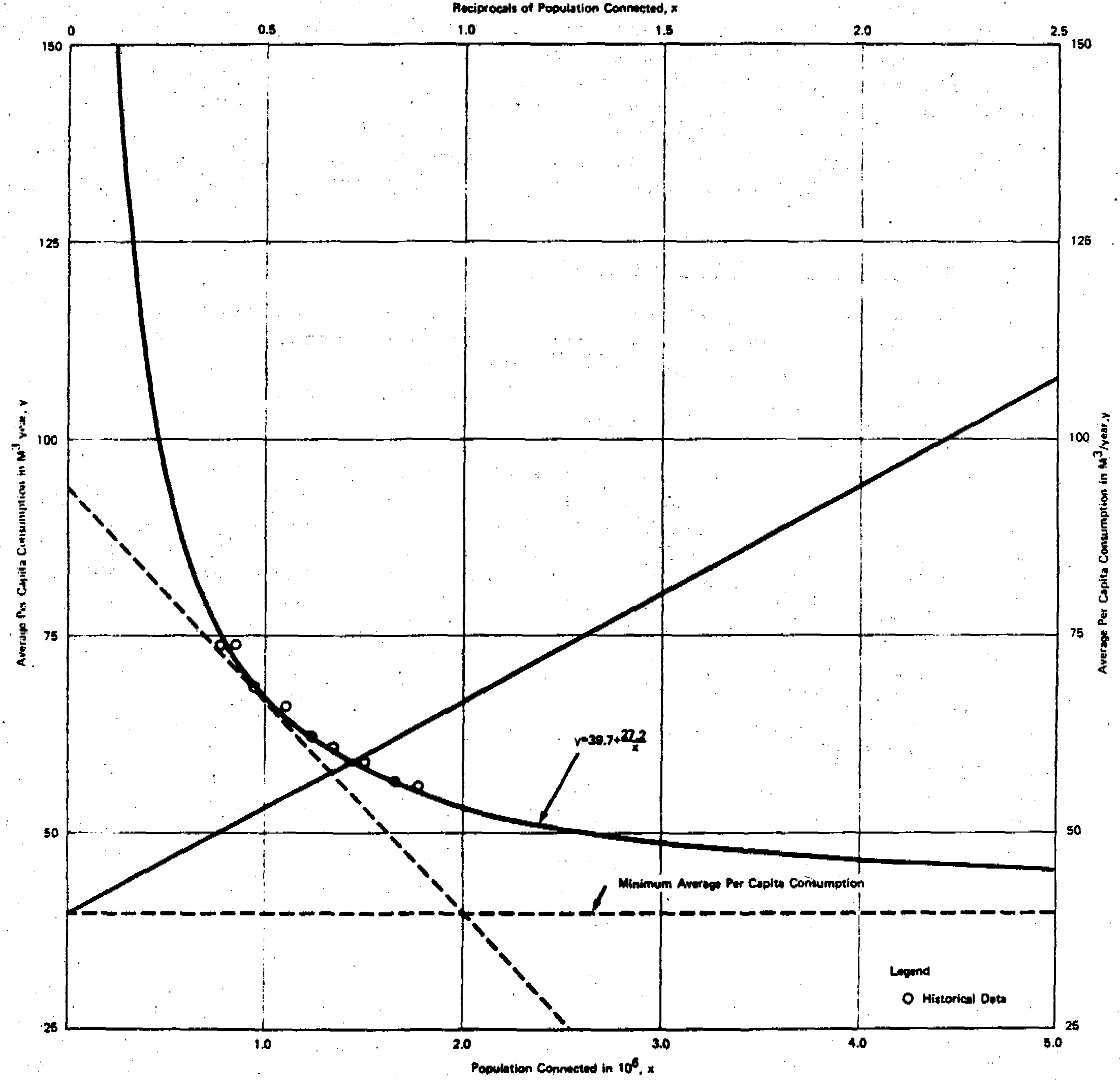


May 1977

TUNISIA

TREND OF AVERAGE PER CAPITA CONSUMPTION

CHART 2



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LEAST-COST ANALYSIS

The principle for least-cost analysis is to plan and execute investments to minimize the sum of discounted capital and current costs given a set of qualitative and quantitative objectives. In practice, the analysis becomes more complicated and requires considerable experience to decide upon standards of reliability and quality. The proper balance between desirable standards and economy can sometimes be determined rigorously but more typically subjective decisions based on experience are necessary. The seasoned design engineer employs short-cuts that probably result close to the optimum and deviates from standard design whenever special circumstances motivate it. If there is anything that characterizes a good design engineer it is probably his ability to see what is singular in each system and on this basis squeeze extra capacity out of existing installations.

Timing and Scale of Capacity Additions

There are two main variables that influence the cost of capacity additions. One is the timing of the investment, i.e. the year of construction, and the other is the scale, i.e. the size of the increment. As was mentioned under the section on demand analysis the proper timing of investments is far more significant than the scale to influence costs. It was shown that building works designed for 8 years three years too early meant cost increases of some 25% whereas building for 11 years of demand instead of the optimal 8 meant cost increases of some 2% only. It follows that the short-term projection is more important than the long-term projection. The conventional wisdom of this would be, stated somewhat imprecisely: "Try to delay a capacity increase as long as possible, but once initiated it should be built fast and big".

Unfortunately, postponing investments to save money makes planning a more risky undertaking since holding off too long can mean the difference between a year of rationing and one of satisfactory supply. Of course, it could be argued that rationing can be avoided by public savings campaigns but in the eyes of many water planners such measures amount to an acknowledgement that planning was erroneous. This attitude is understandable, and at the same time shows the insufficient incentives for imaginative water planning in order to economize. The rewards for economical and punishment for overly generous investment planning bear no relations.

In either case, the investment planner must have a clear idea what factor it is that triggers the need for capacity additions. The bottle-neck analysis discussed under the section on project identification is most relevant for investment planning. Whenever supply fails to keep up with demand it should be clear whether it is because too little water is produced, or whether too much water is lost in a leaky distribution system, or whether the reservoir volume is insufficient to absorb demand fluctuations and so on.

Different Types of Demand

A more detailed analysis of demand soon reveals several kinds of demand relevant for the design. There is of course the average annual demand which is what is forecast in ordinary demand analysis. Then there is another kind, that of the maximum day during the year, which is higher than average annual demand. This maxday demand can be caused by the living habits of the population during the week, but also compounded by seasonal variations brought about by temperature and rainfall variations from month to month. Finally, demand fluctuates from hour to hour during the day, and there is a peak hour demand corresponding in general to the beginning of the daily activities.

The system has to be designed to meet demand during each hour on each day of the year. Since the peak hourly demand may be up to 100% above the average annual demand it follows that during a majority of hours during the year there will be considerable excess capacity in the different components in the system. To economize one should design certain components for the peak hour demand, others for the maxday, and others still for the average annual demand. Exactly which demand will be applicable to each component is a matter of least-cost analysis. Design praxis may vary slightly between countries. The table below gives the US practice and the approximate shares of total investments affected by each type of demand:

ALLOCATION OF PLAN FACILITIES BY COSTS AND DESIGN HORIZON

Facility	Design Horizon	Part of Total Cost %
Distribution Main	Peak hour	7
Distribution storage and booster pumping	Peak hour	27
Transmission Mains	Maximum Day	31
Pumping	Maximum Day	14
Treatment	Maximum Day	4
Source (reservoir)	Annual Use (based on safe yield)	8
Unassignable		9

The table shows that some 35% of the representative project costs are related to peak hour demand, another 50% to maximum day demand, only some 8% to average annual demand whether the remaining 9% is unassignable. Although the proportions will vary between countries the general conclusion still holds that if demand could be smoothed out some components of the system could have their additions postponed and a higher overall utilization would result.

Demand-Controlling Investments

The natural reaction to a situation where demand threatens to outstrip supply should be to reduce demand since this may frequently be the most economical way of matching supply and demand. At times, simple administrative measures such as modifying the tariff structure or raising the average tariff level are sufficient to delay system additions for a few years. Such measures cost next to nothing to implement.

On other occasions, demand may be depressed by introducing or improving metering and/or reduce leaks in the network. Such programs will have a price but they will invariably be cheaper than alternatives to boost supply. Exceptions might be cities located above vast groundwater reservoirs with very inexpensive water, or cities adjacent to large natural surface water reservoirs which can provide water so cheaply as to make supply increases competitive with demand control. Even so, the decision taken should be based upon cost/benefit analysis and the maxim "small is beautiful" applies here too. This is especially true if the costs of disposing of waters after their use are taken into account.

Where project works are accompanied by clearly quantifiable benefits the least-cost analysis has to be broadened to account for project benefits. When the project planner attempts to postpone works in order to lower discounted costs he will also be lowering the present-value benefits. In these cases an optimal point of construction will have to be determined that maximizes net benefits, or minimizes net costs in case all benefits cannot be quantified.

Supply-Increasing Investments

Sooner or later capacity additions cannot be postponed any longer and the project analyst will face the problem for how many years he should design the works and which standards he should build for. The appropriate design periods have been the subject of much analysis and the useful theory will be presented in later sections, and accompanied by several illustrative case studies. Apart frome exercises in least-cost design a number of case studies will be discussed on optimal design periods given different economy-of-scale factors. It should be stressed that the results obtained are strictly valid only in the situations analyzed and cannot be automatically transferred elsewhere. What is necessary in each country and in each time period is to determine empirically investment cost functions on which least-cost analysis can be conducted given a set of cost functions.

Appropriate Quality Standards

Deciding upon which quality standards to follow is a more complex matter. Undoubtedly, designing for lower standards means lower investment and operating costs but also lower benefits. An analogous situation is facing any consumer. He can drive an inexpensive car which will give him good value for his money, or he can drive a very expensive car which will give him more pleasure, comfort, and prestige. In water supply where benefits cannot be quantified with certainty discussions on which standards to follow will at times degenerate into statements of the kind "you get what you pay for" or "you pay less, and you get less".

In the face of limited or absent information on benefits the most sensible approach may be to make the most of the pricing tool and set tariffs that fully recover costs. Rational consumers may then signal to the planner via their consumption how much they want in terms of quality. In cases where large segments of the population are subsidized care has to be taken and lower standards set initially. Such lower standards do not mean providing unsafe water, but could mean water of lower esthetic standards. What is important to stress is that anyone who refuses to design with any other standards than the very best in the full knowledge that financial restrictions will not permit the entire population to be served during the foresseable future is simply not facing the facts. In situations like these, it is useful to see how much each marginal improvement of the water quality costs, and relate the added price to the number of unserved families that could be connected. Such cost-effectiveness studies may be very useful to curtail extravagant standards. At times it may be the population itself that clamors for "only the best". Typically, such calls are the loudest where water is subsidized or where the petitioners themselves are not faced with the difficult task of recuperating investments.

Further on Optimal Timing and Scale of Water Investments

The technical solution that is optimal from the economic point-of-view is the one that minimizes the present-value sum of investment and operating costs over the analyzed period. The condition can be written in shorthand form:

$$\text{minimum} \quad \sum_{j=1}^{n} \frac{I_j + O_j}{(1 + r)^j}$$

where n = the number of years
r = discount rate
I_j = investment cost in year "j"
O_j = operating cost in year "j"

In case there are quantifiable benefits in certain years they should be included as offsetting terms in the respective years. This is in accordance with the more general criterion which is to maximize net benefits but, since water supply benefits cannot be related to investments, the problem becomes one of cost minimization instead.

The simple cost formula is useful and widely used. For instance, an investment planner will often try to stage investments to lower the present value cost and ease the financial strain. The formula will tell him by how much the present-value sum decreases.

Another common application is when deciding between one technical solution with initial high investment costs but subsequent lower operating costs, and another solution with low initial investment costs and subsequent higher operating costs. This is the classical choice between a gravity water supply and a groundwater system with pumping costs. The least-cost formula will indicate which system to select. In both cases it may at times pay to choose the slightly more expensive solution provided that the financial outlay is less. Such a choice is more natural if the quality of data is poor and there is uncertainty how fast demand will grow. It is then better to err by postponing the costliest investments and instead build a slightly more expensive and flexible system.

A third common application of the least-cost formula is when pipe diameters are selected in a system with pumping. A larger diameter pipe will cost more initially but require less pumping and may be economical. A similar application is when in the first stage of a transmission line the system is operated with simple pumping or even by gravity, and in the second stage booster pumping is added to boost the capacity of the line.

When calculating the present-value sums with the formula it is advisable to express all amounts in constant money since purely inflationary effects have no economic effect and obscure the calculations.

On Optimal Scale

Once the year for a capacity extension has been fixed, it is necessary to decide by how much the increase should be. The decision is complicated by the existence of economies of scale for water supply facilities where average costs are falling the larger the scale. There are several circumstances to postulate such falling average costs. Fixed start-up costs and design will vary little with the size of the addition. Because of the efficiencies of scale it will pay off to design and construct works for a number of years instead of having a continuous construction process. The latter would be economically optimal if there were no scale economies since it would imply that there would be a minimum of idle capacity. What puts an upper limit to building for the future is the fact that the investment costs are incurred early and consequently weigh heavily. If one were to stage works, the later extension would be discounted more and add relatively less to the sum of present-value costs.

The theory on how to determine analytically the optimal scale has been elaborated by several authors. The most prevalent models assume that demand increases linearly over time, i.e. by constant amounts each year. Although demand is often assumed to increase geometrically, i.e. by a fixed percentage each year, the assumption of linear increase may be more realistic in situations where demand growth is controlled by a combination of metering, tariff increases and leak control. The exposition below will closely follow the analytical deductions by Lauria et al:

Assuming that demand increases linearly over time and that initially supply matches demand at least, and that the design period is "x" years the demand and supply growth would be as shown in figure below:

FIGURE I. EXPANSION MODEL WITHOUT DEFICITS

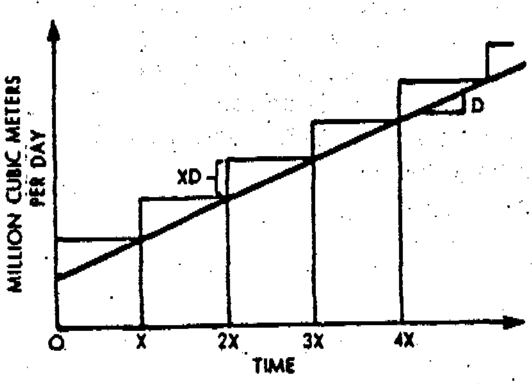


FIGURE 1. EXPANSION MODEL WITHOUT DEFICITS

Year x is the next point of zero excess capacity; by then, demand will have grown equal to capacity. With conditions then essentially identical to those at time zero (i.e., demand increasing linearly to an infinite time horizon and construction costs and the discount rate unchanged), another expansion of scale xD with cost C (xD) is required. Repeating this pattern for each point of zero excess capacity, the following expression of total present value construction cost for the infinite planning horizon can be written

$$C(xD)\left[\sum_{t=0}^{\infty} \exp(-rtx)\right] \qquad (1)$$

where exp(-rtx) is the discount operator for the year tx and r is the (continuous) annual discount rate expressed as a decimal.

The term in brackets in Eq. 1 is the sum of a geometric progression which has the following value

$$\sum_{t=0}^{\infty} \exp(-rtx) = 1/\ 1-\exp(-rx) \qquad (2)$$

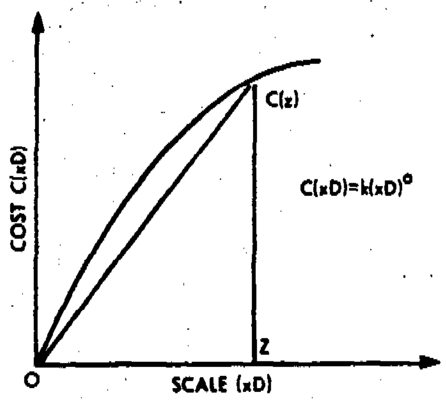
In the water engineering field, the expansion cost in Eq. 1 commonly is a concave power function of the form shown in Figure 2, with mathematical expression.

$$C(xD) = k(xD)^a, \qquad (3)$$

where k is a constant indicating the cost of a system for which $xD = 1$ and "a" is a proper fraction called the economy of scale factor, which indicates the percentage change in cost per percent change in scale, or equivalently, the ratio of marginal to average cost. Note in Figure 2 that the slope of line segment 0-C(z) is the average cost of a system of scale z.

FIGURE 2. POWER COST FUNCTION

FIGURE 2. POWER COST FUNCTION



As scale increases, average cost decreases, which is the condition that obtains when economies of scale exist. Substituting Eqs. 2 and 3 into Eq. 1 results in Eq. 4, an expression of total present value cost in terms of excess capacity period x (the decision variable) and parameters k, D and a

$$\frac{k(xD)^a}{1-\exp(-rx)} \qquad (4)$$

To find the optimal design period x*, that is, the value of x which minimizes total present value cost, the derivative of Eq. 4 with respect to x is set equal to zero; the resulting optimality condition is

$$a = \frac{rx^*}{\exp(rx^*)-1} \qquad (5)$$

The optimality condition shows that x* is dependent upon the scale factor "a" and the discount rate "r". The optimal design period cannot be explicitly solved from Eq. 5 and a more useful approximation, developed with linear regression techniques is

$$x^* = \frac{2.6(1-a)^{1.12}}{r} \qquad (6)$$

From Eq. 6 the optimal design period can be easily solved an the table below has been calculated on this basis:

OPTIMAL DESIGN PERIOD IN YEARS AS A FUNCTION OF DISCOUNT RATES AND EFFICIENCY OF SCALE FACTORS

Discount Rate, r	Scale Factor, a				
	0.5	0.6	0.7	0.8	0.9
0.05	25	19	14	9	4
0.10	12	9	7	4	2
0.15	8	6	5	3	1
0.20	6	5	3	2	1

The optimal design periods in the table are unrealistic in one respect: they assume instantaneous construction. In reality one has to plan construction well in advance, and the construction itself may take three years for works of medium complexity. Accordingly, any optimum period shorter than the relevant construction period is obviously out of the question. With this qualification the table entries are useful for guidance in cases with no initial supply deficit. The general trend of the values is as could be expected. The higher the discount rate, the shorter should be the design period, other things being equal. Similarly, the lower the scale factor, i.e. the more significant the efficiencies of scale, the longer should be the design period, other things being equal, since one obtains the marginal capacity units comparatively cheaper.

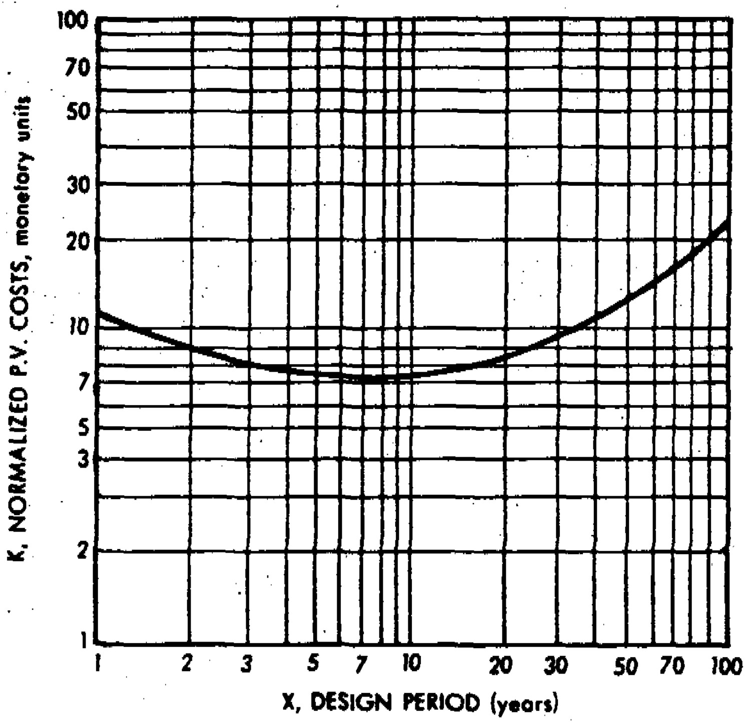
The table assumes constant values being employed in the calculations and a common discount rate used would then be 10%. The table shows por instance, that with a scale factor of. 0.7 one should optimally design for 7 years of demand growth, i.e. there would be excess capacity during a seven-year period.

PENALTIES WHEN DEVIATING FROM THE OPTIMAL DESIGN PERIOD

At times it may be necessary to deviate from the optimal design period, for instance when financial reasons dictate shorter periods. Another situation may be when demand growth is not correctly estimated. In both cases it would be of interest to see *what the cost penalty is from choosing too short or too long a* design period. The answer to this type of questions follows from Eq. 4 and can also be tabulated or represented in graphic form. One such curve showing the total present-value costs vs. design period is represented below. The assumed discount rate is 10% and the economy-of-scale factor is 0.65.

FIGURE TOTAL PRESENT-VALUE COSTS VS. DESIGN PERIOD

FIGURE Total Present-Value Costs vs. Design Period



What is most striking about the total present-value cost curve is its flatness. The optimal design period is 8.1 years for $r = 0.10$ and $a = 0.65$, and the total present-value of an infinite number of investments is then 7.0 monetary units, since the cost is normalized. A total present-value cost of 8, or around 10% more corresponds to either a design period of 4 years or one of 16 years. This is equivalent to saying that for all design periods between these two extremes the cost penalty will be within 10% of the minimum present value sum. One has thus the liberty at relatively insignificant cost penalties to select the design period with other considerations in mind. For instance, one might want to shorten it to ease the financial pressure, or lenghten it if one fears that it will be many years before financing and administrative approval will be obtained for another investment program. The earlier references to the lesser importance of estimating long-term demand correctly are relevant, and also what was said about the short-term projection to determine the timing of investments.

Optimality Conditions Assuming Initial Supply Deficits

The previous model is for expansions only. A common problem, however, is the design of facilities for which there is outstanding demand. This situation often arises when users switch from an existing supply facilities to an entirely new one, or when demands exceed system capacity causing a supply deficit. The installation of treatment plants for housing developments formerly served by individual septic tanks is an example. Others include the construction of water and wastewater systems for new towns and the abandonment of local systems in favor of regional facilities. In developing countries where few communities have public water systems, essentially all such planning falls within the general assumptions of this model.

The initial deficit model retains the previous assumptions but in addition assumes that Do/, the rate of demand at time zero, is unsatisfied as shown in Figure 3. The project to be constructed now will have excess capacity for x_1 years at the end of which time a planning situation identical to that described above (i.e., with equally sized expansions) will be encountered. The planning problem is to determine the optimal value of the initial design period x^*_1.

An expression is written for total present value cost which includes initial construction (the first term in Eq. 7 below) plus the present value cost of an infinite number of future expansions discounted from year x_1 to time zero. The resulting objective function is

$$k(D_o + x_1 D)^a + \exp(-rx_1) \left[\frac{k(xD)a}{1-\exp(-rx)} \right]$$

in which x_oD may be substituted for D_o, where x_o is the hypothetical elapsed period (in years) from the time of zero demand (or zero excess capacity) to the present, assuming demand was increased at rate D as shown in Figure 3.

FIGURE 3. MODEL FOR INITIAL CONSTRUCTION AND EXPANSION

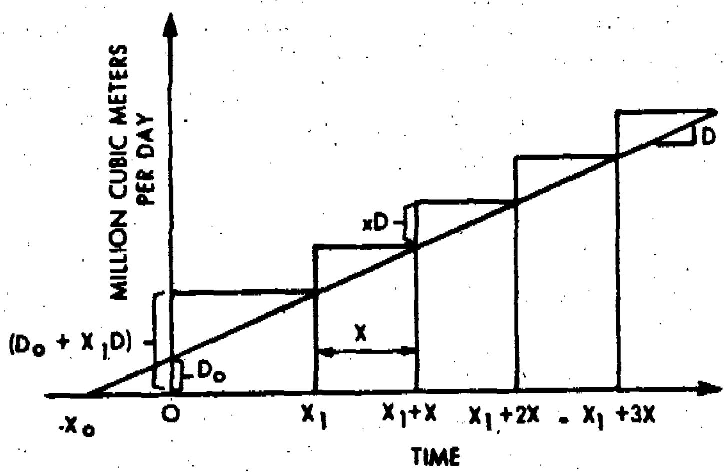


FIGURE 3. MODEL FOR INITIAL CONSTRUCTION AND EXPANSION

In this model, the two decision variables are x_1 and x. The optimal value of x, the design period for expansions, is found from the derivative of Eq. 7 with respect to x set equal to zero. As expected, the optimality expression is identical to Eq. 5, for which approximating Eq. 6 can be used. The optimal value for x_1, the excess capacity period of initial construction, results from the derivative of Eq. 7 with respect to x_1 set equal to zero:

$$Da\left[k(D_{o}+x^*_1D)^{a-1}\right] = \exp(-rx^*_1)\cdot\frac{\left[r\,k(xD)^a\right]}{1-\exp(-rx)} \qquad (8)$$

This equation can be interpreted as follows: The expression $k(D_o+x^*_1D)^{a-1}$, the average cost of the optimally scaled project, when multiplied by the economy of scale factor a, gives the marginal cost of construction at the optimal scale $D_o+x^*_1D$. Multiplying by D, the annual rate of demand increase, results in the approximate marginal cost of providing an extra year's capacity in the initial project.

On the right-hand size, $r\ k(xD)^a$ is the annual interest or capital opportunity cost for any future expansion. The denominator $(1-\exp(-rx))$ is the present worth factor for the infinite series of annual expansion opportunity costs incurred every x years starting in year x_1. These costs are discounted to year zero by the term $\exp(-rx^*_1)$. Hence, Eq. 8 states that the initial project is optimally scaled when the marginal cost of providing an extra year's capacity is equal to the present value of the annual opportunity costs of capital for all expansions. Alternatively stated, the initial project should be scaled so that its cost is approximately equal to the difference between the cost of a project with an extra year's capacity and the present value opportunity cost of capital for all future expansions. The optimality condition of Eq. 8 can be simplified by replacing D_o with x_oD and eliminating k and D from both sides to obtain

$$a(x_o + x^*_1)^{a-1} = \exp(-rx^*_1)\left[\frac{rx^a}{1-\exp(-rx)}\right] \qquad (9)$$

Clearly, Eq. 9 shows that x^*_1 is a function of r, a, x_o and x, but x itself (or more exactly, the optimal value of x) depends on r and a and can be replaced in Eq. 9 by values from Eqs. 5 or 6. Hence, the model shows that the optimal design period for initial construction x^*_1 is a function of the annual discount rate, r, of the scale factor, a, and the elapsed time period to zero excess capacity, x_o. The optimal design period, x^*_1 cannot be solved explicitly but the relationship can be approximated at a relatively small loss in accuracy, by the expression

$$x_1^* = x + \left(\frac{1-a}{r}\right)^{0.7} + \frac{x_o^{0.9}}{(x_o+x)^{0.6}} \quad \text{where } x_o = \frac{Do}{D} \text{ and x is obtained from Eq. 6}$$

By assigning different values to x_o, a, and r the optimal design period x_1^* can be calculated. The table below shows such values related to the most common values of a and r and with x_o equal to 10 years. In other words it is assumed one first has to build to supply an initial deficit of 10 years demand, and then provide excess capacity for future demand growth.

OPTIMAL DESIGN PERIODS WITH 10 YEARS INITIAL SUPPLY DEFICIT

Discount Rate, r	Scale Factor, a				
	0.5	0.6	0.7	0.8	0.9
0.05	30	24	18	12	7
0.10	16	13	10	7	4
0.15	12	9	7	5	3
0.20	9	7	6	4	2

The same caveats as to the minimum practical design periods hold and consequently the very short design periods below three years are not practical.

A comparison between the optimal design periods in the case of no initial supply deficit with those in the table above, corresponding to a 10-year initial supply deficit, shows that the latter are longer, other things being equal. This is hardly surprising. First one has to build an installation to satisfy immediately 10 years demand growth and consequently the additional capacity benefits from lower marginal investment costs than in the case of no initial supply deficit.

As a matter of fact, in the case of a 10% discount rate and with a scale factor of 0.5 the optimal period with excess capacity would be 16 years which is not too far off from 20 years which is a common design period in developing countries. A period of 20 years may seem excessive at first sight but with the background of initial backlogs of unsatisfied demand and difficulties to organize investments, the praxis may not be too far off from the optimum after all. Again, the total present-value cost function is relatively flat and variations in the design period imply relatively small cost penalties. Consequently, if for financial reasons one does not want to build much excess capacity into the system, the loss in economic efficiency would be relatively small.

The fact that common design periods practiced in developed countries may not be too far off the optimum for components with substantial efficiencies of scale is largely coincidental and should not lead to the conclusion that existing practices are acceptable. Neither is it satisfactory to choose the practice in more developed countries, such as the United States, as guidance. There conditions can be much different and investment analysis is not always of superior quality.

What is needed, however, are empirical studies to determine what are the relevant scale factors for different kinds of works in each particular country and then, guided by the relevant discount rates, deduce what the optimal design periods are. The latter should be of general guidance only and it should be clear that deviations are permissible where financial and local conditions so warrant.

CASE STUDY NINETEEN - DEPRESSING DEMAND TO POSTPONE INVESTMENTS

Background: A city in the Western Hemisphere will have to augment its supplies in the near future since existing sources will become insufficient. All known sources close to the city, which is situated in an arid region, are already fully utilized and consultants have proposed the construction of a 200 km long pipeline to bring water from another basin through a series of pumping station that will lift the water some 1,200 meters. The cost of this water will be some ten times what the population is presently paying and efforts are made to delay the costly works by way of controlling demand.

Analysis: In order to defer the large and expensive works it is decided to institute measures in three areas so as to make consumers use water more economically. The steps include, primo, streamlining metering and routines for billings and collections; secundo, leak-detection studies; and tertio, raising tariff to signal the future higher production costs to the population. In addition, other solutions such as recycling of sewage after treatment, and interception of rainwater are contemplated but are considered too speculative given hydrological data.

The Metering Programme

Before improving the metering there is a need to know exactly who are the consumers in the system and it is decided to undertake a connection census. This is long overdue as evidenced by the fact that the property tax registry includes some 60,000 constructed lots but the water company lists only 23,000 individual service connections. At the same time the company claims it is serving some 75% of the urban area population with water which would imply some 45,000 connections assuming there is a good relation between population served and houses connected.

The connection census is conducted by students walking the city from house to house. Information is collected on the existence and state of water and sewerage connections, the number of inhabitants in each house, and the existence and condition of water meters. The census produces rather interesting results. It is found that around 11% of the total number of dwellings are served through clandestine connections that are obviously un-metered. The company loses the revenue corresponding to the water, and in additon the unregistered consumption is more wasteful on average. It is decided as a first step to incorporate these illegal connections and meter them. Apart from more economical consumption, the company's financial situation is improved since the illegal consumers are fined and obliged to pay connection fees.

As a by-product of the census it is accurately determined how many of the houses that are connected (some 90%) and what population receives water through house connections. These data are useful for further demand forecasts and for investment planning. A rough idea how the unconnected population gets its water is also obtained.

The following step is the planning and installation of water meters to make coverage complete. The already installed 15,000 meters proved to be partly inoperative and consequently need replacement and repair. In addition to installing new meters, a repair programme is intensified backed up by improvements in the meter repair shop. The large-scale procurement of new water meters enables standardizing the installed meters, up till now of many different makes. As an interesting detail, it is decided to paint the meters installed in color distinctive to the year of installation so as to provide rapid statistics in the future of their average useful life before reparations.

On the administrative side, meter reading routes are modified to increase the productivity of meter readers, and a system of rotating readers between different parts of the city is instituted so as to make collusion between meter readers and consumers more difficult. It is decided to read meters bi-monthly but bill consumers monthly so as to minimize the credit that the company is extending and make consumers aware of their consumption levels. To the same end, bills have to be paid within 30 days upon their receipt, and failure to do so leads to discontinued service within another 30 days.

Leak-Detection Programme

There is a multitude of leak-detection methods available, such as acoustic sytems, other based on comparisons between day and night flows for separate areas, combined with master meters, use of radio-active tracers and so on. In the case discussed, it is decided before embarking upon a leak detection programme that billings and collections routines should be tested. As a result it is discovered that some 20% of the connections are exempt from payment and many of them do not even have meters installed. Consequently, meters are installed in most of these and a majority of them are gradually incorporated in the billings.

Further, production meters are installed for the first time both at the surface water system and at the well-heads. It emerges that in the past production has been systematically over-estimated. The combined results of correcting for exaggerated production figures, incorporating clandestine connections, and controlling consumption in previously payments-exempt connections show that of total water production a maximum of 15% is lost through leaks. Most water unaccounted-for in the past can thus be shown to have been consumed. Under the circumstances, since 15% is an acceptable level for losses, it is decided to postpone the leak-detection study until the full effect of metering and tariff increases is known. The combined measures of better administrative control and metering makes it possible to account for almost 85% of water produced, and some 80% of water produced is billed.

Tariff Increase

The third step is to increase tariffs for large consumers to levels approaching the costs of the future surface-water scheme. In order to avoid overwhelming public opposition, the tariff is increased in small steps each month. The public's support for savings measures, including the tariff increases, are enlisted by means of education campaigns in schools and on television and radio, where it is explained that water has to be saved in anticipation of the more expensive water. A particular target group of the campaign is the low-income population to demonstrate that the savings will directly alleviate previous widespread rationing.

Net Effect of Savings

As a consequence of the different measures the expensive works are postponed more than two years. Given the total cost of the works of 70 million monetary units and the investment profile, the monetary savings are some 20 million monetary units. Part of available investments funds are used to accelerate distribution works so as to use saved water for consumption and enable a faster utilization of the large scheme once commissioned. The financial effects are noticeable in the form of a larger cash-flow, caused by better control over water billed and higher tariffs. Administratively, the utility is much improved since meter reading, billings and collections routines are all modernized with higher staff productivity as a sequel.

CASE STUDY TWENTY - COST-EFFECTIVENESS OF METER PROGRAMS

Background: A large metropolis will be rationing water within some five years unless there is a better balance between supply and demand. Detailed plans have been prepared to bring in water from adjacent basins but at very high costs. The cheapest of such outside schemes is estimated to cost around 30 million monetary units per m^3 of water brought in per second, and operating costs will be considerable. Furthermore, it has been argued that basing the city's water supply on water from outside areas is risky, since there may be conflicts in a future with outside populations over water rights. It is decided to investigate whether water can be used more economically within the city itself, and whether metering to curtail wastage is cheaper than bulk-water schemes.

Analysis: The scope for reducing consumption through metering and higher tariffs is first explored. On average the metropolis is drawing around 490 lcd. Part is accounted by industrial demands and losses, but the average domestic consumption is a high 360 lcd. Such high per capita consumptions are probably explained by the low meter coverage affecting fewer than 30% of all consumers. Even where there is metering, readings, billings, and collections are hap-hazard with the consequence that consumers consume water with little or no regard to its cost.

Installing water meters could be expected to reduce consumption levels substantially. Other cities introducing metering for the first time have reported saving an average 40%. The very largest consumers in the city are already being metered and it is estimated that a more realistic figure for expected drops in consumption levels might be around 17%.

With average consumption levels in the order of 360 lcd a reduction of 17% would be equivalent to each person consuming 62 lcd less. Since there is an estimated 7 persons per connections, and assuming that 15% of the bulk-water is lost en route and another 10% in the distribution system, the number of meters necessary to save 1 m^3/sec of bulwater would be given by the expression:

$$X = \frac{1{,}000 \times 86{,}400 \times 0.85 \times 0.90}{7 \times 62}$$

$$X = 150{,}000$$

Each of these meters requires a meter box and associated fittings, and will in large quantities cost some 20 monetary units installed. Velocity meters are chosen in preference to volumetric meters since the important matter is to make the population cognizant that each additional cubic meter consumed has a price. The main aim is to create a psychological effect and whether the meter has a margin of error of 5 or 1% is less of a concern.

Given the average cost of a meter of 20 monetary units, the total cost of saving one cubic meter per second of bulk-water by way of installing meters is some 3 million monetary units, or around 10% of the cost of the cheapest bulk-water scheme. There are estimated needs for installing around one million water meters to save in the vicinity of $7m^3$/sec to postpone the costly scheme several years.

At the same time it is recognized that a metering programme entails much more than merely installing water meters. A large-scale administrative programme to modernize meter readings, meter repairs, billings and collections is required and at least selective connection censuses will be needed to detect clandestine connections. Although the purported distribution losses are a "good" 10% these may be underestimated, and a leak detection programme might become necessary.

CASE STUDY TWENTY ONE - CONTROLLING GROUND-WATER EXTRACTION

Background: A large city in the Western Hemisphere has reached the capacity of its water supply system and new sources will be needed. One bulk-water scheme has been designed to bring some $16m^3$/sec from an outside basin at a cost of around 180 million monetary units, excluding operating costs. Before launching this costly project efforts are made to check demand growth and delay the large scheme. Based on available production statistics, the quality of which are in doubt, the city is presently being supplied with $13m^3$/sec and in addition an unknown amount comes from private wells drilled into the underlying aquifer. According to consumption statistics, only around $5m^3$/sec are consumed by the water company's clients implying that some 60% of the produced water is unaccounted-for, i.e. the utility does not know where it goes.

Analysis: Before suggesting what might be tried to check consumption it is necessary to find out how much the city is consuming. The total quantity supplied divided by the total population reveals a total per capita supply of 300 lcd, excluding the unknown quantity from private wells. Together this supply should be sufficient to satisfy needs for years to come even if the entire population were connected. The city need not go to outside sources to fetch water but should instead learn how to use its nearby resources wisely.

One obvious investment area would be a metering program, preceded by a careful connection census and followed by modernized readings, billings and collections routines. Further, tariff increases should be contemplated to signal consumers that unless consumption is restrained they will have to bear the burden of bringing water from outside basins at sharply higher costs.

Parallel with the measures above, efforts should be made to bring the uncontrolled groundwater extraction under the jurisdiction of the water company. It is known there are at least one thousand wells producing water for agricultural, industrial and domestic consumption. For planning purposes, the rates of extraction should be gauged. This might be achieved by monitoring a sample of wells and then generalize to the total number of wells. As a minimum, a well census is imperative to prepare for future licensing and control of groundwater extraction.

There is a second method to roughly estimate groundwater extraction. It consists of comparing the city's distribution of consumers and their respective consumption with that of similar cities in size, composition of demand and climate. This is the method attempted. A very similar city with good metering data is found in a neighbouring country and the cumulative consumption patterns are plotted as shown in the table below:

TABLE CUMULATIVE CONSUMPTION DISTRIBUTION FOR CITIES A AND B

Cumulative Percentage of Consumers by Consumption	Cumulative Percentage of Consumption, City A	Cumulative Percentage of Consumption, City B
Up to 10%	Consuming 35%	Consuming 10%
Up to 20%	Consuming 55%	Consuming 20%
Up to 30%	Consuming 70%	Consuming 30%
Up to 40%	Consuming 78%	Consuming 40%
Up to 50%	Consuming 83%	Consuming 50%
Up to 60%	Consuming 87%	Consuming 60%
Up to 70%	Consuming 91%	Consuming 70%
Up to 80%	Consuming 94%	Consuming 80%
Up to 90%	Consuming 97%	Consuming 90%
Up to 100%	Consuming 100%	Consuming 100%

City A is the comparison city whereas city B is the one analyzed. The cumulative consumption patterns are very different indeed and two explanations come to mind. It would appear there might well be invented meter readings and billings in city B which raises doubts about the integrity of the staff involved. It is extremely improbable that all consumers would consume approximately the same amount of water. It could mean, of course, that no meters were read but that everybody was assumed to consumed a fixed amount of water each month. This might be the case, but that would assign even higher priority to a metering programme, since it would mean that the whole city was completely unmetered for practical purposes.

There is another explanation for the freakish consumption distribution: large consumers produce and consume water outside the public system through their wells. Assuming arbitrarily that city B under study does indeed have a cumulative consumption pattern identical to that of city A, one would be able to calculate the approximate amount of water being withdrawn from private wells in city B.

Such calculations would in all likelihood show that more water is being withdrawn from private wells than is supplied by the public system. The natural course would be to license and meter these wells and charge for any consumption. Such control could be expected to lower extraction rates since water wastage would be curtailed. It could also mean that low-value uses such as agricultural consumption could move away from the metropolitan area or be forced to make use of sewage instead. In either way, groundwater could be used to supply the city and enable the costly outside scheme to be postponed for an indefinite time period.

CASE-STUDY TWENTY-TWO
SURFACE WATER VERSUS GROUND WATER

Background:

A very large city is forecasting supply deficiencies in about 10 years time. Preliminary studies indicate two ways to augment supplies. One solution would construct a surface water scheme to bring 14 m^3/sec from an adjacent basin for the city's needs and thereafter use the waste-waters for energy generation by letting them fall through a series of existing power plants.

The alternative solution would be to continue relying upon the present surface water system which has a maximum capacity of 14 m^3/s and gradually supplement it with wells drilled in a nearby geological formation.

The advocates of the groundwater solution point out that wells would be less susceptible to errors in the demand projections as fas as timing goes since the required construction periods are much shorter than for the alternative new surface water system. Another claim is the more gradual construction would impose less of a financial burden upon the city. Furthermore, since the ground water if of good quality it would actually only require chlorination and no additional treatment works would have to be constructed. Finally, the ground water proponents argue that a ground water solution would also increase energy generation since the waters at present do not enter the power plants.

The supporters of the new surface water scheme maintain that their scheme is the better one since it would provide a gravity supply with excellent waters. Moreover, through the proposed interbasin transfer the load factor in the existing power plants will rise substantially, allowing additional energy to replace thermal generation.

In order to select the preferred alternative it is decided to undertake a detailed comparison based on discounted cash-flow techniques.

Analysys

The detailed cost comparison between the two alternative solutions is shown in the table on the adjacent page. The main consideration for the timing of each scheme are:

COST COMPARISON BETWEEN SURFACI WATER AND GROUND WATER SCHEME

ALT 1 SURFACE WATER SCHEME	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25-60
Total Water Demand, m^3/sec		6.2	6.9	7.8	8.0	8.7	9.4	10.2	11.0	11.9	12.8	13.6	14.4	15.2	16.1	17.0	17.9	18.9	19.9	20.9	22.0	23.1	24.2	25.4	26.5	27.7
New Surface Scheme, m^3/sec		-	-	-	-	-	-	-	-	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0
Old Surface Scheme, m^3/sec		-	-	-	-	-	-	-	-	-	-	-	0.4	1.2	2.1	3.0	3.9	4.9	5.9	6.9	8.0	9.1	10.2	11.4	12.5	13.7
Investment Costs, millions m.u.		151	235	193	190	415	655	668	592	55	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Operating Costs, millions m.u.		-	-	-	-	-	-	-	-	9	9	9	11	16	21	26	31	37	42	48	54	60	66	80	87	95
Energy Benefits, millions m.u.		-	-	-	-	-	-	-	-	(195)	(195)	(195)	(195)	(195)	(195)	(195)	(195)	(195)	(195)	(195)	(195)	(195)	(195)	(195)	(195)	(195)
Net Costs (Benefits)		151	235	193	190	415	655	668	592	(131)	(186)	(186)	(184)	(179)	(174)	(169)	(164)	(158)	(153)	(147)	(141)	(135)	(129)	115	108	100
Discount Factor at 10% rate		1.00	0.91	0.83	0.75	0.68	0.62	0.56	0.51	0.47	0.42	0.39	0.35	0.32	0.29	0.26	0.24	0.22	0.20	0.18	0.16	0.15	0.14	0.12	0.11	0.08
Discounted Net Costs (Benefits)		151	214	160	142	282	406	374	294	(62)	(78)	(73)	(64)	(57)	(51)	(44)	(39)	(35)	(31)	(26)	(22)	(20)	(18)	(14)	(12)	(108)

TOTAL NET COSTS (BENEFITS) = Around 1,270 million monetary units in year 1 prices discounted to year 1

ALT 2 GROUNDWATER SCHEME																										
Total Water Demand, m^3/sec		-	-	-	-	-	-	-	-	11.9	12.8	13.6	14.4	15.2	16.1	17.0	17.9	18.9	19.9	20.9	22.0	23.1	24.2	25.4	26.5	27.7
Old Surface Scheme, m^3/sec		-	-	-	-	-	-	-	-	11.9	12.8	13.6	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5
New Well Scheme, m^3/sec		-	-	-	-	-	-	-	-	-	-	-	0.9	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.1	1.1	1.1	1.2	1.1	1.1
Cumulative Wells, m^3/sec		-	-	-	-	-	-	-	-	-	-	-	0.9	1.8	2.7	3.6	4.5	5.5	6.5	7.5	8.6	9.7	10.8	12.0	13.1	14.2
Investment Costs, millions m.u.		-	-	-	-	-	-	-	-	-	-	96	96	108	108	108	120	120	120	132	132	132	132	144	132	44
Operating Costs, millions m.u.		-	-	-	-	-	-	-	-	71	76	78	80	82	84	86	88	90	92	95	98	100	102	105	108	111
Energy Benefits, millions m.u.		-	-	-	-	-	-	-	-	-	-	-	(13)	(25)	(39)	(52)	(68)	(81)	(96)	(111)	(127)	(144)	(160)	(166)	(181)	(198)
Net Costs (Benefits)		-	-	-	-	-	-	-	-	71	76	174	163	165	153	142	140	129	116	116	103	88	74	83	59	(43)
Discounted Net Costs (Benefits)		-	-	-	-	-	-	-	-	33	32	68	57	53	44	37	34	28	23	21	16	13	10	10	6	(46)

TOTAL NET COSTS (BENEFITS) = Around 440 million monetary units in year 1 prices discounted to year 1.

i) Since the surface water schemes is tied to energy generation, its timing cannot be decided purely on grounds of additional water demands. On grounds of energy requirements it would have to be initiated in year 1 and be fully operable from year 9 onwards.

ii) The wells are constructed strictly in accordance with water requirements with the first wells drilled in year 11.

iii) The basis for comparison will therefore be the new surface water scheme operated at full capacity from year 3 onward, and complemented by the existing, old surface water scheme as need arises. The total capacity of the new scheme is 14 m^3/sec and its estimated lifetime around 50 years. Against this is the groundwater alternative, where the old surface water scheme is operated at its full capacity of 13.5 m^3/sec to take the baseload, and thereafter wells drilled to supplement supply as need arises. The useful life of the electro-mechanical equipment is the wells is assumed to be some 15 years. To be fully comparable during the 50-year period national replacement costs are therefore charged in the groundwater scheme.

<u>Comments on Costs Related to the Surface Water System</u>

The investment costs refer to intake structures, en route storage, transmission lines and tunnels, and treatment works. The investment period is a long nine years, caused by the complexity of the tunneling works.

The operating costs are those of treatment only since the waters enter the basin by gravity. Up till year 12 the treatment costs are minor and thereafter increase proportionately more since the old, existing system with higher operating costs starts supplementing the new surface scheme.

The off-setting energy benefits are obtained from year 9 and onwards in their full amount since it pays off to use the new scheme to full capacity to generate energy irrespective of the water demand of the city. The benefits from power generation of the waters in the old, existing surface water scheme are not credited to the scheme since they do not depend upon the new investments.

After calculating the set costs or benefits for each year, they are discounted to year 1 and summed. For the surface water scheme the present-value sum is around <u>1,270 million monetary units</u>.

Comments on Costs Related to the Groundwater Scheme

Wells will have to be drilled starting in year 11 to add around 1 m^3/sec annually. A major advantage of the groundwater alternative is the shorter construction period which permits wells to be delayed or advanced as demand growth requires it. No investment costs are charged to the old, existing surface water scheme since that is a sunk cost. The investment costs for the additional wells comprise the drilling and equipment of the wells, suction tanks, impulsion lines and booster pumping. Reserve capacity is included in the cost estimates. As mentioned replacement costs are charged from year 25 onwards for the electro-mechanical parts of the well system. This permits a comparison between the two alternatives with different technical lives.

Operating costs are charged for the existing, old surface water system and for the additional wells.

Off-setting energy benefits are credited for the incremental waters produced in the walls only according to the "with-without" rule to determine the benefits are attributable to the project investments. The well waters would not generate energy, were they not raised to the surface, consumed and then brought into the generating plants.

The present-value sum of the net costs (benefits) of the groundwater alternative is around 440 million monetary units.

Conclusion

The groundwater scheme is economically the preferred one since its present value sum of costs is some 440 million compared to around 1,270 million for the surface water scheme. The financial pressure of the groundwater scheme is also less since investments will be spread over a long time period and there will never be much excess capacity. Furthermore, it is less sensitive to variations in demand since the additional wells can be adapted to the evolution of demand.

The example is instructive since it shows that multi-purpose schemes such as the new surface water scheme have to be analyzed with extra care. Multi-purpose schemes often comprise investments which each by itself is not economically justified. The risk is then great that their sum will not be economical either.

CASE STUDY TWENTY-THREE
OPTIMAL TIMING AND SCOPE OF PROJECT

Background:

A proposed irrigation project envisages to capture several mountain rivers and convey the waters to an agricultural plain. The scope of the project is undetermined. On one hand, there is a large demand for irrigation water but on the other hand costs escalate when rivers further and further away are dammed and conveyed for agricultural uses.

One particular river has been suggested for inclusion in the project. It has an average yield of 6 m^3/sec which could be captured by constructing a dam and a tunnel to connect with the remaining conveyance works. The question is whether the inclusion of the river is economically justified in the first place, given that marginal irrigation benefits are 1 monetary unit per m^3 and transmission losses 15%. The second question, assuming the inclusion is indeed justified, is whether a 4 or 5-year construction period is optimal.

Analysis:

The investment cost profile for a 5-year project execution is shown in the table below and the present-value cost sum is calculated to be around 930 million monetary units.

Table. Calculation of Present-Value Sum of Capital Costs

(Million of Monetary Units)

Year	1	2	3	4	6	Total
Costs						
Investments	58	357	357	292	52	1,116
Discount Factor at 10%	1.00	0.91	0.83	0.75	0.68	
Present-Value Cost, Year 1	58	325	296	219	35	933

The present-value benefits are given by the marginal irrigation benefits accruing from year 5 and for a period of 50 years, being the estimated life-time of the project works.

The discounted benefits in money of year 1 will be:

6 x 0.85 x 86,400 x 365 x 1 x (9.934 - 2.487) 1,200 million.

The present-value benefits are larger than the present value-costs and the river should therefore be captured for irrigation purposes.

Optimal Construction Period

The construction period can be shortened by working the equipment continuously and employing more workers. By advancing the costs, the present-value cost sum will grow but so will the present-value benefit sum. The pace of the works should be accelerated up to a point when the present-value set benefit sum reaches its maximum.

In the case studied it was concluded that costs would increase by some 7% as a result of the more rapid execution, and the table below shows the new cost profile and present-value calculations:

Table Investment Cost Profile Assuming 4-year Construction Period

(Millions of Monetary Units)

Year	1	2	3	4	Total
Investment Costs	119	432	394	249	1,194
Discount Factor at 10%	1.00	0.91	0.83	0.75	
Present-Value Cost, Year 1	119	393	326	186	1,024

The cost increase is (1,024 - 933) million, or 91 million. This is compensated by additional irrigation benefits corresponding to receiving 1 m^3/sec for one more year, and the present-value benefits are:

$6 \times 0.85 \times 86{,}400 \times 365 \times 0.75 \times 1 = 120$ million monetary units.

Net benefits would increase as a result of the quicker construction, and a 4-year period is therefore preferable to a 5-year construction. It should be further studied whether a still faster work pace is possible so as to further increase net benefits.

General Observations

Intuitively, the optimal rule would seem to be to try to time investments as closely as possible to the need for them, and then execute the works fast by continuous operation. In this way costly machinery is utilized with maximum efficiency and more labor can be employed by adding shifts. The employment effect of the investment is intensified, and in effect a larger number of workers are employed although during a shorter time period. In the context of developing countries with a relative abundance of labor and scarcity of capital such a shift is obviously desirable.

The construction period of a project is improductive in the sense that no benefits are produced during it. If it could be shortened, particularly by employing more unskilled labor the shadow-wage of whom will be close to zero, and brought closer to the date at which the works will be required, net benefits will in most cases rise. Such rapid construction and with smaller time margins is more risky, however, and the incentives may not be commensurate with the possible savings for the decision-makers involved.

The point is well-taken when deciding upon how labor-intensive the selected technology should be. With labor-intensive techniques there is a risk that benefits are much postponed, thus falling in present-value terms, and that such lower benefits are not compensated by the lower construction costs. No general rules can be given, though, but each case should be decided on its merits.

CASE STUDY TWENTY-FOUR
VARIABLE TREATMENT STANDARDS

Background:

A city is preparing to construct new facilities to treat waters from a new source. The raw waters in the future system are of excellent quality and chlorination alone would suffice to bring them up to bacteriological safety. Even so, full treatment in the form of direct filtration has been decided so as to eliminate a slight problem of color during a few months of the year. With the commissioning of the new treatment plant it is planned close down most existing treatment facilities and only operate them as stand by with a skeleton crew in case an emergency would shut down the new plant.

During the execution of the large investment plan, of which the treatment plant is only a part, the utility is based with financial problems which appear likely to remain for some five years. Planned works are reviewed to explore possibilities for postponing investments and ease the financial pressure during the critical years.

In this context it is suggested to stage the proposed new treatment plant. The first stage would comprise chlorination facilities plus the final reservoir capacity to allow sufficient time for the disinfectants to react with the raw water. The second stage would consist of the remaining treatment components, including the filters. Opponents to the staging claim that nothing would be saved since the new plant would be able to produce water more clearly than the old existing plant, as it would feed the city by gravity and require less chemicals. They also fear that injecting raw water, albeit of excellent quality and chlorinated, into the distribution system would damage the city's fame for good water. To resolve the doubts a present-value analysis is recommended to study what the savings might be from the staging.

Analysis:

The present-value analysis is shown in the Table below:

Table Comparison between Staged and Non-staged Construction

(Monetary Units of Year 1)

Capital Costs	Year	1	2	3	4	5	6	7	8	9	Total
Non-Staging											
Annual Investments		9	124	156	36	-	-	-	-	-	325
Discount Factor, 10%		1.00	0.91	0.83	0.75	0.68	0.62	0.56	0.51	0.47	
Present-Value Cost		9	113	129	27						278
Stating											
Annual Investments		9	32	37	37	-	-	30	70	110	325
Present-Value Cost		9	29	31	28			17	36	52	202

The comparison between the staged and non-staged phasings are made in standard fashion and shows that the present-value cost will decrease by around 80 million monetary units in constant money of year 1 and discounted at 10% to that year.

Against these savings stand the cost penalties associated with continued operation of the existing more expensive treatment plant. These extra costs are quantified in the table below:

Table Additional Operating Costs From Postponing the New Treatment

(Monetary units of year 1)

Operating Costs	Year	5	6	7	8	9	Total
Total Required Water Production, m^3/s		11.9	12.8	13.6	14.4	15.2	
Less Stand-By Production, m^3/s		3.5	3.5	3.5	3.5	3.5	
Remaining Required Production m^3/s		8.4	9.3	10.1	10.9	11.7	
From Existing Treatment Plant, m^3/s		6.0	6.0	6.0	6.0	6.0	
From New Source, Chlorinated, m^3/s		2.4	3.3	4.1	4.9	5.7	
Mixing Factor, Fully Treated Waters Divided by Chlorinated Waters		4.0:1	2.9:1	2.3:1	1.9:1	1.7:1	
Additional Costs Due to Continued Operation of Existing Plants		28	28	28	28	28	
Discount Factor at 10%		0.68	0.62	0.56	0.51	0.47	
Present-Value Costs to Year 1		19	17	16	14	13	79

The additional costs from continued operations of the existing treatment plant are thus in the order of 80 million monetary units, or the same as the investment cost savings from the staging. From the economic point of view it is therefore indifferent whether the construction is staged is staged or not.

From the financial point-of-view the staging would push about two-thirds of the capital costs out of the most problematic period and on these grounds the staging is recommended.

From the point-of-view of water quality the temporary injection of chlorinated raw waters into the system should not be considered unwise or irresponsible as long as they are safe bacteriologically. The reported color problems during a few months each year could be countered in two ways. First, suitable mixing of the waters would lower any color and the mixing factors are indicated in the table. Second, the existing treatment plant capacity could be stretched during the months with higher color by more booster pumping. Although not advisable longer periods, for a few months no problems are likely.

CASE STUDY TWENTY-FIVE
CHOICE OF WATER SOURCE FOR RURAL AREAS

Background:

A medium-sized country with 90% of its population in rural areas has set a medium-term target to give each village a source of potable water within reasonable distance. The long-term goal is to provide all rural areas with piped water within 400 meters of any dwelling.

The target are ambitious since at present only a third of the rural population has reasonable access to potable water and even fewer to piped water. The policy is to supply water free of charge and sector finances have been deteriorated as a consequence. Lack of funds have led to maintenance being neglected, and increasingly more systems are breaking down. Possibly overall service levels have fallen.

The choice of water sources for the rural systems have added to the problems. Since water supply is free of charge irrespective of its cost, villagers have not unnaturally insisted on receiving the best possible system, and as a result surface water systems have dominated over cheaper alternatives. Not only has this been a drain on scarce investment funds but the surface water system's greater complexity have caused problems with operations and maintenance.

The financial and operative problems have reached serious proportions, and it is decided to analyze the economic consequences of constructing too sophisticated systems.

Analysis:

Although not directly related to the economic comparison between different water sources, obvious recommendations would be to charge consumers in proportion to the kind of systems they are requesting so that they will be more willing to accept economical solutions. Similarly, it would make sense to use the sector funds less for new investments and more for operations, maintenance, and rehabilitation of existing ones. To support such greater emphasis on operations and maintenance relatively more should be devoted to training programmes, since qualified staff at all levels is likely the scarcest resource in the sector.

The practice when selecting a new water source has been to consider four different solutions, viz. gravity surface systems, pumped surface systems, boreholes, and shallow wells. The respective investment and operating costs annually are shown in the table below:

Table Per Capita Investments and Annual Operating Costs

(Monetary Units)

Type of Scheme	Annitized Investment	Operating Costs	Total
Surface gravity	30	8	38
Surface pumped	32	15	47
Borehole	39	17	56
Shallow well	10	6	16

The cost-effectiveness of shallow wells is evident. They cost half or a third of alternative systems, use less operating funds and require less qualified staff. It would thus seem highly recommendable to concentrate in the first round upon giving the maximum number of people service rather than opt for more expensive solutions which will only serve a relative minority.

Another method for comparing the different system's cost-effectivement would be to capitalize their respective current costs during 15 years and add the investment costs. The relevant present-value sum of periodic payments is tabulated in discount tables. For the particular case of 15 years useful life and a discount rate of 10% the present-value sum of periodic payments is obtained by multiplying the annual costs by a factor 7.6. We thus have the ranking according to this second criterion:

Type of System	Investment	Capitalized Current Costs	Total
Surface gravity	230	60	290
Surface pumped	250	110	360
Borehole	300	130	430
Shallow well	80	50	130

The conclusion is the same, only presented in a different way. Note that the annuitized cost can not be obtained by dividing the total capitalized cost by the number of years.

The financial benefits from directing a larger share of investments to shallow wells can be seen from the table below which compares the present investment mix I with two alternatives:

Population Served by	Alternative		
	1 (as now)	II	III
Surface gravity	28%	23%	15%
Surface pumped	41%	34%	23%
Borehole	22%	18%	12%
Shallow well	9%	25%	50%
Weighted Average per capita Development Cost	320	283	224
Weighted Average per capita O & M Cost	12.6	11.5	9.6

The switch to investment mix III with shallow wells accounting for half of new systems would enable some 50% more people to be served at the same amount of investment funds and with subsequent lower operations and maintenance costs.

CASE STUDY TWENTY-SIX - OPTIMUM DESIGN PERIOD FOR ELEVATED STORAGE

Background: In a South-Asian state the design practice has been to divide each urban area into separate service zones, each served by elevated storage tanks on flat-land. The justification offered has been that the resulting smaller flows permit the use of smaller pipe diameter with overall savings in distribution costs.

An alternative design method has been suggested where each city would be divided into a few pressure zones or operated as one zone. This would enable scale efficiencies in the construction of elevated storage tanks. To substantiate the claims least-squares analysis has been applied on cost data for storage tanks of the kinds constructed which show that the economy-of-scale factor is 0.39.

A given city is at present divided into 10 pressure zones. Show what economies would result in investment costs for storage capacity, if there had been only one pressure zone. Further, assuming linearly increasing demand, no initial supply deficit and a discount rate of 10%, what would be the optimal design period?

Analysis: In case one large tank would have been constructed its volume would be equal to 10 times the volume V of each smaller tank. The cost of the large tank would be $K \times (10\ V)^{0.39}$. The cost of the 10 smaller tanks would be $10 \times K \times V^{0.39}$ and consequently the relation in investment costs would be $\frac{10}{10^{0.39}}$ which is approximately a relation of 4:1.

The optimal design period for any size tank can be determined from the formula

$$x = \frac{2.6\ (1 - a)^{1.12}}{r}$$

and where x is the optimal design period
a is the scale factor, in this case 0.39
r is the appropriate discount rate, in this case 0.10

Inserting the values in the formula it is found that the optimal design period would be in the order of 15 years.

In the light of the substantial savings in storage cost it would seem advisable to investigate whether considerable economies are not possible by reducing the number of pressure zones in new designs. In already constructed systems it would likewise probably pay off to start interconnecting separate service zones and as demand grows construct larger storage tanks serving more extended areas.

CASE STUDY TWENTY-SEVEN - GRAPHICAL DIMENSIONING OF STORAGE TANKS

Background: In well-managed water systems hourly variations in consumption are available so as to provide guidance for the determination of minimum storage volume. For systems relying upon pumped supply, such hourly statistics are especially valuable since the costs of pumps and their operation, distribution pipe sizes and reservoir volumes are closely related.

In the more general case storage volume should satisfy three needs:

(i) To balance hourly consumption variations
(ii) To provide a reserve against system breakdowns
(iii) To provide a reserve for fire-fighting

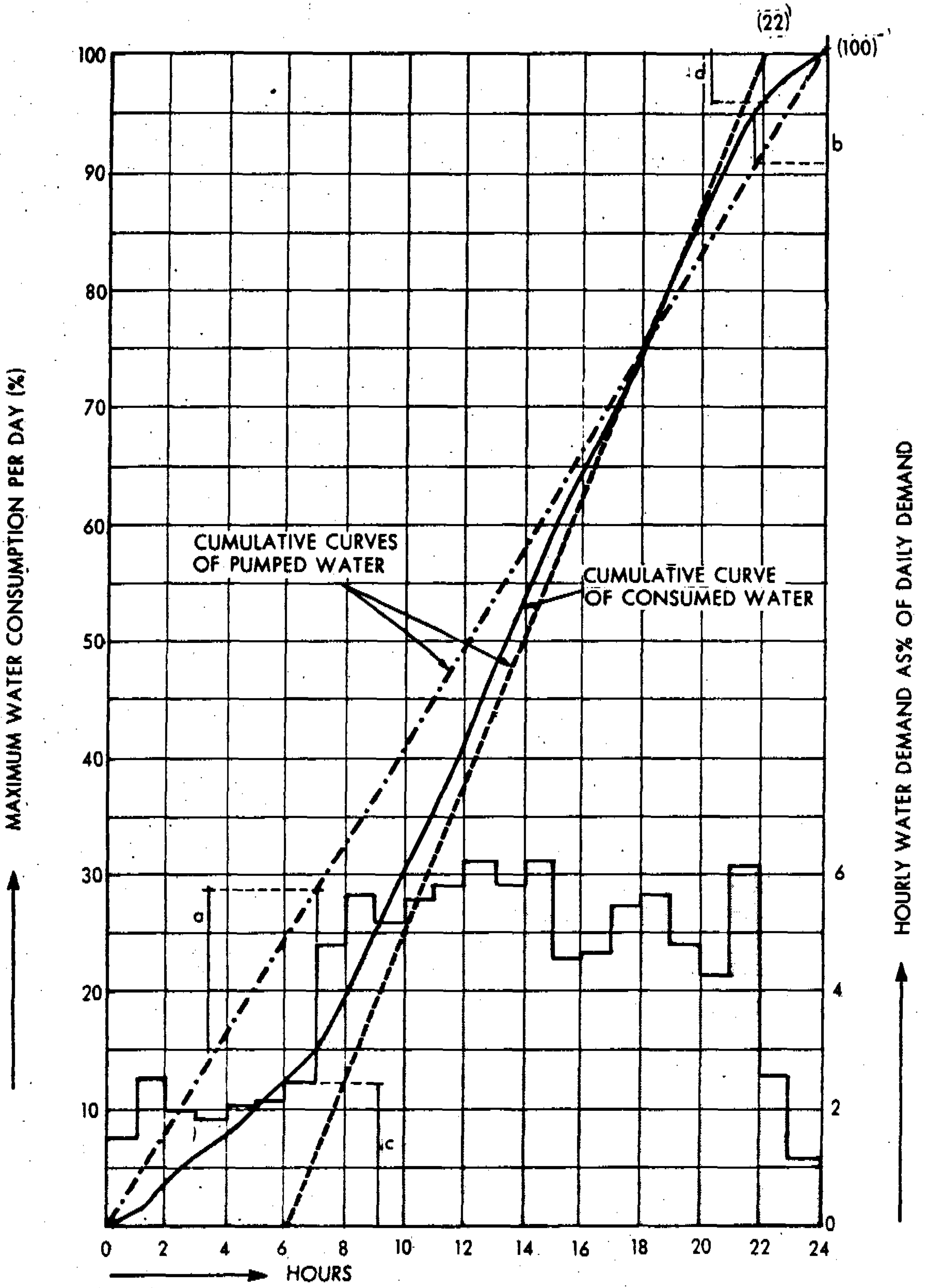
The first kind of storage can be determined graphically as shown under the analysis section. Such a calculation is applicable in the case the design period has been chosen and where the approximate hourly variations are shown. The graphical dimensioning is thus independent of any strictly economic scaling of works.

The reserve capacity against system breakdowns could in theory be related to statistics on frequency and duration of breakdowns and their associated costs, but in practice a percentage over and above the storage required to compensate for hourly variations is selected rather arbitrarily. A higher safety margin is assigned to pumped water systems than to gravity systems under the assumption that the former are more susceptible to breakdowns.

Firefighting above normal storage conflicts with the efforts to design low-cost distribution systems suitable in developing countries. It could be argued that cases with both a system breakdown and a major fire are so rare that one need not design for it. The firefighting reserve could thus be included in the general reserve against system breakdowns. The latter might also be allowed to vary: after a major addition to reservoir capacity the reserve would be ample since it would be optimal to build considerable excess capacity into the reservoir for reasons of efficiencies of scale. This excess would gradually be used and reserve capacity would decrease until the next addition to storage capacity. Firefighting reserves might be excluded altogether to hold costs down. Studies have shown that providing for firefighting may increase the distribution cost up to 15%. Since the distribution system can represent from 20 to 65% of the total system investment it follows that fire prevention might add up to 10% of the total cost in extreme cases. This would seem to be too high a price to pay in the context of developing countries.

Analysis: The first step in graphical dimensioning of reserve capacity for hourly variations is to decide which should be the design year. Once this is fixed the average consumption is forecast and then multiplied by the relevant max day-factor. The latter varies from 110 to 150% in different countries' design guidelines with the most representative value in the vicinity of 125%.

The consumption rates for each hour of the max day are then plotted as shown in the adjacent figure, and the corresponding cumulative demand curve is plotted as well. Once the cumulative curve is known it can be related to the varying supply curves in the diagram to give estimates of the minimum storage volume.



STORAGE REQUIREMENT FOR WATER DEMAND FLUCTUATION

$V_1 = a + b = 14.2\% + 5.0\% = 19.2\%$ $V_2 = c + d = 12.4\% + 3.8\% = 16.2\%$

In the first example supply is assumed to be continuous, either by gravity or by pumping. The total required storage volume can be seen to be 19.2% of the volume consumed during the maximum day. It is composed by 14.2% which is the maximum distance from the supply line down to the cumulative demand curve / corresponding to that water which was supplied by not consumed during the night / plus 5.0% which is the maximum distance from the supply line up to the cumulative demand curve / corresponding to the cumulative unsatisfied deficit during the hours 0700 to 2200 when demand exceeded supply.

In case the supply changes, the respective minimum reservoir volumes can be measured in the figure by inserting the new supply lines. In the case of a 16-hour supply from 0600 to 2200 the minimum volume would be 3.8%, the maximum distance from the supply line down to the cumulative demand curve, plus 12.4%, the maximum distance from the supply line up to the cumulative demand curve, or a total of 16.2% of the max day consumption.

In most developing countries, for lack of reliable hourly consumption data, rules-of-thumb are most often applied when dimensioning storage tanks. Such rules simply give the minimum volume as a percentage of the max day demand, or of the average demand. Alternatively the required volume is expressed in hours of average demand. For instance, a 6 hours storage capacity corresponds to 25% of daily average demand. Whereas such rules-of-thumb may be sufficient for design in most systems, the hourly variations should if possible be determined when planning large and expensive water supplies.

The stipulated storage requirements vary widely in different countries' design norms. Some countries set the minimum at 25% of average demand, others at 100%. The higher norms are not necessarily associated with larger hourly fluctuations but reflect more reserve capacity against system breakdowns. Peak hour rates are reported to vary from 130% up to 300% of average demand. The most representative values might be 180% for medium-size communities, and up to 250% for rural communities, both expressed in terms of average demand. Higher peaks in rural areas can be explained by the more uniform living habits of the population, by the fact that water is carried, and by the relative absence of industry which usually dampens demand fluctuations.

CASE STUDY TWENTY-EIGHT - DESIGN GUIDELINES FOR NATIONAL WATER PLAN

Background: A medium-sized country has decided to make a special effort in the water supply field so as to raise service levels which are considered too low and hampering economic progress. To this end, a five-year investment program is to be adopted with sharply higher investments to enable a majority of the population to connect and provide excess capacity for future growth.

In preparation of project selection and design the main bottle-necks in each system have been identified, and a large number of cost data for systems of different scale have been collected and cost functions have been determined through least-square analysis.

Under the assumption that demand is increasing linearly and that there is an initial supply deficit of 10 years on average, what should be the optimal design periods for different components from the economic point of view?

Analysis: The theory on optimal design periods has been discussed earlier and optimal periods for the most common scale factors and assuming a discount rate of 10% are shown in the table below:

Optimal Design Period in Years vs. Scale Factors

Scale Factor, a	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90
Optimal Period	18	16	15	13	12	10	9	7	6	4

Since an initial supply deficit of 10 years is postulated each component should be designed to absorb the backlog plus provide excess capacity for the periods shown above. The components for which cost functions have been determined are intake structures, sand traps treatment plants without filtration, treatment with filtration, ground storage reservoirs, and sewerage systems excluding treatment. The relevant design periods would follow:

I For Intake Structures

Cost per unit of capacity = $C = \dfrac{\text{Constant}}{u^{0.9}}$ and where u is the population served

This unit cost function may be transformed into the familiar relationship between the investment cost and the total capacity by multiplying by the population "u" on both sides and one obtains:

Total Intake Investment Cost = Constant × $u^{0.1}$

The scale factor, a, is 0.1 and its low value indicates very substantial economies-of-scale for these concrete structures that consist of simple dikes or lateral intakes. Although the optimal design period is not shown in the table above it can easily be calculated from the formula

$$x^*_1 = x^* + \frac{(1-a)^{0.7}}{(r)} + \frac{x_o}{(x_o+x)^{0.6}}$$

and where x^*_1 = optimal design period with supply deficit

x^* = optimal design period with no initial supply deficit, approximated by the formula $x = \frac{2.6}{r}(1-a)^{1.12}$
a = the scale factor
r = the discount rate
x_o = the initial supply deficit, measured in years

Calculations with the scale factor 0.1 indicate an optimal design period of around 25 years. In reality, such a long period means that practical considerations can be given more weight. For instance, if the safe yield of the surface stream is sufficient for the consumption in 35 years, it is natural to build intake structures sufficient to capture the entire safe yield rather than stage the works.

II Sand Traps

These are simple rectangular tanks built to reduce the largest suspended matter in the raw water and economize on transmission works and subsequent treatment. The total cost function was found to be

Total Sandtrap Cost = Constant·$u^{0.55}$
From the table the optimal design period is given as 15 years.

III Treatment Plants Without Filtration

The simple treatment plants are constructed where raw water quality permits and where financial insufficiency prevents the immediate installation of filters. The plants comprise chemical dosification, mechanical or, where possible, hydraulic mixing, flocculation and sedimentation basins, and chlorination. The relevant cost function was found to be:

Total Cost of Simplified Treatment = Constant.$u^{0.52}$

It follows from the table that the optimal design period would be around 15 years.

IV Treatment With Filtration

The plants in question are similar to the simplified ones except that the filters have been added. These are rapid sand filters operating on the declining rate principle. The cost function was found to be:

Total Cost, Full Treatment = Constant$\cdot u^{0.63}$

The table shows an approximate optimal design period of 12 years. It is worthwhile to note that Lauria in a study of simple treatment plants in Guatemala, although these lacked filtration, found a scale factor of the same order. Koenig () reports a scale factor for US treatment plants of 0.68.

V Ground Service Reservoirs

The kind of storage tanks studied were in concrete, mostly half underground, and varying in size from 100 m^3 up to 5,000 m^3. The cost function was determined as

Total Cost, Ground Storage = Constant$\cdot u^{0.75}$

The table indicates an optimal design period of around 9 years. Although the data were mostly for gravity systems, it should be remembered that where pumping is involved the optimal storage will also depend upon the installed pump capacity and on the network capacity. Providing more storage than necessary might postpone the need for more pump capacity, and the design period of 9 years may therefore be considered on the low side.

VI Sewage Collection Systems Without Treatment

These systems had been constructed in communities ranging from 2,500 to 70,000 inhabitants and comprised lateral and main sewers, and evacuation lines. The cost function was found to be:

Total Cost, Sewerage = Constant$\cdot u^{0.42}$

For these systems a design period of around 19 years would seem appropriate although other circumstances such as saturation of demand would play an important role when deciding the system capacity. It is interesting to note that there appear to be slight diseconomies of scale with regards to pipe diameter. This can be seen since the capacity of a pipe, according to Hazen-Williams formula is proportional to the (pipe diameter)$^{2.63}$, and since the sewerage systems in question comprise practically pipe only.

CASE STUDY TWENTY-NINE - DISTRIBUTION DESIGN

Background: Distribution design is an area where there are few general rules available. Costs vary much between different countries and it is dangerous to rely upon rules-of-thumb developed in one particular country with specific cost functions. Demand is also more difficult to forecast since not only its total magnitude but also its location need be forecast. Questions whether a certain area is saturated or not, and whether per capita consumptions may grow, are difficult to answer with certainty and much judgement and experience is needed.

A few common-sense rules can be laid down, however. One should not try to anticipate demand by laying networks in low-density areas in the belief that the population will later materialize. Population growth patterns may change, and the early timing of the works increase their present-value cost. For the same reasons, works should be staged by providing rudimentary, branched networks in the early stages and introducing looping later on if needed. Works geared primarily to increase reliability and ease of operations and maintenance can similarly be excluded from the early stages since the overriding concern should be to first use scarce funds to cover the entire urban area, and thereafter increase reliability.

Adding to the subjective nature of distribution design has been a dearth of empirical studies relating investment costs to central parameters, such as population, population density, daily per capita consumption and others. Recently, however, the World Bank as part of its efforts to lower distribution costs in its projects, commissioned several studies. The results of one of these have been published (Lauria, Kolsky and Middleton "   ") and the salient findings and illustrative calculations will be discussed in some detail.

Analysis: The Lauria study set out to establish quantitative relationships between the cost of distribution networks (including distribution devices) and pipe diameter, network length, population density, served area, and the per capita water consumption among other factors pipe diameters in the study were mostly small, ranging from 25 mm (one-inch) to 150 mm (six-inch). Data were collected in three different countries on separate continents and refer to the years around 1975 and 1976.

Pipe Unit Costs

Unit costs for installed pipe should logically be the sum of a fixed term representing trenching and backfilling, and another term representing the cost of the pipe. The cost function would thus be of the type C/L = Constant $+b.D$ where C is the total cost, L the pipe length, b constant and D the pipe diameter. Alternatively, one might consider a power function of the type, $C/L = k.D^a$ where k is a constant, and a is the scale factor.

Empirical data vindicated both assumptions. In one country the two-term function fitted the data the best, and in another the power function did. As a compromise between the two for purposes of analysis and illustrative calculations a cost function of the type $C/L = 0.2\ D^{0.9}$ was selected. This function would seem to indicate that there are only very slight economies-of-scale with regard to pipe diameter. As a matter of fact, some of the countries studied exhibited diseconomies of scale.

It should be stressed though, that with regard to the carrying capacity of the pipe there existed in all instances substantial economies of scale since a pipe's carrying capacity is according to Hazen-William's formula proportional to $D^{2.63}$, all other things being equal. Inserting this value in the cost function above, one would find that unit pipe costs would be proportional to $\text{capacity}^{0.42}$.

Pipe Length

As could be expected intuitively, pipe length was found to vary with the area served, A, and the number or spacing of distribution devices, N. The relationship established was

$$L = N^{0.4}\ A^{0.6} \text{ with a good fit.}$$

The symbol N can mean public standpipes or individual service connections. Pipe length is relatively insensitive to changes in N as the exponential is 0.4. The order of magnitude of the exponential for A could maybe have been foreseen since length is the square root of area, i.e. the exponential is 0.5 as compared to the empirical findings of 0.6. Depending upon the urbanization and network patterns the relationship will differ somewhat.

At times it is of interest to design the number of distribution devices starting from a fixed maximum walking distance for the population to be served. The pipe length formula can easily be adapted to include this maximum distance, R, since $N = \frac{10,000}{R^2}$. Inserting this value into the original expression one finds

$$L = 2270.A.R^{-0.8}\ .$$

This relation is useful for studying the variations in network length when the maximum walking distance is changed. For instance, halving the distance will increase total network length by $2^{0.8} - 1$, or some 74%.

Pipe Diameter

Average pipe diameter can be expected to increase with per capita flows but fall with increasing headloss or number of distribution devices since each pipe will carry a smaller share of total demand.

For the small diameters studied the relationship could be even more simplified by excluding headloss as a variable and the relation was found to be:

$$D_{av} = 4.5.(P/N)^{0.21}.Q^{0.39}$$

where D_{av} is the average diameter as defined by $(\underline{D}_n\text{-}L_n)$ where D_n is the diameter of the nth pipe, and L_n is its length $\frac{(Dn*Ln)}{L_n}$; P/N is the number of people served by each distribution device, and Q is the per capita flow daily, expressed in leters per day.

The close correspondence with Hazen-William's formula should be noted in which the diameter of a pipe increases as a function of the flow, Q as $Q^{0.38}$. The relatively low value of the exponential explains the small changes in D_{av} when per capita flows vary. Although P/N has an even lower exponential, 0.21, the potential variations are larger since the average number of persons served from one distribution device can vary from 7, corresponding to an individual service connection, up to a couple of thousands of people drawing water from a standpipe under extremely crowded conditions.

Total Network Costs

Total network costs are the sum of the installed piping costs and the cost of the distribution devices, be they public standpipes or individual service connections. Depending upon complexity public standpost have been found to account for between 4 and 25% of the total cost, whereas the house connections have costed from a low 16% up to 50% of the total cost.

The total cost of the piping installed can be found by combining the three relationships determined above, to wit:

$$L = 90.N^{0.4}.\ A^{0.6}$$
$$D_{av} = 4.5.(P/N)^{0.21}.Q^{0.39}$$
$$C/L = k.D^{a}$$

Approximately the three expressions can be multiplied to produce

Alternatively, had the cost function been of the type C/L = k+ bD the corresponding total cost of the installed piping would have been found through simple multiplication.

ILLUSTRATIVE EXAMPLES

A series of examples of the use of the formulas discussed above will be shown. Common to all examples are the following values of the parameters:

A = 100 hectares
P = 30,000 inhabitants
$C/L = 0.2\ D^{0.9}$
Cost per standpipe = US$500
House Connection = US$100

Example I

From the equation D_{av} 4.5 $(P/N)^{0.21}$ $Q^{0.39}$ the trade-off between per capita flow, Q, and level of service, P/N, can be determined for any given pipe diameter. The equation plotted on log-log paper will produce iso-diameter lines as shown in the figure below where the lines corresponding to 25, 50, 75 and 100 mm are shown.

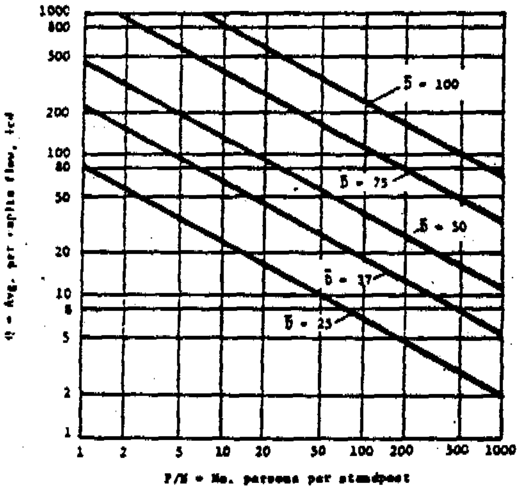


FIG. 1. Per capita flow vs. persons per standpost for various pipe sizes.

It can be seen that a 25-mm pipe is sufficient for a house connection system with 5 persons per connection and 35 lcd but it is too small for a public standpost supply. A 50-mm network, on the other hand, will provide 150 lcd through house connections (given 8 consumers per connection) or 20 lcd through standpipes, each serving 350 people. Clearly this will meet the majority of situations, and average pipe sizes will usually not need to be larger than 50 mm.

Example II

A designer might initially want to form an idea what the very bare minimum network, comforming to "basic needs", would cost. A minimum might be to supply 15 lcd at a peak factor of 2, and with a maximum number of persons per standpost of 1,000. The peak flow is equivalent to 30 lcd which in turn is equivalent to Q = 10 lcd, since the models have assumed a peak factor of 3.

The second parameter, P/N, can be calculated as $\frac{30,000}{10,000}$ or 30 and consequently the total length of the network can be calculated as

$$L = 90.30^{0.4}.100^{0.6}, \text{ or around } 5,600 \text{ meters.}$$

The average pipe size can be calculated as

$$D_{av} = 4.5.(1,000)^{0.21}.10^{0.39} \text{ or around } 47 \text{ mm}$$

The cost of the average pipe would be $0.2.47^{0.9}$ or around US$6.4/m and consequently the entire pipe installed would cost 5,600.6.4, or around US$36,000. To obtain the total cost the public standposts should be added which at a unit price of US$500 and being 30 in number will cost US$15,000. The total network cost will therefore be US$51,000, which is less than US$2 per capita for distribution only.

Example III

A common situation is to provide low-income areas initially with a standpost supply and gradually upgrade into one with house connections as income levels rise. It is desirable that the network first installed should be compatible with the network later on required for house connections.

Suppose that the basic network in example II will be upgraded in five years time into one with house connections where the per capita consumption will be 100 lcd and with a peak factor of 3. With 10 persons per connection there will be 3,000 house connections and the corresponding network length will be

$$L = 90.\ 3{,}000^{0.4} \cdot 100^{0.6} \text{ or around } 35{,}000 \text{ m}$$

The average diameter will be given by

$$D_{av}\ 4.5\ 10^{0.21}\ 100^{0.39} \text{ or around } 44 \text{ mm.}$$

Clearly the diameter is compatible with the basic needs network with a diameter of 47 mm. If, however, water-borne waste disposal will be provided in the future, thereby allowing per capita demands to increase significantly, say to 200 lcd, the average diameter required will be 58 mm. This is not compatible with the basic network. Either the larger pipe will have to be laid in anticipation of the upgrading, or, which might be more economical, the larger mains can be deferred to the time when the sewers are laid when the streets will in any case be disrupted.

Example IV

In designing systems for squatter neighborhoods the designer often has to keep within a predetermined per capita cost, which is all that is affordable by the consumers. For example, assume that for health reasons it is decided that a flow of 25 lcd must be provided, and yet the per capita cost must not exceed \$2.50 (i.e., a total expenditure of \$75,000). The problem is then to determine the appropriate number of standpipes, N. The length of the network $L = 90\ N^{0.4}\ 100^{0.6} = 1{,}430\ N^{0.4}$. The average pipe size $Dav = 4.5 \left(\frac{30{,}000}{N}\right)^{0.21} 25^{0.39} = 138\ N^{-0.21}$. The unit cost of pipe is then $0.2\ (137\ N^{-0.21})^{0.9} = 16.8\ N^{-0.19}$. Putting pipework plus standpipe costs equal to total maximum permitted cost, we obtain:

$(1{,}430\ N^{0.4})\ (16.8\ N^{-0.19}) + 500\ N = 75{,}000$, or $24{,}000\ N^{0.21} + 500\ N = 75{,}000$ whence (by trial and error) N = 45. There will therefore be 670 persons/standpipe, and each standpipe will have a mean service radius of 84 m. The average pipe diameter will be 62 mm (note that since there are so few standpipes the pipe diameter is comparatively large; it therefore presents no problems of compatibility when funds are available to install a more extensive network).

CASE STUDY THIRTY - PUBLIC VERSUS PRIVATE STORAGE

Background

In cities with a history of deficient water service, it is common to find houses equipped with roof tanks. At times,. these become so entrenched in the public mind that building codes may require t~~y~~hem even though rationing is a thing of the past.

There are substantial diseconomies associated with roof tanks. Although in theory such tanks could be a substitute for public tanks most of the time they duplicate them. Actually there may be a number of reasons for poor water service, such as insufficiency in the water source, insufficient capacity in transmission, treatment, distribution networks and insufficient storage volume. Only in the latter case could some savings be achieved in theory. In practice roof tanks are clearly sub-optimal since the economies of scale in storage tanks are not taken advantage of.

Analysis

In one city an estimate was needed to demonstrate how much more expensive private roof tanks would be as compared to public storage. To this end data were collected on recent construction costs for ground storage tanks, and the following relation between volume and investment cost was derived:

Relation between Storage Volume and Construction Cost
(Millions of monetary units)

Storage Volume, m3	Construction Cost
150	0.24
200	0.28
280	0.34
450	0.45
700	0.56
1,650	0.99
2,000	1.16

In contrast, the cost for a commonly used roof tank with a volume of 350 l was 1,500 monetary units.

The town had a population of 30,000 inhabitants and was consuming water at 200 lcd, and there were an estimated 7 persons per connection. Assuming that each connection would have a storage tank one would have to install around 4,300 tanks at a total cost of around 6.5 million monetary units. This would be equivalent to a

6-hour storage volume of the average demand, or a total of 1,500 m^3. Proving the same volume in the form of a large, public tank would cost in the vicinity of 0.9 million monetary units (interpoilating in the table. The roof tanks can be seen to cost around 7 times as much as the public storage tank.

It could be argued that roof tanks when equipped with suitable inlet control devices might reduce the peak flows in the network and thus reduce the average pope diameter with concomitant savings. Since the pipe diamter is proportional to the flow $Q^{0.38}$ one could expect a reduction of the pipe diameter in the proportion of $(\frac{1.25}{1.80}\ 0.38$ under the assumption that the maxday factor is 1.25 and the peak hour factor 1.80. This would be in the best of cases when the entire hourly variations would be smoothed by the roof tanks. The reduction works out at 13% which in all likelihood will not appreciably affect selected pipe diameters since these are often chosen in standard diameters.

In practice there are other circumstances against private roof tanks whichmake them even less economical. Since it is improbable that any fair-sized system could exist without any reserve storage whatsoever for emergencies, the incremental cost of providing balancing storage is smaller than in the calculation shown above. Apart from any reasons of greater economy, public storate is preferable from the water quality point-of-view since water is less likely to become contaminated in a public tank than in private roof tanks.

Concluding then, the case against private roof tanks is very strong and their construction sould be discouraged. However, when they already exist, an estimate of the total installed private volume is in order since they may permit future public storage tanks to be delayed with ensuing cost savings.

CASE STUDY THIRTY-ONE - COST/BENEFIT ANALYSIS OF METERING

Background

A city with some 100,000 connections will be forced in the short-term to launch an investment program to keep abreast of demand that has been growing at a rapid 7% per annum. Projected capital costs are estimated to be some 20, million monetary units for water supply and 10 million monetary units for sewerage, including treatment. The marginal production costs for water and sewage treatment at present have been estimated at 0.02 and 0.03 monetary units per m^3.

Instead of these investments it has been proposed to meter the entire city that is presently completely unmetered. It would be expected that metering would lower the per capita consumption of 290 lcd by some 30%. Assuming that each meter installed would cost 20 monetary units, would last on average 5 years and require another 7 monetary units annually on account of meter readings, is metering justified?

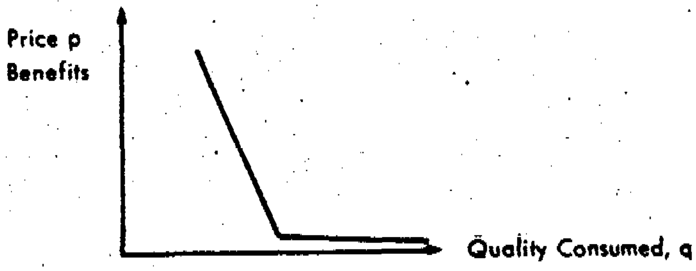
Analysis

The savings from metering would come in two areas. First, since consumption would be lowered by some 30%, the investment programme could be postponed some 4 years. Assuming a discount rate of 10% and, for simplicity a one-year construction period, the savings would be given (1.00 - 0.68) .30 million monetary units, or some 9.6 million.

Second, since less water would have to be produced and disposed of there would be savings in marginal operating costs which would amount to aroudn 3.2 (0.02 + 0.03), 0.20.0.29.365. 7,100,000 million monetary units, or around 2.4 million monetary units. (The factor "3.2" corresponds to periodic payments during 4 years and can be obtained from discount tables; the factor 0.20 are assumed average reductions in water produced; remaining factors follow from the assumptions given.

The total savings are thus in the order of 12 million monetary units, the major share of which is due to postponement of works. Against the savings are the costs of metering. These would be 100,000. 20 + 100,000.3.2.7, or around 4.4 million monetary units. Since the savings are almost triple the costrs, the metering is justified.

In the calculations it has been assumed that the loss in consumer benefits is negligible when they have to reduce their consumption. This assumes a kinked demand curve of the kind shown in the figure:



Consumers will reduce their consumption relatively easily when they are consuming tothe right of the kink on the demand curve since the units represent small benefits to them. It is after the initial reductions that it will become increasingly difficult for them to cut back since more vital consumption needs are affected.

FINANCIAL ANALYSIS

General

Sound financial planning is justified in its own right but its absence may also have economic repercussions. Failure to analyze the financial aspects of an investment program will likely lead to delays in project execution which will diminish the net present value of the project assuming it was properly timed. In addition, delays due to periodic financial mini-crises will inevitably escalate real costs in case a stop-and-go operation will affect contractors several times. The two kinds of increased real costs should not be confused with balooning financial costs due to inflation at work during a longer period.

Failure to plan and provide funds for operations and maintenance expenditure will likely also produce higher economic costs. Existing plant will become inefficiently used and neglected maintenance will be followed by a shorter useful life of the installations, and breakdowns reducing benefits. When breakdowns become frequent, or the quality of service deteriorates much, there is a risk that consumers will try to improve service at their own expense. An illustration would be the duplication in investments where consumers install small water filters in their homes because the public system has failed consistently in producing good and safe water.

The examples show that faulty or deficient financial planning may affect both capital costs, i.e. costs incurred in investment activities, and current costs, i.e. those necessary to keep the system operating.

Financial Statements

Financial planning makes use of three kinds of financial statements with clearly separate functions although being at the same time integrated. The first part is the balance sheet which states what assets the utility has, and also describes how they have been financed. The asset side is balanced by the liability side that lists the different sources for financing of the assets, be it from equity (own funds), or debt. On the asset side a list of all assets is given, specifying whether they are fixed or not. Fixed assets are those facilities used in the operations, such as treatment plants and the network, whereas the other kind, circulating assets, can be examplified by cash and chemicals.

When studying both the assets and the liabilities it is of particular interest whether they are current or longer-term. The term current, or short-term, expresses a judgement whether the assets can be converted into cash in the short-term, or in the case of liabilities whether the probability is high that cash will be required to meet the obligations in the short-term. The difference between the current assets and the current liabilities is called the working-capital of the entity, and the ratio between them is logically called the current ratio. It is a compact measure of the entity's ability to meet itsd commitments over the next year.

Below there is a simplified balance sheet to illustrate the terms:

ASSETS

Current Assets

Cash and Equivalent	30
Accounts Receivable less Bad Debts	60
Inventories/such as chemicals and spares	60
Sub-total Current	150

Fixed Assets

Gross Fixed Assets in Operation	900
Less Accumulated Depreciation	300
Net Fixed Assets in Operation	600
Works in Progress	150
Otherx/Land for instance	50
Sub-total Fixed	800

Total Assets	950

LIABILITIES

Debt

Current

Short-term Debt	20
Portion of Long-term Debty due within a year	10
Accounts Payable	60
Sub-total Current Debt	90
LongOterm Debt	610

Equity

Contributions Made, Grants	200
Accumulated Earnings	50
Sub-total Equity	250
Total Debt and Equity	950

The balance sheet shows identical sums for total assets and total debt and equity. Using the illustrative figures the current ratio can be calculated as 150/90 or around 1.67 which indicates that short-term commitments will likely be honored without difficulty. An important share of current assets are accounts receivable, which are the claims the entity has, for instance on its customers for billed but not yet paid consumption.

The debt/equity ratio in the example is 700/250, or, another way of saying the same thing; out of total assets of 950 there are 250 financed by equity and 700 by debts. There are no absolute rules saying that it is better to finance an entity with more equity. There are examples of water companies financing all their assetswith debt and as long as they can generate enough cash to service the debts no harm is done. In practice, difficulties to generate enough internal cash makes it prudent to finance a share of assets by equity. Where investments are financed entirely by equity, such as government grants, there will likely not be any financial crisis on grounds of debt service but the problem has in a way been hidden. The difficulties may appear when the time comes to renew the assets.

The Income Statement

The balance sheet gives a neutral picture of the assets and does not say whether they are efficiently used or not. This information is provided by the income statementor, as it also called, by the profit-and-loss account. It says whether the entity is able to receive more income than it pays in costs in which case a profit results.

There are two kinds of income surplus which are of special interest. One is the net operating income, or income before depreciation, which is the difference between the revenue rerceived and the "visible" operating costs, such as wages, electricity and so on. The second kind of income surplus takes into account the wear of fixed assets in operation by charging depreciation, and the new surplus is callled income before interest. The latter when divided by the net fixed assets in operation produces the rate-of-return which is a measure how much of a surplus the entity can generate using the net fixed assets.

It should be repeated that depreciation allowances have no economic significance. They are only book-keeping entries to remind us that capital is slowly eaten up. Unless there are provisions to set aside funds to renew them there will not be any assets left eventually. Since depreciation is internally charged it stays within the company for its use. Together with the entity's net income, before taxes and interests, it constitutes the internal cash generating.

Below there is a simple income statement for a typi7cal water supply (and sewerage) company:

Income

Operating Income, Water Sales	400
Other Operating Income, Sewerage Levies	150
Non-Operating Income	50
Total Income	600

Costs

Direct Operating Costs, Wages, Fuel, etc.	300
Indirect Costs, Administration	50
Income Before Depreciation	250
Depreciation	100
Income Before Interest, Taxes	150
Interest	50
Taxes	50
Net Income	50

As can be seen the gross operating income is 600-300, or 300. The relation can also be expressed asan operating ratio which is in the case 50%. The rate-of-return on net fixed assets in operation is calculated as (Operating Income - Operating Costs - Depreciation) /Net Fixed Assets. Assuming that net fixed assets amount to 1,600 the rate of return would be 9.4%.

Cash-Flow Statement

The entity's ability to meet its short-term commitments is sufficiently important to warrant a special statement that is called a cash-flow statement, or flow-of-funds. It describes the cash transactions between the entity and outside interests that have taken place during a certain time period, usually a year. On one side of the cash-flow is the source of funds, on the other their application.

A common source of funds is the internal cash generation which is the net income before depreciation. Another customary source would be disbursements on loans or grants that the entity redeived for instance to execute a project. On the application side the project investments are often the major use of funds but also the debt service, i.e., amortization and interest on past loans, may require a large share of available cash. Any cash that remains after investments and debt service have been covered will add to the entity's cash, or generally current assets, thereby increasing the working capital. Below is shown a simple cash-flow statement:

Sources of Funds

Income Before Depreciation	250
Loan Disbursements	400
Total Sources	650

Application of Funds

Project Investments	450
Debt Service	
Amortization	50
Interest	50
Taxes	50
Increase in Working Capital	50
Total Applications	650

The financing of an ongoing or planned investment program is especially sensitive to prevent any interruptions in the work and a financing plan is therefore regularly set up. It is nothing else than part of the entity's cash flow, and in cases where a full cash flow is prepared the financing plan is net necessary.

CASE STUDY THIRTY-TWO - FINANCIAL PROJECTIONS FOR A WATER COMPANY

Background

A water supply company has requested a loan from a bank to finance a major investment program scheduled for execution during year 4-8. The prospective lender has asked for complete financial statements, covering at least three historical years and five projected years.

Analysis

The complete financial statements are shown on pages PP:123-125 and comprise balance sheets, income statements, and cash-flow statements for years 1 through 8.

The balance sheet can conveniently be analyzed starting with the net working capital which is dangerously close to zero during the years preceding the requested investment program. This would point to the need for a stronger tariff policy since cash shortages might otherwise slow project progress. The point is well-taken since most of the entity's working capital is in the form of accounts receivable which may not be all that easy to realize at short notice. Cash has shown a downward trend during years 1-3 while accounts receivable have grown more than sales.

Debt as a percentage of total equity and liabilities will grow during the period but not alarmingly much. Since the debt service coverage is well above unity in most years there should be nothing alarming in the debt growth.

Equity grows primarily because of increasing revaluation surpluses. Revaluation of fixed assets is done to reflect more fully the replacement cost of the asset base and also to automatically signal when the rate-of-return becomes unrealistically low in relation to the replacement cost of assets in operation. Such revaluation surpluses do not imply any funds flowing into the company but are only a book-keeping entry.

The income statement contains as its center-piece a simplified demand projection. It can be seen that the substantial sales increases during the early years are due to wider coverage while the consumption per connection is expected to decline slightly. This is a common experience when the service coverage increases. Lower-income segments become connected to a larger extent and theirt lower per capita consumption depresses the average. Per capita water production is likewise expected to go down since a program to lower water unaccounted - for from 35 to 20% is planned.

The income statement appears optimistic on several accounts. Both direct and indirect operating costs are projected to increase only slightly which is in marked contrast to the actual evolution during the years 1-3. This might not come about and tariffs would in this case have to be increased more. The rate-of-return during the three actual years is not impressive and is even negative during one year.

The cash-flow statement is derived for each year by comparing the balance sheets at the beginning and at the end of the year, respectively to obtain the differentials on key accounts, and then complement them with relevant data from the income statement. The debt service coverage is one important indicator of the company's financial health. In the case studied it is consistently above unity, and only in one year does it dip below 1.5. This would seem to indicate that the company will have few problems of servicing its debt properly.

The cash captured during the early years is used mainly for investments, and during the later years relatively more goes for debt service to pay off the large loans contracted to finance the works.

BALANCE SHEET, MILLION OF MONETARY UNITS

	Historical Years			Projected Years				
ASSETS	1	2	3	4	5	6	7	8
Fixed Assets in Operation	128.7	152.9	209.6	257.2	285.4	315.5	346.3	468.9
Minus Accumulated Depreciation	27.5	33.2	41.6	54.8	69.2	84.9	102.5	123.9
Net Fixed Assets	101.2	119.7	168.0	202.4	216.2	230.6	243.8	345.0
Work in Progress	16.8	29.4	10.3	4.0	20.0	70.0	95.0	6.0
Cash and Equivalent	3.3	0.8	0.2	0.7	1.4	6.8	3.4	3.5
Accounts Receivable	9.8	8.4	13.4	9.2	11.4	11.4	11.9	12.8
Other Current Assets	1.0	1.0	2.1	1.8	4.0	4.4	4.8	4.3
Sub-total Current Assets	14.1	10.2	15.7	11.7	16.8	22.6	20.1	20.6
Spare Parts Inventory	18.0	12.2	15.3	7.3	6.3	6.6	6.8	7.0
Total Assets	150.1	171.5	209.3	225.4	259.3	329.8	365.7	378.6
EQUITY AND LIABILITIES								
Equity	28.4	29.7	29.9	29.9	29.9	29.9	29.9	29.9
Revaluation Surplus	30.7	32.6	40.1	60.2	78.4	94.6	110.8	127.9
Operational Surplus	31.5	33.6	37.5	39.7	45.9	52.3	58.4	69.0
Total Equity	90.6	95.9	107.5	129.8	154.2	176.8	199.1	226.8
Long Term Debt	49.4	68.1	84.3	82.6	94.3	137.1	153.4	140.4
Current Debt	3.8	4.6	14.0	9.2	6.7	11.5	8.6	6.5
Customers' Deposits	6.3	2.9	3.6	3.8	4.1	4.4	4.6	4.9
Total Liabilities	59.5	75.6	101.8	95.6	105.1	153.0	166.6	151.8
Total Equity and Liabilities	150.1	171.5	209.3	225.4	259.3	329.8	365.7	378.6
Working Capital	10.3	5.6	1.7	2.3	10.1	11.1	11.5	14.1
%Debt/(Debt+Equity)	39%	44%	49%	42%	41%	47%	45%	40%

INCOME STATEMENT, MILLIONS OF MONETARY UNITS

Year	Historical Years			Projected Years				
	1	2	3	4	5	6	7	8
Population, Thousands	394	443	484	521	558	596	637	669
Population Served, Thousands	294	371	435	471	508	549	592	629
%Population Served	75	84	90	91	92	93	94	95
No. of Water Connections, Thousands	35	44	51	55	60	65	71	76
Volume Sold, Million m^3	21.0	24.5	30.6	33.1	35.1	38.0	41.0	43.6
Consumption/Connection/ Month, m^3	51	47	50	50	49	48	48	48
% Unaccounted-For water	35	32	23	22	21	20	20	20
Production, Million m^3	32.5	35.8	39.5	42.2	44.4	47.7	51.2	54.2
Per Capita Production, lcd	305	265	250	245	240	240	240	240
Average Water Tariff/ m^3, monetary units	0.75	1.00	1.01	1.01	1.37	1.34	1.36	1.61
Water Revenue	15.7	24.7	30.9	33.5	46.2	50.9	55.9	70.6
Other Operational Revenue	1.4	2.0	2.6	2.8	2.8	3.0	3.1	3.2
Sub-total Revenue	17.1	26.7	33.5	36.3	49.0	53.9	59.0	73.8
Direct Costs								
Wages	5.2	7.2	11.7	12.6	13.9	15.1	16.3	17.9
Power, Chemicals etc.	7.1	8.3	11.5	12.3	14.2	16.1	18.3	20.5
Sub-total Direct Cost	12.3	15.5	23.2	24.9	28.1	31.2	34.6	38.4
In-direct Costs	2.5	3.3	3.7	2.5	3.1	3.2	3.3	3.4
Total Costs	14.8	18.8	26.9	27.4	31.2	34.4	37.9	41.8
Income Before Depreciation	2.3	7.9	6.6	8.9	17.8	19.5	21.1	32.0
Depreciation	4.1	5.2	6.4	8.1	9.5	10.5	11.6	14.3
Income Before Interest	-1.8	2.7	0.2	0.8	8.3	9.0	9.5	17.7
Interest Charged Operations	1.2	2.0	1.4	1.6	4.9	5.7	6.7	10.0
Non-Operating Revenue	7.7	1.4	5.1	3.0	2.8	3.1	3.4	2.9
Net Surplus	4.7	2.1	3.9	2.2	6.2	6.4	6.2	10.6
Average Rate Base	85	110	144	185	209	223	237	294
Rate-of-Return, %	-2.2	2.4	0.1	0.4	4.0	4.0	4.0	4.0
Operating Ratio, %	87	70	80	75	64	64	57	54

FLOW OF FUNDS, MILLIONS MONETARY UNITS

Year	Historical Years			Projected Years				
	1	2	3	4	5	6	7	8
Sources of Funds								
Income Before Depreciation	2.3	7.9	6.6	8.9	17.8	19.5	21.1	32.0
Non-Operating Revenues (Net)	7.7	1.4	5.1	3.0	2.8	3.1	3.4	2.9
Gross Internal Generation	10.0	9.3	11.7	11.9	20.6	22.6	24.5	34.9
Customer Deposits Growth	0.4	-3.4	0.7	0.2	0.3	0.3	0.2	0.3
Disbursements, External Loans	0.0	0.0	0.0	0.0	14.5	41.5	16.8	0.0
Disbursements, Domestic Loans and Grants	23.7	20.1	16.8	6.0	2.3	7.3	6.1	0.0
Total Sources	34.1	26.0	29.2	18.1	37.7	71.7	47.6	35.2
Application of Funds								
Project Investments	17.0	32.3	25.3	11.5	19.9	54.9	27.1	7.0
Capitalized Interest	1.1	2.1	2.8	4.6	1.2	3.8	6.6	2.3
Sub-total Investments	18.1	34.4	28.1	16.1	21.1	58.7	33.7	9.3
Debt Service								
Amortization	2.1	0.0	0.5	7.8	4.9	6.2	6.6	13.9
Interest	1.2	2.0	1.4	1.6	4.9	5.7	6.7	10.0
Total Debt Service	3.3	2.0	1.9	9.4	9.8	11.9	13.3	23.1
Increase in Working Capital	0.2	-4.6	-3.9	0.6	7.8	1.0	0.4	2.6
Changes in Spare Parts Inventory	12.5	-5.8	3.1	-8.0	-1.0	0.3	0.2	0.2
Total Applications	34.1	26.0	29.2	18.1	37.7	71.7	47.6	35.2

CASE STUDY THIRTY-THREE - FINANCIAL ANALYSIS FOR TARIFF RAISE

Background

A major city is executing a large investment program for the last six years. Most of the works have been for added production capacity which has unfortunately proved premature as demand has not grown as predicted. At the same time, high inflation has escalated construction costs much beyond earlier estimates and also made tariff increases difficult for the consumers to accept. The combined result has been a severe cash crisis and during the sixth years of construction a financing deficiency of some 200 million monetary units is not covered. The deficit is temporarily "resolved" by not paying contractors and suppliers on time but this solution is obviously not practicable for a longer period.

From year seven onwards the city has to seek additional funding to conclude its investment program. The expected financing deficits are so large that a combination of borrowings and tariff increases is called for. Study the reasons for the shortfall in more detail and indicate how much will be required to conclude the program through year ten.

Analysis

The financial situation for the last six years and projected for the next four is shown on page 128. The analysis combines in one table the salient features of the balance sheet, the income statement and the cash-flow, and the focus is on the annual financing deficits.

The financial picture of the last six years' development leading up to a severe financial crisis can best be seen under "Earnings and Cash Flow". One major cause of the cash shortage is the fact that net operating income over the first six years has been rather constant in current money and fallen sharply in constant money since inflation rates have been high. The major cause for the eroded net operating income has been the relatively slow growth in consumption as compared to forecasts.

Equally serious is the fact that inflation has blown up the costs of the investment program while the expected internal cash generation to support the works has not materialized as hoped. The rapid investment pace has been maintained by using the available loans faster but in year 8 these will be exhausted. In that year the deficit grows to 1,400 million monetary units and becomes even larger in years 9 and 10.

The lower-than-expected net earnings and the higher-than-project fixed assets, due to the revaluation, have dpressed the rate-of-return on revalued assets. From levels above 10% in the early years it has fallen below 4% in year 6 and is unlikely to reach 6% during later years in spite of planned tariff increases which will double the nominal average tariff in some 4 years.

Unfortunately, it is difficult to see what dramatic improvements could help the company out of its financial straits. In year 10 more than 90% of the population is expected to be served. No large per capita increases in demand are likely in view of the past experience and further tariff increases. Consequently no substantial increases in the water volume sold are likely. Operations are already fairly efficient as evidenced by the percentage unaccounted-for water which is a commendable 20%, and no decreases in costs are probable. The additional connections that will be made will primarily be in the lowest-income neighbourhoods where payment's capacity is limited. Accordingly, little net revenue will be forthcoming from these connections since both connections costs and consumption rates are subsidized.

One way out might be to increase tariffs even further. Unfortunately, there is a limit to such higher consumption tariffs which has in some cases already been reached. As tariffs become high, some large-scale consumers will switch to private supplies and as they exist from the public system sales will grow even slower. Another solution would be a fixed levy on each connection which might influence sales less but would probably be most resented by consumers.

The alternative to ariff raises would be grants and loans to prop up the company's finances and this will in all likelihood be the solution selected. In order not to burden public budgets, either the national or the municipal ones, most of the additional funds will presumably be in the form of loans. These will saddle the city with a heavy debt burden for many years to come but there is really no alternative.

FINANCIAL PROJECTIONS TO DETERMINE DEFICITS

Balance Sheet	Actual Years						Projected Years			
Assets	1	2	3	4	5	6	7	8	9	10
Property, Plant and Equipment	2220	3250	4270	6270	7650	8480	-	-	-	-
Less Accumulated Depreciation	440	650	880	1240	1680	1950	-	-	-	-
	1780	2600	3390	5030	5970	6530	-	-	-	-
Work in Progress	900	900	1290	1350	2620	3460	-	-	-	-
	2690	3500	4680	6380	8590	9990	-	-	-	-
Current Assets										
Cash	10	20	20	40	20	50	-	-	-	-
Accounts Receivable	90	120	140	190	250	290	-	-	-	-
Inventories	80	80	80	100	110	120	-	-	-	-
	180	230	240	330	380	460	-	-	-	-
Other Assets	30	30	30	20	40	40	-	-	-	-
Total Assets	2900	3760	4950	6730	9010	10490	-	-	-	-
Liabilities and Equity										
Long-term Debt, Less Current Portion	690	960	1340	1820	2570	3200	-	-	-	-
Current Liabilities:										
Accounts Payable	110	150	220	250	220	330	-	-	-	-
Long-term Debt due within One Year	50	90	110	130	250	120	-	-	-	-
	160	240	330	380	470	450	-	-	-	-
Equity										
Contributed Capital	660	740	840	970	1150	1260	-	-	-	-
Retained Earnings	620	790	800	843	960	900	-	-	-	-
Revaluation Surplus	760	1030	1650	2730	3860	4680	-	-	-	-
	2040	2560	3290	4530	5970	6840	-	-	-	-
Total Liabilities and Equity	2900	3760	4950	6730	9010	10490	-	-	-	-
Earnings and Cash Flow										
Revenue	330	390	480	520	690	870	1280	1500	1770	2130
Expenses	210	240	360	480	610	760	920	1160	1460	1920
Net Income	120	150	120	40	80	110	360	340	310	210
Non-operating Income	60	70	140	190	250	330	380	470	580	800
Internally Generated Funds	180	220	260	230	330	440	740	810	890	1010
Debt Service	20	50	10	160	190	190	190	190	230	250
Increase in Working Capital	50	10	60	40	70	100	20	-	130	110
Usable Internally Generated Funds	110	160	190	30	210	150	530	620	530	650
Equity Contributions	100	90	130	170	210	230	270	360	320	380
Borrowings	200	330	170	280	620	620	890	520	-	-
Funds available for Investments	410	580	490	480	1040	1000	1690	1500	850	1030
Production	200	370	260	240	760	620	1220	1140	670	360
Distribution	170	150	170	190	200	230	370	750	900	990
Sewerage	-	-	-	-	-	-	-	610	620	820
Interest During Construction	40	60	60	50	80	140	200	400	320	350
	410	580	490	480	1040	1190	1790	2900	2510	2520
Annual Financing Deficiency	-	-	-	-	-	190	100	1400	1660	1490
Memo										
Average Rate Base	1090	1560	2200	3100	4060	4820	5770	7100	9050	14000
Rate of Return	11.8%	10.2%	7.6%	3.6%	4.0%	3.9%	4.2%	4.7%	5.3%	5.9%
Average Tariff	1.68	1.68	1.84	2.07	2.51	3.13	4.24	4.73	5.31	5.96
Operating Data										
Population million	2.6	2.8	3.0	3.2	3.3	3.4	3.5	3.6	3.7	3.8
Population Served million	1.9	2.0	2.2	1.3	2.5	2.9	3.1	3.4	3.2	3.8
Water Production million m^3	196	216	246	253	253	272	299	322	349	375
Water Consumption million m^3	146	160	172	183	197	211	236	255	278	300
Unaccounted-for Water	25%	26%	30%	28%	22%	22%	21%	21%	20%	20%
Number of Connections thousands	232	247	270	293	313	360	393	426	461	498

OPERATIONAL PLANNING

Introduction

Operational planning comprises efforts to maximize net economic benefits from the use of existing facilities. In contrast to project planning it is not concerned with investments but focusses on how to best use available installations. Just as with project planning it can conveniently be studied as an exercise in cost/benefit analysis. On one hand the aim should be to minimize current operating costs while achieving set objectives. On the other hand efforts should be made to connect the entire population and use facilities to their capacity.

Minimizing running costs in a system presents no particular problems in theory but can in practice assume many forms. In a water supply system depending upon several production sources the role should be to operate the sources in order of ascending short term marginal costs. Made investments should not influence operating decisions since these represent sunk costs, and what matters are only costs that will vary with differing production levels. For instance, in a system depending upon both gravity and pumped supplies the gravity supply will likely be fully utilized before pumping is started since it entails lower operating costs. It is immaterial that the gravity supply might have been much costlier to install since these costs will not vary with production levels.

The second aspect of the operational cost/benefit analysis concerns efforts to augment the benefits. This problem is more interesting in the case of water supply since it embraces not only technical and economic considerations but also cultural and sociological factors. In the present section two areas will be further discussed. The first area relates to appropriate connection policies to help potential users hook up to the system. The importance of proper connection policies is illustrated by the fact that is very rare to find towns or cities in developing countries with the entire population served from the public water system, be it through individual service connections or from public standpipes. Typically the poorer segments remain outside the public system even when they could afford to connect. At the same time there may be excess production capacity. The second area to be analyzed and illustrated in some detail will be tariff schedules to satisfy different economic and financial demands. Tariffs not only have implications for the short-term optimization of installed capacity but can also be used to depress demand and thus postpone capacity additions. This use of tariffs coupled with improved metering has already been amply analyzed under the section on demand forecasting.

A Marketing Approach to Community Water Supply

Undoubtedly, supplying good and safe water safisfies one of the most basic needs of man, at par with needs for food, shelter and clothing. After the first units of water are consumed, however, the perceived needs become less urgent and are influenced by a host of cultural, educational, climatic and economic considerations just to mention a few. What starts out as a physiological need to sustain life becomes a need changing with circumstances and can thus be manipulated. Water becomes a product like any other consumer product which aim at satisfying demand that can be stimulated. This way of looking at water supply is much different from how a water supply engineer views it. He would typically believe demand for water to be impossible to change and an exagerously given variable. Instead the water planner will have to learn how to promote his product, create the need for it, and then supply it and sell it on terms compatible with the population's capacity to pay for it. Rather than passively waiting for customers, the water planner should actively seek them out.

On the demand side it is significant to understand what benefits consumers associate with water supply. The fact that piped water available close to the house is easier to obtain and consume than in cases where water has to be drawn and carried over long distances is easily understood. As a minimum those carrying it, mainly women, could be easily convinced to support a piped water system. For this reason women should be targets for promotion of piped systems in order to enlist everybody's cooperation in the construction and upkeep of rural systems. Similarly, it is simple to explain to potential consumers that the water they will receive from a pipe, if it is clean-looking, is superior to what they are drawing from a polluted well. However, if the choice is between a safe water supply further away than a natural stream with clean but unsafe water, proper health education is required. Such health education will have to precede the installation of a system and acquaint consumers with the risks of drinking unsafe water. In his task, the health educator has to illustrate as tangibly as possible these risks. For instance potential consumers might peek into a microscope showing the contamination of their present supply of water. The goal should thus be to create and strengthen the perceived need for a safe water supply, and later on for waste disposal services. To the extent that externalities of water supply and sanitation services are grasped by the consumer, they become internalities to him and he may be convinced to press and pay for the service. In this respect the work of the health educator is no different from that of an advertising man trying to sell soap.

When marketing his product the water planner must take into account what the potential users are able or willing to pay for the services. To this end income levels and consumption patterns should be surveyed so that quantitative and qualitative service levels are made compatible with the population's payments capacity. Rural villages and low-income urban areas may initially only be able to afford a standpost supply and individual service connections will have to be introduced gradually as economic conditions permit it. It does not follow from what has been said that complete cost recovery from each distinct group is necessary but cross-subsidies could and should be introduced. It does mean that the service level provided should bear some relation to the income levels of the potential consumers.

Parallel with marketing water by way of creating a need for it, efforts should be made to facilitate access to the public system. There ought to be a minimum of legal requirements to connect, and instead of waiting for consumers to request service, the service area should be mapped to identify those that are not yet enjoying service. Just like more expensive consumer goods are sold under instalment plans, so should water supply and later on sewerage connections be made available by extending credit to those requesting them. In contrast to this common-sense observation full payment of substantial connection fees is often required before a consumer is allowed to hook up to the public system. Such a cash outlay often proves insurmountable for low-income households although they could afford the entire fee spread over a number of years. Conceivably, in situations with much excess production capacity and a comfortable financial situation one might even consider abolishing connection fees altogether and recuperate the cost of connections through the consumption charges. In contrast, there are examples of utilities that look at connection charges as one of their main sources for financing and low-income households are shut out of the system. This misses the justification of water supply services which is to produce water and ensure that it is consumed by the population.

CASE STUDY THIRTY-FOUR - MARKETING WATER TO LOW-INCOME CONSUMERS

Background: A city has concluded an investment program leaving it with much excess production capacity. In order to quickly take advantage of the excess capacity the water company intends to provide service to unconnected areas in the city populated by low-income households. A study is commissioned to estimate the potential number of households outside the system, and to examine whether current legal and financial connection policies need be modified to enable remaining households to hook up. In addition, it is decided to gauge the financial impact upon the water company that will result from connecting the low-income groups, given the fact that prevailing consumption tariffs for low-income consumers are subsidized.

Analysis: As a first step the extent of unserved areas is estimated in two ways. One measure is obtained by comparing recently updated maps of the company's water network with the most up-to-date urbanization maps. This type of comparison shows which areas do not enjoy full service. Estimates of investment needs in distribution mains, in secondary networks within the unserved parts, and individual service connections are also made. It is the policy of the company to promote individual service connections. Public standposts are provided free-of-charge in transient areas and where it is unlikely that the population will pay for service through house connections.

The comparison reveals that there are some 30,000 unconnected houses. The above estimate is cross-checked by totalling the water company's record of pending requests for connections. The number of pending applications is much inferior to the estimated 30,000 potential connections indicating a need for promotional campaigns to encourage consumers to request service.

The second step comprises a simple socio-economic sample to estimate average family income among unserved areas. A rapid survey estimates the family income as shown below:

Sample Distribution of Monthly Family Income

Range of Income	Percentage of Sampled Houses
Less than 800 monetary units	10%
Between 800 and 1,200 m.u.	12%
Between 1,200 and 1,600 m.u.	55%
Above 1,600 monetary units	23%

The median family income is calculated to be around 1,400 monetary units per month. In many cases both husband and wife are working with the wife generally working fewer hours outside the house. The average family size is estimated at eight persons. The above median family income could be compared with the average connection fee which is around 2,600 monetary units, and it is clear that financing for the lowest-income consumers will be needed, in order that they may connect.

The third step focusses on the legal connection policies in the belief that connection rates have been hampered by legal requirementes. Contrary to expectations, it appears that legal procedures have not impeded connections since exceptions are already introduced. In areas inhabited by recent rural immigrants no legal title to the land is necessary to connect, and the usual requirement of a building permit for the house is waived. The water company has itself established a joint committee to work with community grass-roots organizations in poor areas. Up till now the committee has been dormant but it is decided to activate it. Somewhat surprisingly, the evaluation of past failures to connect unserved houses demonstrates that the bottleneck has been lack of investment funds within the company rather than lacking motivation on part of the consumers to hook up and pay for the connections. Almost all funds within the company have supported large investment programs in additional production facilities to the detriment of distribution works.

The fourth step combines the findings of the socio-economic survey with the current financial connection policies. The company's policy has been to recuperate the entire cost of the house connection, including a meter, plus the cost of the secondary distribution network from the consumers through the connection fees. All remaining costs are recovered through consumption charges. Low-income households have been granted credit up to five years with no interest charge which in the prevailing strong inflation constitutes a considerable concession.

After calculating the monthly water consumption and connnection charge and relating it to income, the combined burden is shown to be around 8% of the gross family income for the poorest families. Although such a proportion may appear high, examination of past experience in low-income areas reveals that families have mostly managed to pay off. The default percentage has been in the order of 7%, in line with the water company's better-off consumers. There seem to be two explanantions for this encouraging record. First, income levels are notoriously difficult to estimate and interviewed families might have furnished lower than actual earnings in the socio-economic study. The interviewed might have feared that the information could be used against them, for instance for taxation. Second, since the inflation rates have been high the real tariff burden upon the consumers diminishes rapidly with time as the company charges no interest upon the connection loan. Consumers have compensated themselves for inflation through higher wages, whereas the monthly charge has remained fixed.

Concluding, the positive past experience from the practiced legal and financial connection policies and the identification of insufficient internal investment funds, as the main bottle-neck, imply that current connection policies are aceptable. They will therefore be continued while at the same time supplementary financing to accelerate distribution works is sought. It is further decided to impose a moratorium on sewerage investments in the areas in question to not increase the burden upon the households. The inhabitants in the low-income areas have not actively requested sewerage in addition to water, and it would be imprudent to execute any sewerage in addition to water. Constructing and charging for sewerage will have to await the time when he inhabitants themselves press for such services, since the cost recovery of the associated works would otherwise be too burdensome.

Financial Impact of Low-Cost Connections

In view of the water company's strained finances the financial impact resulting from connecting the 30,000 low-income households is evaluated. The detailed calculations of this test are shown in the table below. Provided the company can borrow money for distribution investments with a maturity of five years and a nominal interest charge of 20%, the financial consequences of connecting an additional 30,000 low-income households would be neutral. During the five years of repayment of the connection loans, the annual marginal costs of supplying the consumers would be well below even the low subsidized tariffs. The existing treatment plant will feed the system entirely be gravity and the only incremental production cost of importance will be chemicals.

Financial Impact of Connecting Low-Income Households

CAPITAL COSTS FOR CONNECTING UNSERVED HOUSEHOLDS

Distribution mains	9.5 million for 30,000 houses,	310 each
Secondary networks	16.6 million for 30,000 houses,	550 each
House connections		2,040 each
	Total investment per house	2,900 m.u.

Annual Debt Service at 10% interest over five years (with the capital recovery factor = 0.26) = 750 monetary units

CURRENT INCREMENTAL COSTS FOR SUPPLYING UNSERVED HOUSEHOLDS

Chemicals at 0.07/m^3, losses at 0.28, 28^3 monthly	Annual Cost 30 m.u.
Energy	Annual Cost -
Personnel	Annual Cost -

Total Annual Incremental Cost = 30 m.u.

Total Annuitized Incremental Capital and Current Costs = 780 m.u.

INCREMENTAL REVENUEL PER CONNECTION

Annuitized Connection Fee, 2,590 repaid over five years with no interest	520 m.u.
Annual Consumption Tariff, 28 m^3 per months	290 m.u.

Total Incremental Revenue Per Connection = 810 monetary units

The incremental revenue thus slightly exceeds the incremental financial charges and even on financial grounds, let alone social and economic reasons, the low-income households should be connected in the close future.

CASE STUDY THIRTY-FIVE - SEWERAGE CONNECTION RATES

Background: Large investments are contemplated in three medium-sized South Asian cities to provide the entire urbanized area with sanitary sewerage. Doubts have been expressed whether the proposed works are really of priority. It is claimed that existent sewers are not well used but instead clog up and at times are used as garbage dumps. It is decided to verify the truth of these allegations.

Analysis: Actual service levels for sanitary sewerage are estimated in the three cities through a field survey. The findings are shown below:

Sewerage Service Levels in Three Selected Cities

I Percentage of Total Population Served with Sanitary Sewerage

	Year 1	Year 6
City A	5%	9%
City B	5%	8%
City C	3%	9%

II Percentage of Total Population Served with Individual Systems

	Year 1	Year 6
City A	3%	5%
City B	3%	4%
City C	3%	5%

III Percentage of Population Connected to Installed Sewerage Lines

	Year 1	Year 6
City A	20%	25%
City B	20%	23%
City C	12%	13%

The proportion of the total population actually connected to the sewerage system has changed little during the last 5 years. Only a very small share of the total population in each city is connected, and the share has risen very slowly over the years. There simply does not seem to be a great urge to connect. The observation is borne out by the data on the unsewered population. Only a minor part has any alternative individual system, such as soakage pits, or septic tanks. The tentative conclusion is that the population does not assign high priority to an organized sewerage system, possibly because it is faced with much more pressing demands. Income levels are relatively low and it may well be that food supply, housing and clothing are given priority when competing for limited family budgets.

It can also be seen that areas where a water-borne waste disposal system has actually been constructed have only between 13 and 25% connected. The share of the houses connected has been almost static over the five-year period and the sewerage lines clog up because there are not enough people using them.

Why have so few households actually hooked up?. A comparison with the water network reveals that far from all houses in the areas sewered have water connections, and for anybody lacking water there is little incentive to connect to the sewerage system since water quantities drawn from standposts are small. Moreover, under the financial policies anybody connecting is obliged to pay the full cost of the connecting pipe from the house to the public sewerage line. No financing whatsoever is provided in spite of the substantial cash outlay. Thirdly, there is little point in sewering remaining areas of the cities until most of the population have water connections, and until a major share of the population in already sewered areas have connected to existing sewerage lines.

CASE STUDY THIRTY-SIX - TARIFF BURDEN IN SELECTED CITIES

Background: In a large Asian city connection rates to the public water system has been lagging and the management of the municipal company has identified high connection fees as a main obstacle. Since required cash outlay exceeds 25% of the total annual income for the lowest income groups, it is little wonder that these segments are largely unconnected. Moreover, free standpipe supplies and readily available groundwater provide alternatives to unconnected households. The management wants to increase connection rates by financing connection fees and would like to assess what the maximum combined burden of connection fee charges and consumption charges should be.

Analysis: The survey below of the tariff burden in selected cities all over the world is used as guidance:

Estimated Monthly Water Charges as a Percentage of Estimated Monthly Income for 12 Selected Cities

	Income Quintile				
	Lowest 20%	Second 20%	Third 20%	Fourth 20%	Upper 20%
Addis Abeba	9	8	8	6	2
Ahmedabad	4	4	11	12	27
Bogotá	1	1	1	1	2
Bangkok	1	1	2	2	1
Cartagena	1	1	1	1	1
Kingston	2	3	6	4	1
Lima	5	2	1	1	1
Manila	9	2	2	2	1
México City	Less than 1% at all income levels				
Nairobi	7	6	6	4	2
Sao Paulo	5	2	3	3	1
Seoul City	Less than 1% at all income levels				

Source: World Bank, Development Economics Department.

It would seem that some of the survey data have underestimated income levels and/or overestimated water-related charges since the implied shares of income that would go for water concumption seem very high. Discounting these out-lying observations it appears that connection and consumption charges could well be in the order of 5% of income without causing undue hardship. After connection charges have been repaid the burden will decrease considerably.

The indicative percentage of 5% is also supported by data from a household expenditure survey conducted in the city itself. In particular, the share of the income class mean expended on tobacco and alcohol is as follows:

Less than 3,000	5
3,000 - 6,000	8
6,000 - 9,000	8
9,000 - 12,000	8
12,000 - 15,000	8

For all income groups the share for these "expendable" expenditures is above 5%. It does not seem unreasonable to require connecting housefolds to pay 5% of their gross income on combined connection and consumption charges. To facilitate billings and collections such charges would have to be supported by propaganda campaigns to explain why the charges are necessary. Such campaigns are often useful when major investment plans require tariff increases and can in such cases be helped by the tangible evidence of ongoing works. The importance of good public relations in social sectors such as water supply and sanitation cannot be underestimated.

With regards to maximum permissible water-related charges it is difficult to give upper limits. Investments are rather limited by insufficient public savings, and an efficient utility manager who manages to raise tariffs should be encouraged to do so.

TARIFF THEORY

Introduction

Before examining more closely the various aspects of water supply and sewerage tariffs, it may be helpful to answer the more basic question: "Why should water supply and sewerage be priced at all?". It is indeed not uncommon to encounter the opinion that social services should be supplied free of charge. Advocates of this position claim that through the service charge the poorer segments of society are discriminated against since they may not have the means to pay. They may hence be deprived of the basic human right of good and safe water according to this line of reasoning.

Such views are best answered by studying how low-income people fare in systems where no or very low charges are levied. It is common knowledge that the poor are the first to be left outside the public system or make do with water vendors or public stand pipes. Since the poor have few means to influence the water company to extend service into their area the situation may persist.

The water authority, in turn, may be unable to undertake the necessary investments for lack of funds. Without any dependable source of income they have to rely upon municipal or national budgets for financing. Now developing countries typically have difficulties raising public revenue, partly for lack of efficient administrations. A water supply entity dependent upon other branches of the public administration will find it difficult to plan investments without any certainty that the financing will be there. Furthermore, reliance upon others for funding entails the risk that the entity may be told how funds should be used, for instance in which towns or areas works should be undertaken. Such considerations, often political in nature, may not coincide with the most pressing needs.

Additionally, where no charges are levied subsidies will be unevenly distributed. Whoever consumes more will receive larger subsidies. As is well known, those consuming the most per capita are precisely those that could best afford to pay for the service, since per capita consumption is well correlated with income. The proclaimed equitable system with no tariffs turns out to favor the wealthier groups and discriminate against the economically weaker.

Not only that. Water usage becomes wasteful when it is free and the service correspondingly costlier. This is frequently encountered in unmetered systems where consumption charges bear no relation to consumption levels, and where consumers have no incentive to economize on water use.

Summarizing, a water system without tariffs related to consumption will likely become wasteful and inequitable with the better-off receiving higher subsidies than poorer groups. The poorest population segments will likely have limited or no access, quality of service will suffer because the water authority will be without a dependable source for financing. Such a system is far from ideal and tariffs should instead be levied. A fortiori, charges should be set a level that recovers the totality of the capital and current costs associated with investments and operations, so as to encourage efficient water consumption.

The Three Roles of Tariffs

Any tariff charged will entail three consequences. Firstly, it will influence resource allocation and the efficient use of resources. Secondly, whereever charges are allowed to deviate from costs income will be redistributed. Thirdly, irrespective of the economic consequences a tariff will raise financial revenue to cover capital and current costs. The first two aspects, related to efficiency and income redistribution are economic in nature. They work against each other since a completely efficient tariff will not redistribute any income whereas a tariff with redistribution will by definition not be economically efficient. A distinction should be made between the average tariff level which can be obtained in different ways through varying tariff structures. The structure can have unit costs increasing or decreasing with rising consumption but average tariff levels could be the same. It is primarily through different tariff structures that income is redistributed since water consumption levels and income levels are positively correlated.

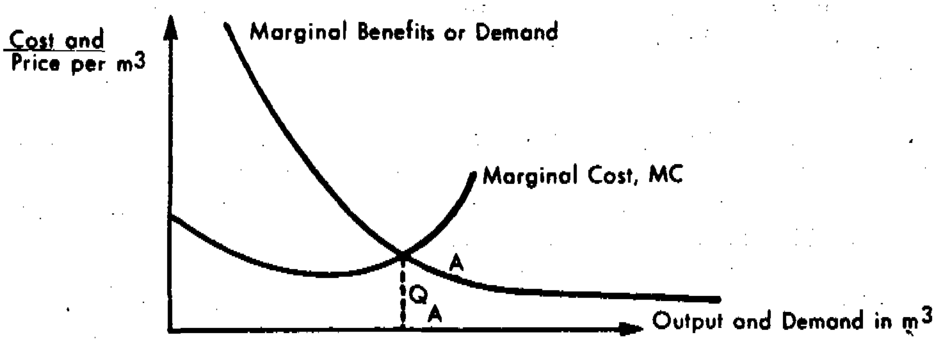
Economically Efficient Tariffs

An efficient tariff charges each consumer the marginal cost of the water supplied to him. It follows there is a marginal cost for each consumer, and that it can change overtime and with production levels. In practice, marginal costs can be approximately the same for consumers within a given area of a city, or for the whole city, or even for entire regions. The marginal or incremental cost, as it is also called, is defined as the cost of supplying one additional unit, in this case another cubic meter of water. To comprehend why a tariff equal to the marginal cost is economically efficient it is useful to study Graph 1 below.

Graph 1

WATER DEMAND CURVE AND WATER MARGINAL COST CURVE

GRAPH 1 Water Demand Curve and Water Marginal Cost Curve

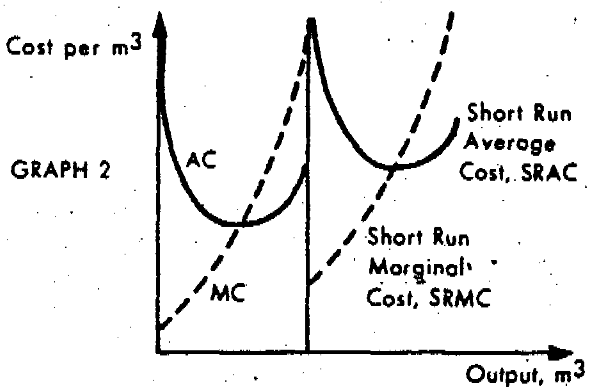


The graph illustrates the conventional wisdom on what demand curves for water look like and which has been confirmed in a few empirical studies. Water demand becomes increasingly inelastic with lower per capita comsuptions while it is more price sensitive for high consumption levels. This helps explain the large reductions in consumption following the introduction of metering. The marginal cost (MC) curve assumes high costs to supply the first cubic meter (since costly capacity costs is required), costs falling over an interval (where only operational costs are required to increase output), and finally costs increasing when additional works become necessary to further augment production. The interesting point in the graph is A, where the MC-curve and the demand curve intersect. Point A with the production Q_A is optimal from the resource allocation point of view and is obviously on the MC-curve. The optimality can be understood by studying output levels different from the optimal Q_A. If output were larger than Q_A it would cost more to produce such water than the consumers would value it at. The demand curve not only shows what consumers are willing to pay per unit water at different outputs, but it also shows benefits they derive from them. Correspondingly, if output were below Q_A it would pay to increase output up to Q_A since the benefits of these additional quantitites exceed the cost of supplying them. Only Q_A is the output level where the benefit from consuming the last cubic meter water is equal to the cost of supplying it.

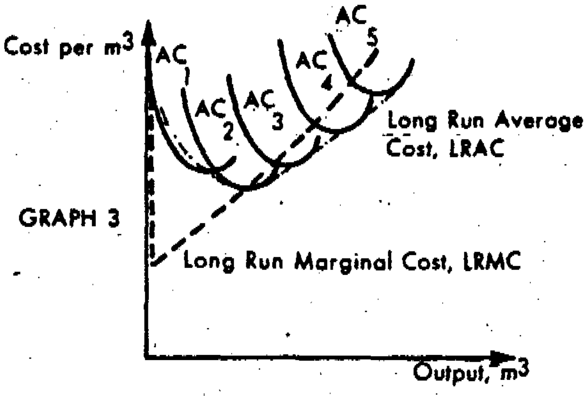
There is another rationale for insisting on marginal cost pricing in the case of water supply. Since water project benefits can only be estimated in exceptional circumstances, and even then not very reliably, MC-pricing provides some guarantee that project investments are justified. In case the incremental output from a water project is not consumed when tariffs are set at marginal costs, it signals that consumers attach lower benefits to the output than the cost of supplying them. The conclusion is that the project is economically nonoptimal. Conversely, if the project output priced at the marginal cost is absorbed at once and unmet demand still persists, the investment was amply justified and further investments are justified up to a point. The use of marginal cost pricing has the effect of shifting the burden of justifying investments away from the cost/benefit analyst to the consumers themselves. All the analyst will have to do is to price water correctly and then observe the consumer response.

However identifying appropriate marginal costs for the pricing decisions is not easy. For one thing, it is not always clear which should be the marginal cost to guide tariff decisions. Graphs 2 and 3 below illustrate the difficulties.

GRAPH 2



GRAPH 3



Graph 2 represents the straightforward definition of marginal costs, the short-run marginal cost. The curve simply tells how much it costs to produce one additional cubic meter of water at different output levels. The first cubic meter supplied by a system is exceedingly expensive since it requires the construction of the entire system whereas additional units will only require operating costs. This implies that the pure marginal cost curve is discontinuous. The short run marginal cost will rise to a level when the initial capacity has been exhausted and operating costs have reached a level where investing in additional capacity becomes justified. The marginal cost then jumps again and the process is repeated. For comparison the respective average cost curves have been shown in the graph. It can be seen that in part of the interval the MC-curve is below the AC-curve, in part it is above.

Although it is theoretically correct to price water along the short-run marginal cost curve, in practice its wild gyrations make it impractiable. Instead one might attempt to price according to the curve shown in Graph 3, the long run marginal cost. The LRMC-curve can be constructed from the long run average cost curve which is the envelope of the series of short run average cost curves SRAC. The LRMC-curve in part is below the LRAC-curve, in part above it. Pricing along the long run marginal cost curve is more practical since it smoothes the gyrations of the definitional marginal cost curve. In the interval where the LRMC-curve lies above the LRAC-curve the tariff will also generate financial surpluses, while subsidies are needed when the LRMC-tariff is below. The long run marginal cost curve includes the charges for capital expansion, and it serves as a guide for investment decisions, signalling to water consumers what the overall cost of water is and what it will be in the future. In order to provide an opportunity for consumers to adapt their consumption and investment patterns, the tariff based upon the long-run marginal cost should be implemented <u>before</u> the works are initiated. It should furthermore be levied both on existing and future consumers since each cubic meter consumed in the system requires operating costs and possibly investment costs.

PRACTICAL CONSIDERATIONS FOR MARGINAL COST PRICING

The long run marginal cost curve is somewhat difficult to pinpoint in practice and planners need something more operational. Such a formula for approximating the long run marginal cost is provided by the so called average incremental cost, AIC. It is defined as the ratio between a numerator equal to the sum of discounted capital and current costs over a specified period, and a denominator which is the sum of the discounted annual outputs related to the capital and current costs in the numerator. AIC should be calculated each time a major capacity addition is decided and the annual production volumes should refer to the incremental output for the capacity additon, up to the point where its useful life is over. In arithmetical form AIC is written

$$AIC = \frac{\sum_{t=1}^{T} \frac{\text{(Capital Cost + Current Costs)}_t}{(1 + r)^t}}{\sum_{t=1}^{T} \frac{\text{(Annual Incremental Project Output)}}{(1 + r)^t}}$$

Here T stands for the number of years that the capacity addition is expected to serve, and "r" for the appropriate discount rate, equal to the opportunity cost of capital.

The AIC may signal the approximate trend over the next 10 years since major additions will often be designed for this period. It will serve as a guide for investment decisions and smoothe the marginal cost curve since it spreads capital costs over and extended period. It also takes into account differing levels of capacity utilization through discounting the annual outputs. Whenever demand is slow to grow into the available capacity, outputs during early years will be relatively small, and the heavier output during later years will be more discounted. The combined effect will be a small present-value sum of water. Since the water sum appears in the denominator, the resulting AIC wil be high, reflecting a poor scale and timing of investments.

The application of AIC-pricing will not obviate the need for periodical adjustments during the lifetime of the addition. AIC is calculated in constant money and would recuperate the investment costs if charged over the project lifetime in a non-inflationary economy. Since tariffs are in current money to account for inflationary changes in operating costs, the AIC tariff will have to be periodically adjusted. In countries with rapid inflation, and where it may be politically difficult or administratively cumbersome to adjust tariffs, water rates have in cases been linked to a suitable index and adjusted automatically. Such smaller and more frequent corrections also seem to be more easily accepted by consumers as compared to infrequent, large tariff increases.

Income Redistribution through Tariffs

Completely efficient tariffs are rare or non-existent, partly due to the difficulties of charging each consumer his particular marginal cost. As soon as tariffs are allowed to differ from the marginal cost, income will be redistributed. Such redistribution may go both ways. There may be large industrial consumers to whom supply is cheap given efficiencies of scale in water production and distribution. Yet they may be forced to pay the same price or even more than small domestic consumers. Similarly, there may be consumers living for instance in a hillside area with expensive supply, but who pay no more than the standard rate.

In addition to such accidental income redistribution due to administrative inertia or impracticality of discriminating, there are also good reasons for employing water tariffs as a vehicle for income redistribution. The most direct and important form water supply can serve this purpose is simply to make supply available to everybody through vigorous connection policies combined with standpost supplies. Over and above this, low-income consumers can also be subsidized by the welthier consumers via properly designed tariff schedules.

Water supply tariffs are well suited for this. First of all, there is a good correlation between income levels and consumption levels. Such a covariation can be illustrated by comparing Lorenz curves, showing income distribution, with distribution curves of water consumption. Their general appearance is quite similar confirming the findings of positive income elasticities of water demand. In case the Lorenz curve were identical to the consumption distribution curve the water income elasticity would be unity, highly propitious for redistribution.

A second factor in favor of redistributing income via water tariffs is the relatively low price elasticities of water demand. After demand has been allowed to adjust to metering and tariff increases, water demand is little sensitive to price changes, and certainly so for low-income consumers. This implies almost vertical demand curves. If the price is permitted to deviate from the marginal cost, the demand output will will not change much from the omtimum level. Loss in efficiency from income-redistributive tariffs could be expected for large consumers, however. At an extreme, tariffs for large consumptions would be so high that individual consumers might construct their own supplies.

A third factor in favor of income-redistributive water tariffs is the fact that water companies are often more efficient than for instance tax collection services. In addition, there is in most countries the effective sanction of discontinuing water service in case consumers refuse to pay bills.

The Financial Function of Tariffs

The function of raising revenue to defray investment and operating costs takes on added importance in developing countries.

There the financial revenue base is much more narrow than in developed countries, partly because average income levels are lower, partly because the income distribution is more unequal. In this context, the application of tariffs to raise as much fiscal revenue as possible will also be those that redistribute income. Strong revenue-generating tariffs will necessarily conflict with the requirements for efficient tariffs along marginal cost lines. As was mentioned earlier, a tariff based on marginal costs would result in financial deficits whenever the marginal cost happens to be below the average cost. Although such shortfalls could in theory be met from general tax revenue, it is far from certain that this would be preferable from the efficiency or equality points of view. It could well be that public revenue is raised through taxes that introduce more serious distortions than non-efficient water tariffs.

There are other factors speaking against the application of marginal cost pricing where such tariffs will produce losses. Permitting or even encouraging a water company to incur losses will likely lead to a lower operating efficiency within the water company itself, as a carefree attitude about cost control and efficient operations may be the result.

Suggested Average Tariff Levels

Any water tariff will have to strike a compromise between the conflicting demands of economic efficiency, income redistribution, and generation of financial revenue. Exactly what the balance should be will have to be determined in each individual case and will be influenced by a host of other considerations, such as administrative capability, past tariff policies, and financing practices. For reasons outlined above the average tariff level is suggested to be set so as to make the water entity financially autonomous. This means disregarding the marginal cost pricing whenever financial result where marginal are above average costs, however, they could well guide the tariff level for units consumed above a suitable minimum consumption. This might entail the generation of excess cash although in practice such funds could be used to finance the vast unmet investment requirements of the water supply and waste disposal sectors in developing countries.

Suggested Tariff Structure

Income is primarily distributed by adopting proper tariff structures although it could also be achieved by setting a straight unit cost above marginal costs of supply. The most appropriate tariff structure would seem to be a two-tier tariff of the so called life-line type. A minimum amount of water is provided at a fixed rate, and consumption in excess thereof is charged at the full marginal cost to satisfy the requirements of economic efficiency. Apart from encouraging the consumption of the minimum amount of water on grounds of health benefits, a tariff of this type could also cross-subsidize by charging varying amounts for the first basic quantity. For instance, if the basic allowance is set at $15m^3$ monthly, corresponding to 100 lcd for a family of five, the charge could be nominal for the lowest-income consumers, and many times more for high-income brackets.

Actually, income levels for different consumers are not available on an updated and reliable basis and some proxy for income has to be found. The most fitting would seem to be the value of the property supplied with water. Such property values are readily available in most countries since they are a basis for taxation. Income levels and property values are well correlated and varying the payments for the basic allowance as a function of property values, income can in the process be redistributed through the tariff.

Charging for Sanitary and Stormwater Sewerage

Sanitary and stormwater sewerage are different in nature from water and should accordingly be charged separately. Sanitary sewerage, being the direct consequence of water supply, should be charged together with it, for instance as a percentage of the water bill. This has the advantage of being administratively simple. Although in theory both those with sewerage connections and those without should pay, although not necessarily equal amounts, public acceptance will likely make it necessary to charge only those with sewerage connections.

What has earlier been said concerning externalities applies with particular force for sewerage. It is common to find situations where a city discharges polluted water into a recipient to the detriment and nuisance of communities downstream. Clearly, the polluters should shoulder responsibility but most often this does not happen. The relationship between improved sanitary sewerage and a healthier population is largely unknown and it is thus difficult to judge to what extent such external economics should be incorporated into the tariff decisions. As for water supply, the lack of quantitative relationships between improved sanitation and health are regrettable but little can be done about it.

Stormwater drainage is a service with few, if any, health benefits. It is unrelated to water supply but concerns the evacuation of rainwaters. Good drainage of a property can be expected to raise its value, and it is natural to recuperate such investments through levies on property values. Such betterment taxes can be levied on all properties that benefit from the improved drainage, in proportion to the benefits derived.

Where sanitary and stormwater drainage services are combined, the resulting tariff will have to be a compromise between the types of tariffs discussed above.

CASE STUDY THIRTY SEVEN - SEASONAL PRICING ALONG MARGINAL COST PRINCIPLES

Background: In an arid sea-side area tourism has developed rapidly, favored by a pleasant climate and relative proximity to major tourism markets. One upcoming obstacle for futher growth are the limited water resources in the area. At present ground-water from wells some 110 km away supplies the tourism zones as well as the resident population. Once these wells are fully used it will probably become necessary to desalt seawater which will cause production costs to jump. In order to postpone as much as possible the introduction of desalting it has been suggested to price water along marginal cost principles to signal to consumers the high cost of developing the last stage of the well field. By doing this it is expected more economic water-consuming installations will result, and that current consumption will be more careful. At the same time it is acknowledged that any impact upon hotel operators resulting from higher water tariffs should be held within reasonable limits, so that the desirable tourism industry will not suffer.

Analysis: In order to serve as a proper price signal for future investments, the true cost of water during the foreseeable future should be reflected in the prices consumers pay. Prices should also optimize use of existing capacity by encouraging the transfer of demand from peak to off-peak seasons. Pricing along marginal cost would equate the value to the consumer of consuming the marginal unit with the cost of supplying it.

The implication is that as long as there is excess capacity the consumers should pay only for the short-run marginal cost, or SRMC. These comprise only incremental operating costs since past investments are treated as sunk costs. As demand reaches system capacity, SRMC will rise due to increased friction losses - and increased pumping costs. Either the SRMC will become so high as to justify investments in additional capacity or, more likely, technical limitations will fix maximum yield and additional works to provide more production capacity will become necessary. At this point, the price consumers are willing to pay for the final unit of existing capacity should justify the additional investment, i.e. they should be willing to pay the long-run marginal cost, LRMC which includes running costs as well as capacity costs.

The correct handling of capacity costs is especially problematic when peak loads occur. A peak load is said to exist at any price when the quantities demanded in different periods are unequal. A common example would be when the quantities produced are not storable at a reasonable cost, which is thought to be the case here. The peak can be of two kinds, a "firm" peak and a "shifting" peak.

In the first case, the quantity demanded during the peak period is superior at all prices to the quantities demanded during the off-peak period. In the second case, the peak may shift if a sufficiently high price is charged for peak consumption and a sufficiently low price for off-peak consumption. The underlying assumption in both instances is that demand exhibits some elasticity, i.e. a price change will induce a change in the quantity demanded.

A pricing policy aims at maximizing the sum of the consumers and producers not benefits over the peak and off-peak periods. The optimal policy in the firm peak case is to charge all the capacity costs, in addition to variable costs, to the peak consumption, and make the off-peak consumption pay only its variable costs. The prices are thus completely cost-determined. In the shifting peak case account has to be taken of the demand curves in the various periods and their elasticities. The efficient pricing policy is again to charge the capacity costs to those periods which make the peak demand upon capacity, but in addition make the prices proportionate to the strength of their demands. In this way different consumers pay different prices for the same product and the pricing policy discriminates in direct proportion to the capacity costs they impose. All units pay for their variable costs, of course.

In the case of the tourism area under study consumption exhibits a seasonal peak pattern with the summer quarter consumption (July-September) being around one and a half times the yearly average. The main determinant is the seasonal tourism, but for climatic and employment reasons the consumption of the resident population has a summer peak as well. Nothing is known about the elasticity of demand curves for the different calendar quarters, and a recommended pricing policy will therefore be based only on what is known about costs. If the peak is firm, such a procedure is satisfactory but with a shifting peak the prices will have to be adjusted in a trial-and-error fashion so as to approach the optimal pattern. In other words, if a peak price would be announced for a pre-determined peak period, consumers might want to switch from the predetermined peak to the off-peak period in such a way as to make the predetermined "peak" the real off-peak and vice versa. Due to the long peak period (three months) in the present case, it is improbable that the peak will shift significantly so that this complication is unlikely, and the concern is rather to induce consumers to economize on water use during the peak season.

For the actual determination of the long run marginal cost in the tourist area, it is approximated by the average incremental unit cost, AIC. This cost is the sum of present-value investment costs divided by the sum of the present values of water quantities produced by the facilities during their life-time. The AIC charged to the quantities consumed during the facilities useful life would consequently recuperate the investments costs in real terms. In the case analyzed the AIC is taken to be the cost of the next major capacity addition which is the one developing fully remaining known groundwater resources. The investments involved are for wells, transmission lines with pumping stations, and minor complementary distribution works.

For the calculations the capacity and maintenance costs are charged entirely to the peak quarter consumption in the belief that the peak is firm. In essence, it is the peak consumption that sets the investment pace and it should therefore be signalled what costs it is causing. With additional information on demand once a peak price has been introduced, the capacity charges may be spread over a longer period. If thus costs are allocated according to this criterion the following costs during the peak quarter are obtained:

COSTS IN MONETARY UNITS PER M^3 OF PEAK QUARTER CONSUMPTION

Category	Capacity Costs	Maintenance	Operating	Total Costs
	I	II	III	IV
Tourism	400	40	10	450
Non-tourism	260	30	10	300

The present tariffs are uniform all through the year. The charge is 68 monetary units per m^3 for all consumers, except for public standpipes for which consumption the responsible municipalities pay 34 monetary units per m^3 consumed. In proposing a future higher tariff scale some concessions should be made to these lower tariffs on social grounds whereas the full average incremental cost could be charged to large consumers. A suggested schedule migth then be:

PROPOSED WATER RATES IN MONETARY UNITS PER M^3 CONSUMED

Quarterly Consumption	Rate during Each Calendar Quarter			
	I	II	III	IV
Public standpipes	34	34	34	34
For first 100 m^3	68	68	68	68
For units between 100 and 1,000 m^3	10	10	300	10
For units above 1,000 m^3	10	10	450	10

A peak quarter consumption of 1,000 m^3 corresponds to the consumption of a hotel of some 20 beds, and practically all hotels fall into this category. A peak quarter consumption of 100 m^3 corresponds to the consumption of a family of around 10 persons. Most public buildings would consume more than this.

The tariff schedule proposed, although theoretically roughly correct, might have to be modified to gain public acceptance. To blunt any opposition from domestic consumers their present rates have been maintained provided their consumption is prudent. Since public standpost consumption is assumed to be relatively inelastic, partly because it is not paid in cash by the consumers themselves the corresponding rates have also been kept constant and would remain so as long as the financial requirements of the system are met by total revenues. To ease the financial strain on consumers that would see their tariff burden much increased, it is proposed that payments of the peak quarter bill could be spread over the whole year if the consumers so wish.

Expected Impact upon Hotel Profits

Opposition to a tariff increase up to the full economic cost could be expected to be strong. It has been argued that on macroeconomic grounds it is justified to subsidize the entire infrastructure, as water subsidies will be more than balanced by increased fiscal revenues generated by the tourism industry.

However, even if the subsidies are more than recuperated at the macroeconomic level it would be erroneous to take this as justification for them. Subsidizing consumption of costly water is inefficient and more distortionary than cash grants or tax concessions. The case for the subsidy seem based on the fear that hotel entrepeneurs are in a buyers market and can effectively play off subsidies from different countries. Prospective hotel owners would probably not be insensitive to an increase in water tariffs without some form of compensations as the following table indicates:

IMPACT OF WATER TARIFF INCREASE ON HOTEL PROFITS

	De-luxe Tourism	Medium-Cost	Low-Cost Tourism
Gross Income in m units per night	7,500	4,000	2,000
Gross Profit at 50% Occupancy (before depreciation and financial charges)	2,200	1,300	700
Average Consumption of Water in m^3 per night	0.90	0.75	0.50
Rise in Water Bill with peak rate at 450 m.u. per m^3, off-peak at 10 m.u.	90	75	50
Cost Rise as Percentage of Gross Profits	4%	6%	7%

The impact is the greatest on the cheaper tourist accommodations whereas the de-luxe hotels should be able to absorb the higher water charges in spite of their higher depreciation charges. The data support the intuitive conclusion that the region should concentrate on high-class, year-round tourism to obtain a higher degree of utilization of the infrastructure.

The incremental tax revenue according to estimates from incremental tourists are estimated at some 23% of total tourist expenditure, excluding any multiplier effects. A tourist is reckoned to spend from 2,900 up to 10,700 monetary units daily depending upon accommodations. The corresponding incremental tax revenue will then vary from 600 to 2,400 monetary units per day. On a macroeconomic level the water subsidies are clearly recuperable, since other subsidies and social costs are small.

CASE STUDY THIRTY EIGHT - INCOME REDISTRIBUTION THROUGH WATER TARIFF

Background: In a South-American country the policy has long been to recuperate investment and operating costs from tariffs. Accordingly, charges have been set at average levels dictated by the financial needs. At the same time, tariffs have been used to encourage the consumption of a minimum water amount on grounds of health benefits. A monthly water allowance has therefore been supplied at a fixed rate, and any consumption in excess thereof has been charged at progressive unit costs. In addition, for equity reasons the fixed charge for the basic water allotment has varied in relation to the value of the property, with more valuable properties paying several times more than the low income consumers. In an effort to standardize tariff structures over the entire country, although letting average tariff levels be determined by local cost conditions, it is decided to undertake a study on the income redistributed as a result of water tariffs.

Analysis: Contemplating the suitability of water tariffs as a means for income redistribution, it is clear that the scope depends upon the price elasticity. If water demand were completely inelastic, the potential for income distribution is high with no adverse effects on resource allocation. On the other hand, a very price-sensitive demand would lead to distortions as soon as tariffs would be allowed to deviate from marginal costs. In the case of the cities studied, preliminary findings are that price elasticities of water demand vary from - 0.4 to around 0. These relatively low values are encouraging then for the purpose of redistributing income.

To gauge the income shifted between the different consumer categories, the absolute monetary transfers between population income quintiles as a result of water tariffs were estimated. These were then related to the median income levels to arrive at their relative importance.

Data on tariff schedules and payments were obtained for 18 cities and towns and are shown on the adjoining table. In all localities is a two-tier system implemented with a fixed amount being charged for a basic monthly allowance, usually 25m^3, and constant or progressive unit rates applied for consumption in excess of the basic allowance. The fixed charges vary according to property values with sharp progressivity.

WATER TARIFF SCHEDULES FOR SELECTED CITIES
(In monetary units)

City	Lowest Fixed Charge	Highest Fixed Charge	Monthly Allowance	Unit Rate for Excess
A	5	130	15 m^3	0.8-5.4/m^3
B	4	192	30 m^3	0.4-0.7/m^3
C	7	150	25 m^3	1.4/m^3
D	5	70	25 m^3	0.7/m^3
E	5	50	25 m^3	1.4/m^3
F	15	190	25 m^3	1.5/m^3
G	5	80	25 m^3	1.3-1.6/m^3
H	5	170	25 m^3	0.8-1.6/m^3
I	16	200	25 m^3	1.4/m^3
J	8	80	25 m^3	1.2/m^3
K	3	40	25 m^3	0.7/m^3
L	7	155	25 m^3	0.8/m^3
M	10	200	25 m^3	1.4/m^3
N	9	72	25 m^3	0.9/m^3
O	8	60	25 m^3	0.8/m^3
P	5	71	30 m^3	0.4-1.7/m^3
Q	14	70	25 m^3	0.5/m^3
R	5	70	25 m^3	0.7/m^3

Comments: The lowest fixed charge ranging from 3 to 16 monetary units can be compared to the minimum daily income which is around 25 monetary units, although not always strictly followed. The ratio between the highest fixed charge and the lowest varies from 48:1 to 5:1. The average tariffs charged show large variations between the different cities in response to different hydrological conditions and varying sucess in satisfying the financial requirements.

The findings on relative transfers are shown in the table below:

AVERAGE TRANSFERS AS A PERCENTAGE OF AVERAGE INCOME
POPULATION INCOME QUINTILES

	First	Second	Third	Fourth	Fifth
A	0.0	2.1	1.2	0.3	-0.6
B	0.0	0.6	0.3	-0.1	-0.1
D	0.0	0.7	0.4	0.1	-0.2
E	0.0	0.5	0.3	0.0	-0.1
F	0.0	0.5	0.7	0.3	-0.3
G	0.0	0.5	0.4	0.2	-0.2
J	0.0	0.4	0.4	0.1	-0.2
K	0.9	0.8	0.5	0.2	-0.3
M	0.0	0.4	0.8	0.1	-0.2
N	0.0	0.8	0.3	0.0	-0.2
P	0.0	0.5	0.8	0.2	-0.3
Weighted Average	0.0	1.3	0.8	0.2	-0.4

As can be seen from the table the relative transfers vary between the cities, in magnitude and in terms of who receives the largest transfers. In general, the tariff schedules are constructed in such a way that the highest income quintile subsidizes all the others. The share of their income destinated for this purpose is minimal with the maximum share of gross income appropriated being 0.6%. From this point of view there would seem to be little difficulty in augmenting transfers by raising the tariffs for the highest categories, subject to the risk that they may choose to construct private supplies.

Methodology and Assumptions

To estimate the absolute transfer for each income group and city, the following procedure was used:

i) The average monthly water bill per subscriber was calculated for each category in each city on the basis of actual billings.

ii) The average monthly water consumption for each subscriber group in each city was calculated from meter data.

iii) The average tariff level charged per cubic meter in each city was calculated, by taking gross revenues and dividing by the total amount of water consumed.

iv) The average transfer for each subscriber category in each city was thereafter approximated by the following expression:

Average Transfer: = (Average Consumption
x Average
Tariff Level) -Average Monthly Bill).

The transformation of consumer categories according to the value of the property into income levels was made assuming that assessed property values are positively, but not necessarily proportionally, related to income. It was also assumed that consumers connect in order of income, i.e. the walthier will connect before the poor. Accordingly, where service levels were below 100% coverage, as was the case for all the cities surveyed, it was assumed that those without service correspond to the poorest segments.

The calculated average transfers were then assigned to each income group. If for example a water supply company serves 80% of the potential population, the estimated transfer for the 25% of the connections with the highest property values, becomes the transfer to the 20% with the highest income.

The income data were obtained for population quintiles from another source, and the relative transfers were calculated as the ratio between average transfers per month and median income per month. As mentioned, it was assumed that the lowest income quintile was generally not served through house connections but through other means, such as public standpipes or private systems. In almost all the cities the connection rates were in the order of 80% illustrating the fact that a large share of the population will be deprived of high-quality service unless special efforts are made to connect them.

The findings on relative transfers are shown in the table below:

AVERAGE TRANSFERS AS A PERCENTAGE OF AVERAGE INCOME

POPULATION INCOME QUINTILES

	First	Second	Third	Fourth	Fifth
A	0.0	2.1	1.2	0.3	-0.6
B	0.0	0.6	0.3	-0.1	-0.1
D	0.0	0.7	0.4	0.1	-0.2
E	0.0	0.5	0.3	0.0	-0.1
F	0.0	0.5	0.7	0.3	-0.3
G	0.0	0.5	0.4	0.2	-0.2
J	0.0	0.4	0.4	0.1	-0.2
K	0.9	0.8	0.5	0.2	-0.3
M	0.0	0.4	0.8	0.1	-0.2
N	0.0	0.8	0.3	0.0	-0.2
P	0.0	0.5	0.8	0.2	-0.3
Weighted Average	0.0	1.3	0.8	0.2	-0.4

As can be seen from the table the relative transfers vary between the cities, in magnitude and in terms of who receives the largest transfers. In general, the tariff schedules are constructed in such a way that the highest income quintile subsidizes all the others. The share of their income destinated for this purpose is minimal with the maximum share of gross income appropriated being 0.6%. From this point of view there would seem to be little difficulty in augmenting transfers by raising the tariffs for the highest categories, subject to the risk that they may choose to construct private supplies.

Income is redistributed in two ways via the tariff schedules. First the fixed charges vary much. Second the fact that the unit rates for excess consumption are much above marginal costs signifies that the large consumers pay more than their share of costs.

Considering the recipients of transfers, it is obvious that the upper limit to transfers is the amount of water they will request. The cost of such water will likely not be much more than say 5% in any instance. If transfers were used to subsidize their connections, however, the beneficial impact would be larger, and this would seem to be the priority use of the funds appropriated from the highest-income categories.

CASE STUDY THIRTY NINE - WATER TARIFFS TO RAISE PUBLIC SAVINGS

Background: A South-Asian city has seen its water supply system deteriorate over a number of years and has now drawn up an ambitious program to build supplies for the future. The works have been delayed as neither the municipal, nor the national budgets have been able to provide financing. It has been indicated that instead of thinking in terms of scarce grant financing the city might do well to consider borrowing funds to execute the works. Financial market conditions are such that it might be possible to borrow at an interest rate of 8% and with a maturity of 15 years, which corresponds to a capital recovery factor of 0.117. In order to gauge how much could be borrowed, and consequently invested, the water company is considering raising tariffs to generate a surpluse which could be used to service debts. For the calculation of the financial surpluses that might be generated it wants to make use of a recent socioeconomic study conducted in the city.

Analysis: The results of the socio-economic survey are summarized on the adjoining page and shows the income distribution of the city's some 100,000 families. Representative family budgets are included for the lowest income categories for which tariffs would be most budensome.

Assuming tentatively that it might be possible to request each household to pay one day's gross earning per month towards its water supply operations and investments it is possible to calculate what this would mean on average given the approximate income distribution among the families:

34.0% of the families have a monthly average income of 290 m.u.
27.0% of the families have a monthly average income of 450 m.u.
19.2% of the families have a monthly average income of 650 m.u.
9.6% of the families have a monthly average income of 1,500 m.u.
6.8% of the families have a monthly average income of 4,500 m.u.
3.6% of the families have a monthly average income of 7,500 m.u.

In the case of the three higher income brackets the real average incomes are higher than indicated. Since is uncertain how much higher the average is and in order to make estimates conservative the lower income estimates are used.

Assuming then that a maximum monthly tariff of some 3.3% of gross family earning is feasible, the monthly average tariff would be 0.34x3 + 0.27x14 + 0.19x21 + 0.096x50 + 0.068x150 + 0.036x250 = 33 monetary units.

At present the city has some 22,000 individual service connections. On the basis of data for the operating and maintenance costs for these connections it is estimated that the current costs for each connection amount to some 15 monetary units each month. Although some of these costs would not increase linearly with more connections, the estimate is used for current costs per connection if the entire city were to be connected.

Assuming further that it would be feasible to connect 80% of the entire city within the medium-term (while providing the remainder with standpost service) one would then expect that on average these 80,000 connected households could generate an annual surplus of (33-15)x12, or around 200 monetary units. This surplus could be used to service a debt which, given the leding conditions with a capital recovery factor of 0.117, could amount to around 1,700 monetary units per household. The total investment plan that the city could hope to execute would then be in the order of 130 million monetary units. Raising tariffs would require considerable streamlining of metering, billing, and collections service but it is likely that the water company itself would stand a better chance of succeeding than most local tax administrations. In addition, there would be the psychological advantage of being able to show for which purpose the funds are raised.

PAYMENTS CAPACITY AS EVIDENCED BY SOCIOECONOMIC STUDY

Monthly Family Income Distribution

Percentage	No. of Families	Percentage	Cumulative
Below 300 m.u.	32,700	34.0%	34.0%
Rs. 300-550 m.u.	26,000	27.0%	61.0%
Rs. 550-1,500 m.u.	18,400	19.2%	80.2%
Rs. 1,500-4,500 m.u.	9,200	9.6%	89.8%
Rs. 4,500-7,500 m.u.	6,300	6.6%	96.4%
Above 7,500 m.u.	3,500	3.6%	100.0%
Total	96,100	100.0%	

Representative Family Budgets for Low-Income Groups

Income Level	Below 300 m.u.			300-550 m.u.			550-1,500 m.u.		
	No. of Family Members			No. of Family Members			No. of Family Members		
Category	5	7	9	5	7	9	5	7	9
Food	130	180	210	160	200	225	182	230	250
Clothing	16	15	15	20	25	20	40	50	50
Education	5	10	10	8	15	20	30	45	45
Medical Aid	7	8	12	10	12	15	20	30	25
House Rent	30	40	45	80	80	85	100	125	125
Fuel	8	10	15	10	12	15	20	25	30
Entertaiment	15	10	10	20	15	10	30	20	30
Other Expenditures	57	30	30	57	53	50	93	82	80
Total Expenditures	268	303	347	365	412	440	515	607	635
Average Income	275	282	298	377	437	457	575	638	653
Surplus (Deficit)	7	(21)	(49)	12	25	17	60	31	18