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THE COSTS AND BENEFITS OF

WATER METERING

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Energy, Water and Telecommunications Department

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WATER METERING

Abstract

The decision on whether or not to meter household water supplies is frequently a subject of debate. Essentially the decision should be based upon economic considerations, following some type of cost-benefit analysis. While the theoretical economic concepts which are relevant to the metering decision are well established, they are often not understood or accepted by water supply engineers and policy makers, and as a result they are rarely applied in practice.

This paper briefly states the theoretical framework, which can be easily applied by most water supply authorities when making the metering decision, and presents several examples of such an application. In most of the examples presented, the metering of household supplies was found to be generally justified; in one, it was found to be clearly inappropriate.


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Introduction

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is frequently a subject of debate. 1/ Essentially the decision should be based
upon economic considerations, following some type of cost-benefit analysis.
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decision are well established, they are often not understood or accepted by
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applied in practice.

This paper briefly states the theoretical framework, which can
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decision, and presents several examples of such an application. In most of
the examples presented, the metering of household supplies was found to be
generally justified; in one, it was found to be clearly inappropriate.

The Traditional Approaches to the Metering Decision

Historically, water supply authorities have in many instances taken
one of two extreme positions on whether or not to meter domestic supplies -
either that all supplies, however small, should be metered, or that no metering
whatever is justified or acceptable. Thus, given two countries in broadly
similar circumstances, one might decide for the first alternative and the
other for the second, each defending their position vehemently. This suggests
that the decision tends to be a product of technical education and social
context, rather than of close analysis. It is therefore instructive to
examine the reasons commonly given for metering or not metering domestic
supplies.

Traditionally, when there has been resistance to the metering of
domestic water supplies, it has been based on three types of argument. First,
there is the belief that water is a special or unique commodity, and that any
measure that restricts consumption is inherently bad. Water authorities are
often reluctant to consider the possibility that even the cheapest source of
additional water may be too expensive in comparison with the benefits it would
provide.

The "unique good" line of reasoning may be countered in a number
of ways. Clearly, the use of water for washing cars or watering lawns is
not of infinite value either to the individual or the community. Furthermore,
by definition, the provision of new water supplies is dependent not on average
but on marginal values, and while the average value of water consumed by

1/ See Rees (1972), Warford (1968), Phillips and Kershaw (1976), Bartone
(1976), Hanke (1970), and Saunders and Warford (1976).
domestic users may be high, its marginal value may be negligible. There is also an anomalous situation, in many developing countries at least, where undertakings apply this "unique good" argument and are reluctant to meter supplies, and yet make high lump sum charges for initial connection to the system or high monthly fixed charges, which effectively deny access to lower-income families.

The second argument used against household metering is that, if water is paid for on a quantity basis, people will be deterred from using it, with adverse effects on their own health and the health of those with whom they come into contact. In fact, this "externality" argument is the sole possible justification for treating water as a commodity, the consumption of which should not be inhibited by such mundane considerations as price. Even so, this argument is not convincing. There is no evidence from either developing or developed countries that metering of household supplies has led consumers to reduce water use to a point where their health is affected; in fact the evidence tends to the contrary in developing countries -- excessive waste from unmetered systems leads to inadequate supplies for many sections of the community and so to dependence on polluted traditional sources or on a small quantity of extremely expensive water purchased from vendors. In any case, the possibility that rising costs and prices may induce a less than optimum consumption of water can be remedied, if it threatens to become a serious problem, by giving consumers a "lifeline allowance," that is, an allowance which entitles consumers to use water at a low subsidized price up to a certain level of consumption, after which they must pay the full marginal cost of supply. Tariff schedules such as this are becoming increasingly common in the developing world.

The third argument used against the metering of domestic water supplies is that the financial costs are very large, and that from a short run operations point of view, metering would increase the net costs of the water utility. A typical example of such an argument came out of a six year investigation of domestic metering carried out on behalf of the South West Worcestershire Water Board in England. The study concluded: "It will be seen that there is little evidence to suggest that any significant financial economies can be expected due to reductions in consumption in a temperate climate, by the introduction of universal metering. The cost per installation per annum at 1974-75 prices to do this in an existing ratable value collection area is likely to be £ 8.36, 45.9 percent of the average domestic water charge of £ 18.2 per house. Universal metering, however, provides benefits of being able to quantify the various usages of water by different categories of

1/ Although, due to lack of proper health education, they may not make proper use of the supply, whether metered or not.

consumer and the unaccounted loss in the distribution system, but it is questionable whether this is worth the expenditure and allocation of resources that would be necessary if this system of charging were to be adopted as a national policy". (Phillips and Kershaw, 1976, pp. 215-216).

Arguments such as this, based on short run financial considerations ignore the real long-term resource costs to the national economy of providing increasing quantities of water to consumers. They also ignore the steadily mounting costs of removal, treatment and subsequent disposal of increasing quantities of wastewater. From a resource allocation point of view, the likely cost of future supply and removal is more important than the cost of existing facilities. If water demand continues to grow, the most valuable result of introducing metering could be to encourage economy in water use, since the marginal price would be positive instead of zero (and, in the typical case where sewer charges are linked to water consumption, the marginal price would also reflect waste disposal costs). 1/ This would either defer the need for future investment, or, should the increase in demand eventually tail off, obviate the necessity for some investment altogether. 2/ These savings could be important both in the context of the national economy and in the narrower field of the water undertaking's operations: since the marginal costs of supply are in most instances increasing, deferring new source development implies deferring raising charges.

An Appropriate Framework for Analysis

The decision on whether to meter individual households should be the subject of cost-benefit analysis. The quantifiable benefits are due to the reduction in water usage which would normally be expected to result from the introduction of metering. This would lead to a corresponding reduction in the operating and maintenance costs of existing water supply and wastewater disposal facilities, and as discussed above, might also permit postponement of a series of investments in new works. The value of these benefits is the difference between the present value of the stream of capital and recurrent costs in the absence of metering and the (smaller) present value of the stream reflecting the reduced demand after metering. This saving, S, may be approximated as the product of the reduction in total water flowing into the household, R, and the marginal cost of supply and disposal, c; or S=cR. 3/

Other benefits of metering are more difficult to quantify. Metering can permit an equitable allocation of costs to users (and is probably simpler

1/ In climates where required system capacity is very dependent upon seasonal demands, the introduction of metering also allows seasonal tariffs to be employed; for an example in the USA, see Griffith, F.P., (1977).

2/ For well documented examples of reduction in consumption brought about by metering, see Hanke (1970) and Berry (1972).

3/ This simplification assumes that the sequence of investment and hence the marginal cost is not significantly affected by the reduction in demand. For a detailed discussion of several different methods for estimating the marginal cost of water supply, see Saunders, Warford and Mann (1977).
and more reliable than alternatives based, for example, on property values or fixtures installed). 1/ Also, because consumers receive a regular statement of their use of the service, it is likely that metering induces a certain amount of discipline in water use, irrespective of price considerations. Metering further enables lower-income consumers to reduce their costs by conserving water, and it allows "lifeline" rates to be introduced where these are considered desirable. Finally, metering provides valuable operational information to the utility, enabling demand trends to be established and areas of high loss or waste identified so that corrective measures may be taken (however, it may reasonably be objected that this information could normally be obtained with sufficient accuracy by the use of sample metering).

As a counterweight to these benefits, metering involves two types of cost -- costs to the utility and costs to the consumer. The former, essentially financial costs, are fairly readily identified, and in most analyses (such as that by Phillips and Kershaw, quoted above) are the only ones considered. They include the initial cost of purchase and installation of meters (and of setting up repair facilities, warehouse space, inventories, etc.), the maintenance and periodical replacement costs of the meters, and the cost of computing the customer's bills (the actual cost of billing and collection can be assumed to be broadly the same whether the system is metered or not). In this discussion the present value of these financial costs has been designated M.

On the assumption that the installation of meters results in a reduction in the quantity of water which a consumer allows to flow into the household, the consumer incurs two different sorts of costs. The first of these, denoted E in this paper, is the cost associated with reduction in wasteful use of water; that is, the direct expenditure on repairing and subsequently maintaining the household system so as to minimize the wastage of water and the disutility which the consumer incurs from reducing wastage and encouraging others in the household to do so. The second type of costs are those due to the reduction in "useful" consumption, that is, they represent the value of the consumption that has been foregone. 2/ Of course, estimating the value of consumer costs is difficult, since normally there is very little data on the shape of the consumer's "demand curve" (the relationship between consumption and price).

1/ The use of property values as a basis for water charges can result in charges which do not directly correspond to the quantity of water consumed; see Annex 1.

2/ It should be noted that the customer's costs are not, as might intuitively be assumed, the costs he is now required to pay for the metered service. To the extent that these costs increase because of metering, this effect has already been allowed for in the increase in the utility's costs considered above, assuming that the utility passes the costs on to the consumer.
For purposes of simplicity, many analyses assume (for example in projections of future demand) that, despite an initial reduction in consumption when meters are installed, demand thereafter is unaffected by price (in economic terms, that demand is perfectly inelastic between zero and whatever the metered price happens to be). This would imply a demand curve of the following shape:

![Demand Curve Illustration]

The area under the curve between \( V_0 \) and \( V_1 \) being zero, the value of foregone consumption is therefore also zero. In this case the only costs to the consumer would be those associated with putting his household system in order and personally attempting to reduce wastage. If he makes decisions in a rational manner these costs would not exceed the value of the water he is thus saving, that is the area of the rectangle \( p(V_0 - V_1) \).

More reasonably, however, one would expect increases in price to have some influence on demand. In an unmetered system the price is zero (charges being unrelated to consumption), and as a first approximation one may assume a linear relationship between demand and price up to the price, \( p \), for metered actual consumption. (For extremely small uses the demand may become much more inelastic, as evidenced by the very high unit rates commonly paid in developing countries to water vendors.) The demand curve would then appear as follows:
The value of the "useful" consumption foregone is triangle $K$ under the curve, that is $1/2 \ p \ (V_2 - V_1)$. Given that the consumer might also be expected to make repairs to reduce wastage which is of no value to him, and to incur some personal disutility in turning off the tap and encouraging other members of the household to turn off taps to reduce wastage, he will do so to the extent that the financial cost of the repairs and the disutility of policing wastage, does not exceed the area of the polygon, $[p(V_o - V_1) - 1/2 \ p \ (V_2 - V_1)]$, denoted above as $E$.

Summarizing, the savings due to reduction in water consumption and wastewater discharge, $S=cR$, have to be balanced against the utility's metering costs, $M$, the consumers' personal disutility and expenditure on plumbing repairs, $E$, and the consumers' foregone "useful" consumption $K$. Assuming that the price, $p$, is set equal to the marginal cost of supply, $c$, (as on economic efficiency grounds it should be), then the metering decision relationship becomes

$$cR > M + E + K.$$

In the case where, due to inadequate information, consumers' costs have to be ignored, the test reduces to:

$$cR > M$$

In many situations, it is difficult to predict with any certainty the value of $R$ (although sample metering will greatly help); the most feasible way to approach the metering decision in an actual situation is therefore to ask the questions: What reduction in consumption would be sufficient to justify metering? Is such a reduction likely to occur?

Although water supply authorities normally do not have sufficient information to answer the second question with precision, enough information should be available to allow an "educated guess" to be made. While the resulting estimate will not be exactly accurate, such an exercise can preclude major metering decision mistakes. For example, if the calculations suggest that a 5% reduction in consumption per connection would provide sufficient cost savings to justify the introduction of metering, it would be safe to assume that a metering program would be successful. If on the other hand the reduction would have to be 95% per connection, the appropriate course of action -- that is, not to meter -- is also clear. In cases in which the required reduction in consumption does not clearly point to a decision either to meter or not to meter, the implication is presumably that whichever way the decision goes, serious errors will be avoided. Sensitivity of the results to variations in the assumptions underlying $E$ and $K$ can be handled in a similar way.

\[1/\] From the discussion above it is evident that $(E+K)$ can range between zero and $p(V_o-V_1)=cR$. The equivalent range in the decision relationship is from $M=0$ at the one extreme to $M < cR$ on the other. Assuming that consumer costs $(E$ and $K$) are in most instances greater than zero, ignoring them would tend to bias the decision slightly in favor of metering.
The Metering Decision in Several Asian Cities

This section summarizes the results of metering decision exercises which were carried out in two large Asian cities (populations exceeding two million) and for smaller cities which were included in a national water supply program. 1/

City A

The city is located over a large aquifer and water is relatively cheap. Water supply investment costs are almost constant in real terms and additional investment takes place in relatively small increments. This is due to the fact that, whenever additional water is needed, an additional borehole is drilled in the closest feasible location to where the need is greatest. Marginal production and disposal costs were estimated at 5.82 US cents per 1000 Imperial gallons (1974 price levels). For this "smooth" long run marginal cost case, these costs were estimated by summing the annuitized investment and operating costs of each borehole and dividing through by the annual yield of that borehole; an allowance was then made for increased pumping costs in the sewage disposal system.

These costs are probably understated, since they do not take account of increasing marginal costs due to the decline in the water table nor of the eventual need to provide more efficient sewage disposal methods than the present coarse screening and direct river discharge. However, no reliable data was available on these additional costs (nor on the likely timing of any major sewerage investment), nor on the likely expenditures which would be necessary to put household systems in good working order.

The costs of metering (at 1974 price levels) an average 1/2 inch connection were estimated as follows:

<table>
<thead>
<tr>
<th>Cost</th>
<th>(US dollars)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchase of 1/2 inch meter</td>
<td>$ 27.50</td>
</tr>
<tr>
<td>Installation</td>
<td>2.50</td>
</tr>
<tr>
<td>Auxiliary equipment</td>
<td>0.50</td>
</tr>
<tr>
<td>Total initial cost</td>
<td>$ 30.50</td>
</tr>
<tr>
<td>Equivalent annual cost</td>
<td>8.04</td>
</tr>
<tr>
<td>(assuming a discount rate of 10% and a meter life of five years)</td>
<td></td>
</tr>
<tr>
<td>Annual recurrent cost</td>
<td>3.50</td>
</tr>
<tr>
<td>(maintenance, reading)</td>
<td></td>
</tr>
<tr>
<td>Total annual cost</td>
<td>$ 11.54</td>
</tr>
</tbody>
</table>

1/ Although the cities and countries must remain unnamed, all circumstances described and all data given are though to be factual.
These costs also are probably understated, since although in this city meters have a very short life and are replaced on average after only five years, nevertheless in 1974 over half of the meters then installed were out of order. In a more refined analysis, the costs of setting up more effective meter inspection and repair facilities should be taken into account.

Assuming marginal water supply and disposal costs of 5.82 cents per thousand gallons, and an annual metering cost of $11.54, then from the utility's point of view metering a 1/2 inch connection would only be justified if this would result in reducing consumption through that connection by about 550 gallons/day. However, total production was about 63 million gallons/day, averaging about 700 gallons/day for the 90,000 connections (including some commercial users). On average, therefore, metering would have had to reduce water use by about 80% to be worthwhile. Clearly for most consumers in City A this would be unlikely. 1/

If allowance were made for consumer costs (which, as is apparent from the above theoretical discussion, can considerably increase the "break even saving") it is clear that, except perhaps for those larger users which have a serious effect on the water table or on the sewage disposal situation, metering in City A is unjustified.

City B

This city is currently overpumping available groundwater and is increasing investment in more expensive surface water sources and treatment capacity.

Water supply investment costs are rising in real terms and the investment stream is relatively lumpy, that is, each investment project is designed both to satisfy existing shortages in supply as well as to create excess capacity for a three or four year period. Given such a situation, the appropriate means by which to estimate marginal cost is that of determining "average incremental cost". This is done by dividing the present worth of the stream of incremental investment and operating costs (discounted in this case over 20 years at 10%) by the similarly discounted "present worth" of the incremental amounts of water consumed. 2/ The result of this calculation showed that the cost of water supply and disposal in City B is 79.5 US cents per 1000 Imperial gallons (1975 price levels).

1/ Comparison with City B and the smaller cities examined later in the paper shows that the initial purchase price of meters in City A is extremely high. If it were reduced to $17.00, typical of the cost for those other cities, the annual cost of metering would fall to $8.78/ connection. The "break even saving" would then be 415 gallons/day, representing a reduction of about 60% of current consumption. The decision not to meter still appears justified.

2/ For a more detailed theoretical rationale for the average incremental cost method and a description of instances in which its use is most appropriate see: Saunders, Warford and Mann (1977).
The cost of metering was calculated as follows for a representative 1/2 inch connection:

<table>
<thead>
<tr>
<th>Year</th>
<th>Operation</th>
<th>1975 US$</th>
<th>Present Value (10% Discount Rate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Purchase meter</td>
<td>17.00</td>
<td>17.00</td>
</tr>
<tr>
<td>0</td>
<td>Install meter</td>
<td>4.70</td>
<td>4.70</td>
</tr>
<tr>
<td>3</td>
<td>Clean</td>
<td>4.70</td>
<td>3.53</td>
</tr>
<tr>
<td>4</td>
<td>Overhaul</td>
<td>9.10</td>
<td>6.22</td>
</tr>
<tr>
<td>7</td>
<td>Overhaul</td>
<td>9.10</td>
<td>4.67</td>
</tr>
<tr>
<td>9</td>
<td>Clean</td>
<td>4.70</td>
<td>1.99</td>
</tr>
</tbody>
</table>

Total 38.11

Equivalent annual cost of meter installation and maintenance (assuming a meter life of 10 years and a discount rate of 10%): $6.20

Annual cost of meter reading 1.25

Total annual cost $7.45

With marginal water supply and disposal costs of 79.5 cents per 1000 gallons and an annual metering cost of $7.45, the difference in water production per 1/2 inch connection, with and without metering, necessary to achieve equivalent savings in costs would be approximately 27 Imperial gallons a day. 1/ From consumption records it was found that approximately 220 gallons per day flow through an average 1/2 inch metered connection. Sampling of several areas in City B showed that per capita consumption from unmetered connections was about 40% higher than through metered, or about 300 gallons/connection/day compared to 220. It is therefore reasonable to expect the "breakeven".

1/ This calculation, of course, depends on the estimate of marginal production cost which in turn depended on projected consumption figures and the stream of investment through time, which in the case of City B assumed that universal metering would be in force. If metering were not in force, water consumption figures would presumably be somewhat larger and needed investment would have to be brought forward in time. Given that the costs of supplying water in City B are rising (in real terms) through time, the marginal production cost estimate would probably be slightly larger if metering were not practiced, thereby causing the calculated 27 break-even differential water consumption figure to be slightly smaller.
savings of 27 gallons/connection/day would be achieved by metering, and hence, it was decided that, on average, the policy of continuing to meter of 1/2 inch connections would be justified. (No allowance was made for consumer costs, since in particular no data could be obtained as to the condition or likely repair costs of household systems.) Of course, metering may not be justified for selected groups of customers where for physical or administrative reasons the costs of metering are significantly greater than the average amounts assumed in this exercise. This possibility is being examined by the city water supply authorities.

**Six Smaller Cities**

These cities were being served under a national water supply program, one of the policies of which was the introduction of universal metering. Based on previous experience in the country, it was anticipated that the majority of meters would be 1/2 inch size, would receive no regular maintenance after installation, and would require replacement every five years. The cost of metering a typical connection was estimated as follows:

<table>
<thead>
<tr>
<th>Description</th>
<th>1976 US$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply of meter</td>
<td>16.80</td>
</tr>
<tr>
<td>Installation cost</td>
<td>3.35</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>20.15</strong></td>
</tr>
<tr>
<td>Equivalent annual cost (5 years @ 12%)</td>
<td>5.59</td>
</tr>
<tr>
<td>Annual reading and billing costs</td>
<td>4.16</td>
</tr>
<tr>
<td><strong>Total annual costs</strong></td>
<td><strong>9.75</strong></td>
</tr>
</tbody>
</table>

Hence the monthly cost would be just over $0.80 per meter.

As would be expected, the average incremental cost of new water supplies to the various cities varied widely, depending for example on the availability of groundwater and the capacity and condition of the existing system (at the present state of development of these cities the installation of sewerage is not feasible, and no allowance was made in the analysis for any increase in wastewater disposal costs). Ignoring the consumers' costs, the reduction in consumption which would be necessary to justify metering (i.e. \( cR \gg M \)) was calculated as follows:
Judgements were then made on whether those savings would be likely to be achieved, and on the value of consumer costs. Such records as are available for these cities indicate average domestic metered consumption in the range 20 - 35 m³/month per connection, while consumption through connections which have just been metered (but which have not yet been billed at metered rates, so that the full effect of the metering has probably not been felt) averages 45 - 65 m³/month per connection. Specific comparisons between two cities, F and H, with comparable average income levels and similar numbers of persons per connection (9.5 and 10 respectively) show 23 m³/month used through metered connections and 63 m³/month through newly metered. It therefore appears very likely that the required "break even saving" of about 3.4 m³/month (about 6% of unmetered consumption) will be achieved by metering.

It also appears likely that this saving would have little value to the consumer. In the case of both City F and City H, the current domestic water tariff is only US$ 0.06/m³. (It should be noted that this is well below the estimates of the marginal costs of supply and should therefore be progressively raised as circumstances permit.) Using available data, the demand curve for water in cities F and H was very crudely approximated as:

<table>
<thead>
<tr>
<th>City</th>
<th>Average Incremental Cost (AIC) 1976 US$/m³</th>
<th>&quot;Break Even Saving&quot; m³/month</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>0.31</td>
<td>2.6</td>
</tr>
<tr>
<td>D</td>
<td>0.22</td>
<td>3.7</td>
</tr>
<tr>
<td>E</td>
<td>0.47</td>
<td>1.7</td>
</tr>
<tr>
<td>F</td>
<td>0.23</td>
<td>3.5</td>
</tr>
<tr>
<td>G</td>
<td>0.75</td>
<td>1.1</td>
</tr>
<tr>
<td>H</td>
<td>0.25</td>
<td>3.3</td>
</tr>
</tbody>
</table>
The consumer costs, $K$, due to a reduction of the "break even savings," $3.5 \text{ m}^3$/month, are therefore $\frac{1}{2} \times 3.5 \times 3.5 \times 0.06/40 = $0.009$/month; this is imperceptible, and there is no reason to suppose that, considering the average consumer, a saving of at least $3.5 \text{ m}^3$/month would not take place.

Given that the meters are installed, and assuming that the above demand curve roughly represents the situation in cities F and H, the consumer costs due to raising the price from zero to $0.06/\text{m}^3$ (and so reducing demand from 63 to an assumed 23 $\text{ m}^3$/month) can be calculated. These are the area under the demand curve between the two points, that is, $\frac{1}{2} \times 40 \times 0.06 = $1.20$/month. The economic benefit of this reduction is however $40 \text{ m}^3 \times \text{AIC}/\text{m}^3 = 40 \times 0.23 = $9.20$/month. After deducting the cost of metering and the value of foregone consumption, the net economic benefit is $9.20 - 1.20 - $0.80 = $7.20$/connection per month. Note that no allowance has been made for consumer expenses, $E$, to put the household system in order and reduce wastage; however, at the prevailing costs of labor and materials in the two cities, repair costs are unlikely to exceed one month's benefits.

On the basis of this analysis, metering of "typical" domestic consumers in these six towns is clearly justified. This does not however justify the national policy of universal metering. Even in the six towns examined it was found that many consumers use less than 10 $\text{ m}^3$/connection/month, and to meter these may not be economically justified; some form of block metering may be better, essentially as a monitoring device. Also, some peripheral areas and smaller towns still to be served by the national program may have less expensive public water supplies, since in many cases they can use local groundwater, and as marginal cost and average household consumption fall, the metering justification becomes weaker. Finally, the introduction of metering in smaller rural or peripheral urban communities in developing countries sometimes encourages customers to return to their traditional sources, which are often polluted, thus forfeiting the health benefits which are a primary justification for extending the supply.

Extending the Analysis

The metering exercises described above are admittedly of a preliminary nature. Each took less than two weeks to complete. Such studies need to be refined by the collection of additional information. One necessary task is the analysis of water use by type of consumer, for the impact of metering and therefore the relationship between metering costs and potential benefits is likely to vary according to consumer category. The general objective of this analysis would be to rank types of consumers in the order of the priority they should receive in the metering program, and to determine a cut-off point below which metering would not be worthwhile. It may be necessary to distinguish not simply industrial, commercial, and residential usage but also subcategories. For example, distinctions might be made between residential consumers according to whether or not they are connected to the sewerage system or have septic tanks, or whether or not they have gardens.  

1/ For typical data on the distribution of residential consumption in a developing country, see Annex 2.
An allowance should also be made for any savings in production costs from improved detection of losses from the distribution system. Of course, since remedies for detected leaks are not costless, such savings should be counted on a net basis, after deducting the costs of repair.

It may also be relevant to determine the seasonal pattern of water consumption. Thus, during the summer peak period, a given reduction in aggregate consumption will achieve greater production cost savings than an equivalent reduction during the winter season. Moreover, it is likely that summertime activities such as lawn watering and dust damping may be more responsive to metering (or price changes) than uses of water for drinking and washing. To take account of the seasonal complication, and assuming as before that prices will reflect marginal costs, the metering decision relationship becomes

\[ c_R^{o}R^{o} + c_R^{p}R^{p} > M_{o} + E_{o} + E_{p} + K_{o} + K_{p} \]

where subscripts \( o \) and \( p \) refer to the off-peak and peak periods respectively, and, as before, judgement is exercised as to the likelihood that a sufficient reduction in wasted plus consumed water will occur to warrant the introduction of meters.

**Additional Considerations for Developing Countries**

The analysis presented in this paper has been concerned with only two of the alternative to the general water supply "metering" question, i.e., metering households. For developing countries there is also a large spectrum of other possible waste control and revenue-generating measures which should be considered.

In numerous countries, due to existing poor levels of water supply service, personnel and management problems within the water utility, and shortage of capital, it may be preferable to consider other forms of water wastage control. These could include orifices in service lines, roof tanks with orifices, Fordilla and other self-closing valves, and public standposts operated by water employees or by licensed vendors. 1/ Each of these alternatives has specific advantages and disadvantages, and each should be subjected to a cost-benefit exercise similar to the ones outlined above.

The important consideration in such exercises is that the real resource costs to the economy of producing additional water be weighed against the costs of wastage control. If the custodian of a public standpost is paid a salary equal to or greater than the revenue which he collected during the day, the traditional public utility prescription, as illustrated by Phillips and Kershaw [1976], would be to dispense with his services. However, even if he

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collects no revenue at all, his employment may still generate net long run resource savings to the economy if his presence prevents a sufficient amount of waste: in such a case the traditional public utility approach would clearly be incorrect from a national resource allocation point of view. 1/

It is, of course, impossible to generalize about the extent to which the traditional public utility short run cash flow approach and the economic cost-benefit approach outlined in this paper will result in different conclusions on the metering decision. Certainly cases might be found in which the financial costs of a metering and wastage control program exceed the increased revenues to the utility for a significant period of time. The most likely instance in which this could result would be when the costs of additional supply are projected to begin increasing rapidly within the next five to ten years, and in which the utility follows a pricing policy of basing its tariffs on historical financial costs rather than the more relevant incremental expansion costs. For the cities examined in this paper, however, (assuming that marginal cost pricing is practiced) when metering was found to be justified on economic grounds it was also found to be financially desirable for the utility (projected incremental revenues were greater than the projected incremental metering costs to the utility).

The existence of intermittent water supply service, which is frequently observed in cities of the developing world, can further complicate the metering decision. One obvious complication is the difficulty of demand forecasting; when demand has been frustrated by actual shortages, past trends of consumption clearly have little relevance for the future. Another complication concerns the inaccuracy of meter reading (air in the pipes) and frequency of meter stoppage (due to damage to meters running when dry and to pipe scale clogging meters when the water comes back on).

The presence of intermittent supplies also causes complications when attempting to measure the benefits of metering. For example, the authors have observed an example in which water consumption in a significant number of households actually increased after metering was instituted. Before metering, the system ran dry each day and numerous households were unable to consume the quantity of water they desired. After universal metering, however, it was possible to maintain water pressure twenty-four hours a day: while no production cost savings (which are relatively easy to measure) were observed, the benefits of the water supply system were presumably increased since some consumption was transferred to households which valued the water relatively highly from those which valued it less.

Conclusion

The metering decision should be based upon a cost-benefit exercise in which the costs of metering (purchase of meters, installation, reading and

1/ From the short run cash flow point of view of the public utility, however, money must be generated both to pay for the water dispensed through the standpost, and to pay the attendant's salary.
billing costs) are compared with the savings in the costs of water supply and disposal that are likely to result. Any loss in consumer satisfaction due to the reduction in water consumption should also be included as a cost of metering. Since the reduction in consumption necessary to make such a judgement is often difficult to predict, the way in which gross error may be avoided is to specify the reduction in consumption that would justify metering, and make a judgement on that basis.

The important lesson that emerges from this type of exercise is that one should not be "for metering" or "against metering," but should treat each case on its merits. Moreover, there will always be some consumers who should be metered and usually some who should not. The exercise is also important in that it focuses attention upon the real costs of water supply and disposal, that is, those costs that are incremental rather than those that have been incurred in the past. Finally, the principles outlined with regard to conventional water metering apply equally to any other form of restriction of water consumption that is employed, this being particularly relevant for developing countries.
REFERENCES


In one ward in a city in South Asia, in which part of the properties were metered and part were charged for water on the basis of assessed property value, metered properties were examined and a comparison was made of the actual water charges, based on metered consumption, and the charges which would have been made if the properties had been unmetered, i.e. charges based on property value.

- The property value-based charges would, overall, be about 15 percent lower than the metered charges. If the meters were removed, the percentage charged as a water rate would therefore have to be increased.

- Even after this adjustment, 60 percent of the properties would be paying less than their fair share (based on actual consumption); typically this underpayment was about 50 percent, but might be as high as 90 percent. The other 40 percent of the sample would, in contrast, be overpaying, in many cases substantially (10 percent over 100 percent).

- There was no identifiable category of properties for which application of the property value system produced a charge which was equivalent to what would have been charged if the properties were metered.

These conclusions may merely reflect the particular inefficiencies of the property valuation system in the country in question. However, it is evident that such distortions may encourage an undertaking to resist metering for some high value properties (since this would cause revenues from these particular properties to fall), even though high value properties will often be occupied by large water consumers, where, for reasons of resource conservation, metering should command high priority.
ANNEX 2

Typical Distribution of Metered Consumption

The following table shows the distribution of consumption in a capital city of a country in South America, in which all water supplies are metered.

<table>
<thead>
<tr>
<th>Consumption m³/connection/month</th>
<th>Cumulative percentage of connections (Cumulative percentage of consumption) by category:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Domestic 1/</td>
</tr>
<tr>
<td>0 - 15</td>
<td>18.9 (3.7)</td>
</tr>
<tr>
<td>16 - 30</td>
<td>47.9 (18.2)</td>
</tr>
<tr>
<td>31 - 45</td>
<td>69.1 (35.3)</td>
</tr>
<tr>
<td>46 - 100</td>
<td>93.7 (69.5)</td>
</tr>
<tr>
<td>101 - 1000</td>
<td>100.0 (93.7)</td>
</tr>
</tbody>
</table>

1/ Accounting for 88.4% of total consumption.

These values appear typical of cities in the developing world. If such a pattern is observed in the case of a city that currently does not meter water supplies, but based on the results of a cost-benefit analysis is contemplating a metering program, the water utility should initially concentrate on identifying the 30 percent of domestic connections which account for about 65 percent of consumption in that category, and on the 15 percent of other connections which account for over 85 percent of the remaining consumption (for example in the city in question, only 3 industrial connections accounted for almost one half of water consumption in that category).