KALBERMATTEN ASSOCIATES, INC.
Water and Wastes Management Advisory Services

SOMETOWN, ANYWHERE:

AN EXAMPLE OF WATER SUPPLY AND SANITATION OPTIONS

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SOMETOWN, ANYCOUNTRY:

AN EXAMPLE OF WATER AND SANITATION OPTIONS

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BACKGROUND

Sometown is a regional center in a predominantly agricultural area. It serves as a commercial center for this area, and has a well-established light industry as well as several food and cotton processing enterprises. Average incomes in the area are slightly above the national average (GNP: $800). The town hosts a liberal arts college and a technical institute. It is located a few miles from the coast, with the town extending either side of a river that at one time was an important commercial port. However, increased siltation following deforestation of the foothills, and the availability of better deep water moorings elsewhere, have closed the harbor except to local traffic. There is still, however, a substantial fishing industry.

The climate is tropical, with a distinct rainy season; annual rainfall averages 1800 mm.. Much of the rainfall occurs during heavy storms, and flooding is a problem in low-lying areas of town, because the storm drainage system has inadequate capacity to deal with the increasing runoff as urbanization spreads. In addition, solid waste removal is inadequate, especially in low-income areas, and domestic wastes are deposited in the drains and cause partial blockages.

Water for the municipal supply is abstracted from wellfields 5 km. east of the city limits. Water quality is at present excellent; the water is chlorinated, but only as a precaution against contamination during transmission and distribution. However, this source is now reaching the limit of its capacity, and there is some evidence of saline intrusion into the aquifer from the adjacent coastal strip. Other nearby groundwater resources are fully utilized for agriculture; there is substantial daily traffic of cash crops into the markets of the town.

With average abstraction from the wellfields running at about 90 per cent of capacity, peak demand during the dry season regularly exceeds the supply capacity, so that water has to be rationed.

The next expansion of the water supply which is being contemplated would involve using the waters of a small river 47 km. distant. To provide a reliable supply, a dam would have to be constructed, to form an impounding reservoir. The water would flow by gravity to Sometown, but would require full treatment, including disinfection.

There is a simple sewer system serving the older parts of town adjacent to the river. Effluent is discharged directly to the river without treatment, and during the dry season water quality in the river is poor.

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[1] President and Vice President respectively, Kalbermatten Associates, Inc.. Paper © 1990, KAI.

In more prosperous neighborhoods, houses not connected to the sewer system have septic tanks and drain fields, but with increasing population density and water usage, aggravated by lack of tank emptying, these drain fields have become overloaded, and much effluent now either forms surface ponds, or is discharged illegally to the storm drains. Septage is invariably dumped into water courses or the river itself.

Some people without either sewer connections or septic tanks have pit latrines, but there is no provision for emptying them, and they are very unhygienic. Many people use alleys, storm drains and open spaces for defecation, creating serious health hazards: filariasis is on the increase, helminthic infections affect over half the children in the area, and diarrhoea (especially in childhood) is endemic.

The population in the municipal area is growing rapidly, at about 6.4 per cent each year. More than half of this increase is accounted for by migration from outlying rural areas, as deteriorating or eroding soils make it harder to survive by farming. As a result, there is a growing number of unplanned squatter areas around the periphery of the town, with rudimentary shelter.

Government policy requires municipalities to provide water supply and sanitation services within municipal boundaries. Until recently, the central government provided subsidies for services to low-income groups, but increasing economic difficulties have led to progressive cutbacks in these subsidies, and it seems likely that they will be phased out completely within a few years. The municipality is concerned about the financial implications, as its budget is already stretched.

BASIC DATA

Statistics are not very reliable, but those that exist, supplemented by preliminary surveys (undertaken by social scientists and their students from the liberal arts college, with assistance and guidance from municipal technical staff) suggest the following:

1990 population	111,000
Overall growth rate (about 45:55 natural growth:migration)	6.4 per cent
2000 population (estimated)	207,000
Water supply:	
Population with house connections	64,000
Population dependent on standpipes or illegal connections	37,000
Peripheral population dependent on vendors	10,000
Water source capacity	25,000 m^3/day
Average 1990 output (gross)	22,464 m^3/day

Estimated breakdown of consumption	
Metered connections (industry, commerce)	1,643 m^3/day
Metered connections (domestic)	13, 248 m^3/day
Unaccounted-for water	
Standpipe supply: 27,000 @ 20 lcd	540 m^3/day
Vendor supply: 10,000 @ 8 lcd	80 m^3/day
Illegal connections: 10,000 @ 75 lcd	750 m^3/day
Municipal uses (firefighting, markets)	448 m^3/day
Physical leakage (balance: 26 per cent)	5,755 m^3/day

Sanitation:	
Population served by sewers	27,000
Population served by septic tanks	37,000
Population served by public facilities	22,000
Population with private latrines	15,000
Population without any service	10,000

Clearly, with only 66 per cent of gross water consumption metered (and with even that consumption measured by production and revenue meters that will themselves be subject to error), this breakdown is not precise. Similarly, only rough estimates can be made of people who consider themselves to have access to a public latrine and those who have nothing. However, it is enough to allow a first comparison of alternative solutions to the need to provide service to everyone by the year 2000.

THE TRADITIONAL MODEL

Water Supply

To meet the objective of providing service to everyone by the year 2000, an additional 96,000 people have to be served. Of these, perhaps 13,000 would be in comparatively recent peripheral squatter settlements, which would be served by vendors rather than piped water supply and sewerage. The remaining 83,000, as well as the 47,000 people now without legal piped supplies, would be given full piped water supply and sewerage. Assuming that industry and commerce continue, as at present, to use about 10 per cent of net supply; that per capita average domestic consumption falls slightly from the present 207 lcd to 190 lcd (reflecting a higher proportion of recent immigrants); that municipal uses account for 2 per cent of gross supply; and that physical leakage falls to 20 per cent of gross supply (since a greater proportion of the distribution network will be recently laid), the water requirements for the year 2000 would appear as follows:

Domestic piped supply: 194,000 @ 190 lcd	36,860 m^3/day
Domestic vendor supply: 13,000 @ 8 lcd	104 m^3/day
Industry and commercial	4,225 m^3/day
Municipal usage	1,050 m^3/day
Total net consumption	42,239 m^3/day
Physical leakage, 20 per cent of gross	10,560 m^3/day
Total required gross production	52,799 m^3/day

Thus, source capacity would have to be more than doubled from present levels.

The estimate for the new dam, transmission main, and other necessary ancillary works is $10.0 million. In addition, the distribution system has to be extended and upgraded as necessary to accommodate the new population as well as providing a higher level of service to existing customers. An approximate estimate for this work is:

Upgrading distribution for 37,000 people now dependent on standpipes or using illegal connections @ $30 per capita	$1.1 million
New distribution system for 93,000 population @ $120 per capita	$11.2 million

The total cost to be borne by the municipality for water supply improvements, including source development and distribution (but excluding in-house costs, which would be met by the homeowners) is therefore estimated at $22.3 million.

Sewerage

The water introduced into the community would have to be removed, in order to prevent further serious environmental degradation, particularly of the low-lying districts of the town. Both sewers and a sewage treatment plant would have to be constructed. Assuming that sewerage costs approximately 3 times the cost of water supply improvements, and that for 13,000 people in peripheral squatter settlements on-site latrines would be encouraged, as temporary measures, but no financial assistance would be provided (and again excluding any cost on of-site improvements, such as constructing bathrooms, or of upgrading septic tank systems to connect them to the new sewer lines) the investment requirements are:

130,000 people @ $360 per capita	$46.8 million

The total capital cost of providing traditional water supply and sewage collection and disposal services to serve the population in the year 2000 is therefore approximately **$69 million**, plus on-site costs. In addition, this approach will involve: design and supervision fees for expatriate consultants; use of foreign exchange for importation of equipment, materials and spare parts; and relatively high costs for operation and maintenance.

THE NEW MODEL - WATER SUPPLY

It is of course possible - indeed, it is unfortunately likely - that some source of finance would eventually be found to provide the funds needed for this capital investment. Experience suggests that in a few years lack of adequate funds for operation and maintenance, lack of spare parts, and insufficient skilled operators and technicians would have claimed another casualty: a system in which there are high levels of physical leakage, many illegal connections, silted up and corroded sewers, and treatment plants discharging effluents not markedly better than the incoming raw sewage. The municipality is determined to avoid such a wasteful investment.

The alternative is to concentrate on making best use of existing installations, and to design new services so that they match the communities that they are to serve: it is unnecessary and wasteful to plan to provide full piped water supply and sewerage to a rapidly evolving squatter community, which in a few years may be radically transformed. Water conservation measures, use of a range of technologies matched to community living conditions and ability to pay, and introduction of treatment and disposal technologies that reduce the need for expensive interceptor sewers and centralized treatment plants, may avoid the need for additional major investments. All of these methods are known and have been successfully used in a number of countries, but not so far in a comprehensive and integrated system. They offer not only the advantage of reduced costs and simplified operations (so that they are sustainable in the context of developing countries), but protect the environment and make better use of natural resources.

Alternative standards of domestic water supply service

In 1990, under 60 per cent of the population live in houses with house connections. Over time, it is likely that this proportion will fall, as increasing in-migration tends to lower average household incomes. However, for the purposes of this example, assume that it remains at 60 per cent; planning for 2000 should then assume that 120,000 people will have house connections[2].

In 1990, one third of the population is served through standpipes or illegal connections. Standpipe service is not very satisfactory to the users (because of long lines and the need to carry water home), and is also unattractive to the municipality (since it is hard to collect revenues or control waste). The distribution system to serve standpipes may also be actually of larger diameter (because of the few concentrated points of supply) than one for house connections. Planning for 2000 should therefore concentrate on phasing out standpipes in existing areas of the city and replacing them with "patio" or yard connections; these provide a convenient private

[2] This is equivalent to assuming that house connections are provided to the natural rate of population increase of the original 64,000, plus half of those households previously dependent on standpipes, plus 25 per cent of the migrants, since some of the migrants will also be able to afford this service standard.

faucet for each family, and are a great help in promoting better health and hygiene. At the same time, a vigorous campaign should be mounted to detect and eliminate illegal connections, replacing them by house or patio connections. Planning for 2000 should anticipate a total of 60,000 people dependent on patio connections.

The existing 10,000 people in peripheral settlements, as well as some of the migrants that will arrive during the decade 1990-2000, may not live in the type of settlement that lends itself to a piped water distribution network: unfavorable topography, poor soil conditions, inadequate streets, etc., make service provision difficult. There is also the practical problem that the authorities usually have little idea where these peripheral settlements are going to spring up, and so designing to serve them is impossible. For planning, it should be assumed that 14,000 people will be served by standpipes, and another 13,000 by vendors.

Domestic water conservation

Commonly used flush toilets require about 20 to 28 liters per flush; the average person may flush the toilet 4 times each day, so that water use for this purpose alone may amount to 80-90 lcd (about 40 per cent of the present metered domestic water consumption noted in the 1990 data above). In recent years, toilets using only 4 to 6 liters per flush have been introduced into the market (models with even lower usage are under development), making water savings of 60 lcd feasible. Such units are not significantly more expensive than less efficient models, and should therefore be required on all new construction (and for all replacement units). It is assumed that the number of people with full in-house plumbing increases from the present 64,000 to 120,000; if the additional 46,000 people are provided with water-saving toilets, the water saving will be 46,000 x 60 lcd, or 2,760 m^3/day.

For the existing 64,000 people with full in-house plumbing, water usage for toilet flushing can be reduced substantially, to perhaps 12 liters/flush, by using water-saving kits dropped into the toilet tank. Free distribution of such kits, supported by a strong promotion campaign, may cost the municipality $200,000 (12,800 households @ $15/household)[3]. The resulting water savings will be 64,000 x 40 liters, or 2,560 m^3/day[4]. (For people without full house connection service, it is assumed that alternative, low-water use forms of sanitation will be adopted - see below).

[3] Experience in the United States suggests that a mass mailing, consisting of a toilet water use reduction device and two shower flow restrictors, can cost less than $1 per household and have an acceptance rate up to 35 per cent. For maximum impact, however, this may have to be followed up by a door to door campaign, with costs up to $15 per household.

[4] Where new water source development will be expensive, free distribution of such kits is well justified. For example, San Jose, California, is providing free kits to 217,000 homeowners, and anticipates savings of $100 million in deferred capital costs and lower operation and maintenance expenditures.

The traditional way of bathing in Sometown is to use a dipper and a bucket of water, but more and more people are installing and using "modern" bathroom fittings with showers. By requiring all new installations to have higher efficiency shower heads (using only 8-10 liters/minute), it is possible to save 25-40 lcd, at a cost of between 0-$10 more than standard units[5]. Water savings (assuming that, of the houses with full service, half the existing ones[6] and all the new ones will have such devices) could amount to 88,000 x 30 lcd, or 2,640 m^3/day.

The total water savings just by requiring more efficient installations in full-service houses could therefore total 7,960 m^3/day net, or about 9,950 m^3/day gross (after allowing for the projected 20 per cent leakage rate) - about 35 per cent of the additional source capacity calculated to be required for the traditional model if there were no water savings.

Water pricing

An important element in conservation is appropriate pricing. At a time when the town is clearly facing an imminent severe shortage, and when new source development will be expensive, a public relations campaign should be mounted to promote water conservation and to explain why water tariffs must be kept in step with true costs. Past tariffs have not been adjusted to keep in step with inflation, and so no longer cover even the full cost of running the present installations. Now is the time to introduce a two-step tariff for residential consumers with full house connections (those with other levels of service will probably be kept on a lower rate): the first step in the tariff, sufficient for comfortable but not luxurious use (say, up to 100 lcd, which represents about 17 lcd less than current usage of 207 lcd less the effects of water-saving toilets and showers) would be at the full cost of today's service, while any usage above that level would be charged at a higher rate, for example, one reflecting the marginal cost of bringing the new source into commission. Similar sharply increasing tariffs should be used to stimulate recycling and efficiency in industry.

Vigorous disconnection policies should be applied for non-payment (including government offices, often the worst offenders).

Industrial/commercial water conservation

It is very difficult to project industrial and commercial usage, since industries can vary so widely, from water-intensive to virtually water-free, and since usage even within the same industry varies

[5] Part of these costs will be included in the cost of the water saving campaign described above, in which shower head inserts would form part of the "kit" distributed to households.

[6] To ensure that people living in existing houses install only water-efficient devices when replacing or upgrading their installations, it is of course vital to ensure that such devices are freely available in the market, that plumbers are familiar with them, etc.. Ideally, no other types should be available.

considerably according to the processes adopted[7]. The projections for the "traditional" model indicate a growth of industrial and commercial demand by a factor of 2.5 over the decade, compared to a population increasing by a factor of 1.86. Insistence that all future industries adopt water-conserving practice (either in choice of original process, or by instituting on-site recycling) should keep the rate of growth lower than the population increase without inhibiting industrial expansion; for planning, an arbitrary factor of 1.75 can be assumed.

Reduction in physical losses

Present physical losses of 26 per cent of gross supply are not uncharacteristic of systems around the world where maintenance is given low priority. In a situation where new sources are remote and expensive, much greater attention should be given to detecting and repairing leaks. In Sometown, this should not prove difficult, as the existing network serves directly only some 101,000 people; the expanded network will have to serve 194,000, so a very substantial proportion of it will be new. In these circumstances, every effort should be made to maintain leakage below 10 per cent of gross supply (figures even lower than this may be achievable, and may be economically justified as demand on the system continues to grow).

Revised water supply projections for 2000

With this revised approach, the following projections can be made of needs for the year 2000:

120,000 people with house connections @ 200 lcd (slightly less than 207 lcd 1990 level, reflecting impact of tariff policies)	24,000 m^3/day
Less: effect of water saving devices	- 7,960 m^3/day
60,000 people with patio connections @ 40 lcd	2,400 m^3/day
14,000 people dependent on standpipes @ 20 lcd	280 m^3/day
13,000 people dependent on vendors @ 8 lcd	104 m^3/day
Industry and commercial usage (1.75 x 1990 level)	2,875 m^3/day
Municipal usage (1.86 x 1990 level)	833 m^3/day
Total net consumption	22,532 m^3/day
Physical leakage (10 per cent of gross)	2,504 m^3/day
Total required gross production	25,036 m^3/day

7 1 ton of steel may require 5 tons of water, or 200 tons, depending on how it is made; similarly, 1 ton of paper may require 60 tons or 350 tons. Even in "water-intensive" industries, the proportion of water actually used up is small: for example, typically around 20 per cent in food processing, 25 per cent in paper manufacture, or 33 per cent in textiles.

This emphasis on water conservation, appropriate service standards and efficient use does not avoid the need for a new source - there will still be a shortfall by the year 2000 (or even before that, if the estimates are in error because people do not respond as predicted) - but radically changes the nature of the problem. The need to have a new source in operation has been postponed 10 years, which means that there is much more time available to explore alternative solutions.

As an example, by 2000 the projected sewage discharge from houses with house connections and from commercial and industrial establishments (assuming a 90 per cent return to the sewers) would be about 17,0000 m^3/day. By the year 2000 the gross demand will be increasing at about 1,600 m^3/day each year (population growth rate x 25,000 m^3/day). The projected shortfall in supply in this first year could therefore be met if only about 10 per cent of this sewage were recycled for irrigated agriculture, releasing existing wellfields for municipal use (and, of course, once this principal of substitution was established and accepted, the potential for progressive phasing out of the use of fresh water for irrigation is considerable[8]).

Potential water supply cost savings

Avoiding the need to develop a new water source within the study period results in savings of $5 million. In the longer term, use of local wellfields, made feasible by progressive substitution of treated sewage effluent for irrigation supply for those agricultural operations nearest the city, will be a very much more economical source (since the 47 km. transmission main is no longer needed, nor is treatment, other than chlorination; against this must be offset the cost of conveying the treated sewage to the fields - the treatment would be required in any case prior to discharge - and of bringing the water to the city).

It is assumed that the area of town where the 1990 supply was through standpipes and illegal connections will require limited upgrading to support the projected house connection service standard; this affects 37,000 people. Elsewhere, new distribution services will be required to serve a further 93,000 people. The cost of these works (using the same per capita costs as for the traditional model) would be $12.3 million. However, just as a mixture of service standards in terms of convenience and per capita consumption is considered in the new model, so also should various standards for the design of the distribution system itself.

The advent of small personal computers has made it much easier to apply computer-aided design (CAD) programs to the design of distribution systems. Experience in applying these programs indicates that frequently the standards insisted on are unrealistic: high residual pressures in areas of single-story shacks; high fire flows in towns with no firefighting equipment; minimum pipe

[8] For example, an innovative approach to finding new water resources for municipal use is being tried in the Imperial Valley in California: the Metropolitan Water District of southern California is financing measures to improve irrigation efficiency (new flow-regulating reservoirs, improved canal lining and more flow monitors), in exchange for the 106,000 acre-feet of annual water saving.

sizes that are vastly too large for the communities they serve; or ranges of pipe sizes for which no spares are held in inventory. The sheer tedium of manual calculation also inhibits repeated design attempts to find a true optimum solution. A recent review of the application of these programs in Indian cities revealed cost savings varying from 8 to 40 per cent! Assuming that a cost saving of at least 25 per cent can be achieved by efficient design carefully matched to the community, the estimated cost of the distribution system needed to serve the year 2000 population is:

Upgrading distribution for 37,000 people now dependent on standpipes or using illegal connections @ $24 per capita	$0.9 million
New distribution system for 93,000 population @ $96 per capita	$8.9 million

The total distribution system cost is therefore $9.8 million, a further saving of $2.5 million.

Against the savings have to be set the costs of toilet water saving kits ($200,000) and of measures to reduce physical leaks. The latter will be self-financing: experience shows that well-planned leakage reduction campaigns pay for themselves (in terms of additional revenue gained from sale of water) within a very short time (if water is properly priced, in terms of long run marginal cost, the point at which they cease to pay their way is of course the economic breakpoint below which it is not economical to reduce leakage).

Allowance should also be made for the costs of essential "software": public information campaigns to promote water conservation; introduction and enforcement of water-saving processes in industry; education and training for plumbers and other craftsmen who will install new devices; training of agency staff in computerized design; etc.. (This is included under "Sanitation"; see below.) Although in the short term these inputs may appear expensive and almost beyond the institutional capacity of the municipal agency, over the long term they will have enormous benefits through the establishment and maintenance of an ethic of efficiency in water use.

THE NEW MODEL - SANITATION

The major savings come from adopting sanitation systems appropriate to housing conditions and water usage. As far as possible, reliance on centralized sewer systems is minimized; systems serve local districts, with local treatment and discharge of treated effluent to adjacent agricultural areas. On-site systems are used wherever water use is low enough to allow this option.

Specifically, three types of system are envisaged:

Conventional sewerage

This currently serves 27,000 people. In future, it is assumed that it will serve 60,000 people (half of the total with house connections for water supply), who live in the dense core of the city where other options are less cost-effective. The costs are estimated as:

Rehabilitation of existing network: 27,000 people @ $180	$4.9 million
Extension of network: 33,000 people @ $360	$11.9 million

Alternative sewerage

37,000 people currently have septic tanks, and house connections for water supply. As development proceeds, these people will be most efficiently served by "solids free sewerage", small-bore sewers laid at a shallow depth, using the septic tanks as interceptor/treatment units. The remaining 23,000 people who will have water supply house connections in 2000 will be served using modified forms of sewerage (shallow sewerage and simplified sewerage), which have been shown to cut network costs by 40 to 50 per cent. The estimated costs are:

Upgrading septic tanks to SFS: 37,000 people @ $150	$5.6 million
Alternative sewerage: 23,000 @ $200	$4.6 million

On-site solutions

15,000 people already use on-site toilets and latrines. By the year 2000, it is planned that every household either with a patio connection or dependent on a public standpipe for water supply should have on-site sanitation. This implies an additional 59,000 units, for a total of 74,000. There is no cost to the municipality for the construction of these units; like all on-site or in-house works, they are undertaken at the cost of the homeowner.

There will probably be 13,000 people in recently-established squatter communities who will rely on water delivered by vendors, and who will not have shelter permanent enough to justify latrine construction. In such areas, public toilets on the fringes of the settlements, financed by low per-use charges (as has been successfully done in India), will be provided:

Public toilets: 13,000 people @ $15	$0.2 million

The total cost of this combination of measures is therefore $27.2 million, representing a saving of approximately $20 million over the traditional model.

Given these potential benefits, the municipality should not do everything it can to encourage construction and adoption of such alternative systems, both for water supply and sanitation. There should be a strong promotional and educational campaign, training of small contractors, assistance to local component fabricators to establish the necessary manufacturing capacity, etc..

This may need to be supported by a program of home improvement loans to assist lower-income households. To allow for these costs, an allowance of $3 million is added to the estimates; this is approximately equal to 15 per cent of the project cost, excluding conventional sewerage.

An important "selling point" for the municipality is that, while these systems suit people's current needs, they can be upgraded as soon as people's circumstances permit. A patio connection can easily be converted into full in-house plumbing, and then on-site sanitation would need to be modified into an SFS system, with the latrine pits serving as the interceptor tanks.

CONCLUSIONS

Use of a mixture of systems, which are designed to encourage water conservation and efficiency, and which are closely matched to housing conditions and effective demand for service, can provide service to the entire community at considerable savings in capital cost:

Traditional systems of water supply and sewerage	**$69 million**
Combination of various systems, including conservation measures	**$40 million**
Savings	**$29 million (42 per cent)**

Note that these savings (which will be matched by equivalent savings in operation and maintenance costs, and in foreign exchange requirements) can be achieved using well-tried technology. Designing the project in detail, and putting it into effect, will require development of techniques for consulting and involving the communities affected, but does not require any technical pioneering. These savings should enable Sometown to undertake other needed environmental improvements, such as improving its stormwater and solid waste management systems; the experience gained on community-managed systems for water supply and sanitation should prove valuable when seeking cost-effective ways to extend these other important services into low-income communities.

THE WAY AHEAD

Once the concept of providing service through a mixture of service standards has been adopted, there is an opportunity to revise the entire approach to water and sanitation services. Absence of universal sewer systems means that there is no longer any justification for major interceptor sewers conveying sewage from all over the city to centralized treatment plants. Instead, a series of local treatment facilities, using stabilization ponds and other non-mechanical biological treatment systems (such as constructed wetlands, ornamental ponds, etc.), would be provided around the city's periphery; as these are over-run by development, they can readily be relocated and the land reused, or the facilities can be placed in greenbelt or park areas where the treated effluent can be used for irrigation and non-contact recreational uses. Working catchment area by catchment area provides great flexibility - sewerage planning is no longer dominated by the need to construct large diameter downstream pipes in the first phase - which is precisely what is needed at a time when the city is growing fast but unpredictably. In-house and community-based systems offer a chance to build community management skills, important at a time when it is clear that municipalities are not capable of managing all services (for example, solid wastes) without some local-level support.

The city should now explore the opportunities for introducing a number of important new ways to make better use of resources and improve environmental conditions:

- Development of on-site systems for treating wastes. Examples are household- or community-sized versions of marsh treatment systems, in which plants purify the wastes and remove nutrients (in some versions, these are enclosed in greenhouses for better system control)

- Promotion of in-house recycling of toilet flushing water, as is being done for some commercial buildings and factories in Japan and the USA, reducing effluent discharges by as much as 95 per cent

- Substitution of treated sewage effluent for wellwater for irrigated agriculture

- Use of surplus effluent for growing trees in shelter belts, fuelwood plantations, and public open spaces

- Use of humus removed from on-site sanitation units as a soil conditioner for agriculture, reforestation projects, or public parks

- Disposal of septage onto solid waste tips, to speed decomposition to humus and to promote methane formation (for use in local heating networks)

- Injection of treated sewage effluent into coastal aquifers to form a barrier to saline intrusion

- Use of the final ponds in stabilization pond systems for aquaculture

If these projects are based on decentralized sanitation districts, they will be valuable sources of employment for the low-income and migrant community. Sometown will be a living example of the adage **"Waste is merely an asset in the wrong place"!**