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Action Plan for Urban Waterways Improvement in Madras and Varanasi

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KEY TERMS, CONVERSIONS, ABBREVIATIONS, AND DEFINITIONS

30 Rupees	1 US Dollar (1995)
Rs.	Rupees
1 crore	10,000,000
1 lac	100,000
BOD5	Biochemical Oxygen Demand. The amount of oxygen demanded by organic matter of sewage origin, in the course of its biochemical oxidation, at 20 degrees centigrade over a five-day period in the presence of excess oxygen.
COD	Chemical Oxygen Demand. Also known as "oxygen consumed." The amount of oxygen required to oxidize carbon and hydrogen by chemical oxidants. It is a value considered in estimating the strength of industrial wastewater.
Faecal coliform	Characteristic organisms of the human intestine, always present in large number in domestic sewage. They serve to indicate recent pollution.
TSS	Total Suspended Solids. The total organic and inorganic matter in waste water as determined by a laboratory filtration test. It does not include dissolved solids.
l	Liter
m	Meter
m3	Cubic meter
mg	Milligram
ml	Milliliter
LPCD	Liter per capita per day
MLD	Million liters per day
O and M	Operation and maintenance
NGO	Non-Governmental Organization

I. EXECUTIVE SUMMARY

This report presents an action plan for improving the quality of water bodies in two Indian cities, Madras and Varanasi. These cities share problems common to other Indian cities and many emerging countries.

Accelerating urbanization joined with little sewage treatment, have devastated many of India's urban rivers, lakes, and other bodies of water. As of 1995, 27 percent of the total Indian population live in cities, compared to 17.29 percent in 1950. The vast increase in urban population has loaded the country's urban waterways with contaminants.

Household wastewater causes most of the pollution of urban rivers in India. Indian cities typically treat little of their sewage. Of India's 3,119 towns and cities, a mere eight have full sewage disposal and treatment facilities and another 209 have partial facilities. Even when treatment occurs, it often falls short of official standards.

Not surprisingly, international standards show that Indian rivers have strikingly high levels of biological oxygen demand (BOD) and coliform counts. Prompted, in part, by this devastation, the country has made strides in establishing an appropriate institutional and regulatory framework for cleaning its waterways, including: (1) the creation of state Pollution Control Boards and a body of urban environmental legislation in the 1970s; (2) the clean-up of the Ganges River focussed on over one million cities under the Ganga Action Plan Phase 1 in the early 1990s; (3) the start of decentralization of resources and responsibilities, from central and state government to local governments under the Nagarpalika Act of 1994; and (4) privatization, and capital market liberalization and reforms that reenforce decentralization, and permit finance of urban environmental infrastructure.

Yet many challenges remain to overcome. Urban environmental service provision presents a complex managerial problem. Fragmentation of services has created poor incentives for performance. In economic terms, monopoly dominates water, sanitation, and solid waste provision. In socio-political terms, government has little incentive to respond to local people's needs and demands. In particular, state governments have suspended the election of mayors and council persons ("corporators") in many municipalities, including Varanasi and Madras, for long periods. In this context, NGOs, social marketing, and environmental monitoring can play an important role in increasing public accountability and motivating clean-up.

A conceptual framework for waterways improvement and a technical framework for such improvement and sewage treatment, preface the action plans for Madras and Varanasi.

Conceptual Framework for Urban Waterways Improvement

Effective efforts to improve urban waterways typically have three components. First, a long-range vision guides action. Second, a careful consideration of cost--particularly balancing costs with benefits--plays a crucial role. Third, the political will and leadership must exist to maintain a long-term commitment.

Setting a Vision. Developing a vision depends on the images and hopes that residents hold for their waterways. In most cities in India, much of the contamination of urban waterways has occurred only very recently, in the last 20 to 40 years. Many local residents, particularly older one who once swam in these bodies of water, have a vision of returning these waterways to their prior condition. However, the massive increase in wastewater from urbanization and diversion of much river water for other uses, makes this vision extremely expensive and impractical. Nevertheless, other less ambitious and costly images are possible, including water quality sufficient for fishing and boating, and for removing the stench of waterways.

Cost and Sewage Treatment Approaches. Treating water to high standards is extremely expensive. The high cost and demanding operation of the standard technologies in developed countries--conventional biological systems such as activated sludge--often, make these systems inappropriate for emerging countries. Yet no clear cut alternatives exist. As a result, intelligent choice of a sewage treatment technology for Indian cities requires examination of a range of alternatives and matching their characteristics with local needs and resources.

Political Will: Macro and Micro Investments. Heavy investments (which we call "macro improvements) often involving national and international funders, and many levels of the government are key to dealing with the bulk of pollutants and, hence, waterways quality. These macro investments depend on the political will and leadership necessary to generate these large sums long-term. Small projects often undertaken by NGOs that involve the public ("micro improvements") can help generate the political will necessary for macro investments, as well as enhance the individual NGO's positive environmental impact.

Technical Framework for Waterways Improvement and Wastewater Treatment Systems

Wastewater treatment removes pollutants--such as Biological Oxygen Demand, Bacteria, and Suspended Solids--through mechanical (often called "primary") and biological (often called "secondary") treatment processes. Primary treatment removes settleable suspended solids through filtering, screening, and sedimentation. Secondary treatment most efficiently removes organic substances that are soluble. Although rare in emerging countries, tertiary treatment may be required to remove substances little affected by primary and secondary treatment, including heavy metals and certain chlorinated hydrocarbons.

Two broad categories of treatment exist. "Conventional systems"--including activated sludge, trickling filters, and rotating biological contactors--are usually the systems of choice in the United States and other developed countries. "Non-conventional systems"--including a variety of land-based pond systems--are much less used. However, joining some degree of sewage treatment creatively with conveying sewage downstream offers much lower costs and better suits conditions in emerging country cities rather than full secondary treatment.

Typically, wastewater treatment represents, by far, the largest cost component of waterways improvement programs. Greater degrees of treatment rapidly escalate expense. Secondary treatment capital costs are twice those of primary treatment. The incremental cost of tertiary treatment is three times that of secondary treatment. Even secondary treatment of all wastewater represents an unaffordable option for most low-income cities. Such cities must rely on primary treatment and conveying the sewage outflow downstream of population centers, away from vulnerable stretches of waterways, and use rivers' self-cleaning capacity.

Activated sludge processes are well suited for developed-country cities, but not particularly for those in emerging countries. Relatively large and prosperous cities in developing countries can best justify the cost of activated sludge. Where activated sludge is already the biological treatment process chosen by local officials, reforms should seek to save energy, evaluate and optimize plant operation, and disinfect sewage through maturation or polishing ponds.

In addition to activated sludge, a number of other technology imports from developed countries appear to have little to modest use in developing country cities. Rotating biological contactors (RBC's) appear inappropriate. Upflow Anaerobic Sludge Blanket (UASB) systems fail to provide a practical alternative to conventional biological treatment systems for large cities, either in developed or emerging countries.

Other technologies appear better suited to most cities in emerging countries than activated sludge. When properly operated, high-rate trickling filters fit developing country cities that have unstable or erratic electric power. Pond systems offer distinct advantages for Indian cities where adequate, suitable land is available. Pond systems: (1) have relatively low capital and operation and maintenance costs; (2) can disinfect; and (3) require much less land area if joined with preliminary treatment, primary sedimentation, and high-rate trickling filters--indeed, this combination of processes appears to suit Indian cities well.

Madras: Analysis and Action Plan

Madras is the fourth largest metropolis in India (after Bombay, Delhi, and Calcutta). The Madras Metropolitan Area's population has grown rapidly from 553,000 in 1901 to four million today. Relative to these other three metropolitan areas, Madras is poorer and is water scarce. Nevertheless, the city has considerable wealth and a dynamic industrial economy, and is an agricultural distribution center.

Madras' four waterways have become highly polluted only recently, in the last thirty years. The household wastewater generated from urbanization is the major source of contamination. Combined with diversion of water from these waterways for agriculture and the small seasonal flows of these waterways, household wastewater causes extremely high pollution levels in these waterways (averaging 200 to 600 BOD)--often above that of typical raw sewage (200 BOD). In effect, these waterways now consist mostly of concentrated sewage most of the year.

The organization responsible for wastewater and, thus, waterway quality is the local water/sanitation company, Metro Water. Metro Water is one of the more dynamic water/sanitation companies in India. It is, for example, at the forefront of privatization.

However Metro Water has focussed overwhelmingly on solving Madras' water problem. Various water projects financed largely by the World Bank are projected to increase supply from 330 million liters per day (MLD) to 1,164 MLD by 2011. In contrast, the wastewater treatment system has a capacity of about 260 LD--about 22 percent of anticipated supply in 2011. No investments are underway or in an advanced planning stage to deal with this imbalance.

A number of technical considerations play an important role in sewage collection and treatment. Metro Water has chosen to deal with the flat topography of Madras by multiplying the number of sewage pumping stations to the remarkable figure of 110! This great number is an operations and maintenance nightmare. Reportedly, many of these pumping stations and the sewage treatment plants discharge large amounts of untreated effluent directly into the waterways when flows exceed capacity (not only during the Monsoons but also during the dry season), apparently, to economize on operating costs. In addition to expanding the existing sewage treatment plants, the operation at the plants requires substantial improvement. Privatization may well be the best answer. Intercepting sewage before it enters waterways and sewering the rapidly growing unsewered areas outside of Madras City proper are also essential.

Overall, the imbalance between water supply and sewage collection and treatment--exacerbated by uneven sewage treatment--is an unexamined crisis. The waterways have borne the brunt of this imbalance so far. Long-term risks include deterioration of the health, quality of life, and economic development of Madras.

Although much less critical than wastewater, garbage collection, also, causes substantial waterways pollution. The Corporation of Madras is responsible for garbage collection and disposal and storm drains. Its performance at these tasks is highly uneven. The government of the State of Tamil Nadu has suspended elections in Madras for mayor and corporation representatives ("corporators") for the last twenty years. The lack of local elections has contributed to low accountability of government agencies and little sharing of information with the public. For example, the Tamil Nadu Pollution Control Board and Metro Water have laboratories and are responsible for monitoring water and sewer quality, but seldom make the results public.

Various analyses and efforts have sought to clean up the waterways of Madras over the last three decades. All have failed because they focussed on beautification and neglected to address pollution levels.

Recently, environmental NGOs have become a driving force behind improvement of waterway quality. One NGO--Exnora International--has leveraged its considerable success in organizing primary garbage collection into a waterways clean-up effort. Another--Water Action Monitoring Project (WAMP)--is an umbrella organization, for NGOs interested in waterways improvement, led by Exnora. Particularly as Madras has had no elections in the last twenty years, these NGOs represent one of the few existing means through which citizens can influence government on decisions affecting waterways.

Exnora International has become adept in organizing both the poor and elite, and involving the public from its success in community based primary garbage collection. Hence, this organization and WAMP are highly appropriate entities to undertake a number of micro projects that can have some effect on waterways quality but that, more importantly, can generate the political will for macro improvements.

However, Exnora and WAMP have yet to become significant players in sewage collection and treatment and, hence, the decisions on the heavy investments necessary for substantial improvement in waterways quality.[1] Independent water monitoring is one way to involve these NGOs more directly in the decisions on macro investments. Another avenue is the development and public dissemination of an action plan--such as that contained in this report--for waterways improvement.

In this context, the Action Plan for improving waterways of Madras includes the following macro and micro improvements.

Macro improvements:

- Rehabilitate and expand by fifty percent the capacity of the four existing wastewater treatment plants. Activated sludge is recommended.
- Extend sanitary sewers to the unsewered population of Madras City and to the existing population of the Outer Urban Area
- Construct intercepting sewers along portion of the Cooum River, the Buckingham Canal, the Adyar River, and the Otteri Nullah, and channel flows to treatment plants
- Construct a sanitary landfill

[1] In contrast, the Sankat Mochan Foundation of Varanasi lacks the grassroots project and ability to work with government of Exnora International but has become a player in the macro decisions affecting the Ganges through the technical expertise of its organizing members.

- Independent program management to oversee and coordinate these technical functions

Micro improvements:

- Establishment of an independent wastewater monitoring program
- Analysis, publication, and information dissemination on waterways quality and an Action Plan for Improving Waterways Quality
- Sanitary upgrading of slums along river banks
- Cattle waste demonstration project
- Support NGOs to assist public agencies in project operation and implementation
- Technical assistance to Metro Water in privatization, and administrative, and financial reform.
- Construct greenbelt and walkways along banks
- Surveys of health-care providers, households, and industrial users of water

Varanasi: Analysis and Action Program

Varanasi is one of the oldest living cities of the world, with a recorded history of 3,000 years. Hindus and Buddhists consider Varanasi sacred, and the holiest city of the Ganges. Roughly 60,000 people take a "holy dip" in the Ganges at Varanasi opposite the ghats--stone steps leading down from temples lining the left bank (facing downstream). In sum, the quality of the water along the ghats is a special concern.

In the last two decades, however, the urban development of Varanasi has begun to threaten river water quality. Household wastewater makes the main contributor to pollution of the ghat area and the river at Varanasi.

Since 1990, a central government project--the Ganga Action Plan Phase I--has invested roughly US $50 million in sanitation improvements to reduce this pollution--in particular, in the construction of an 80 MLD activated sludge sewage treatment plant (Dinapur) and a facility to pump sewage from the main trunk line to this treatment plant (Konia Pumping Station). The performance of these facilities and the Ganga Action Plan Phase 1, generally, has become highly controversial. However, all sides agree that pollution in the ghat area remains extremely high--particularly bacteria counts, which are in the tens and hundred of thousands per milliliter. A key reason is that sewage treatment plants cover only a modest fraction of total wastewater--100 to

140 MLD, at best, out of a total of over 250 MLD. In addition, two minor tributaries to the Ganges--the Varuna and the Assi Rivers--function largely as sewage channels.

Two other sources of wastewater threaten Ganges and ghat water quality in the future. First, two fast-growing areas--the area downstream and south of the Assi River, and the Trans-Varuna Area--virtually lack sewerage. Second, water projects are projected to increase piped-water supply to 350 MLD by 2016. However, no comparable investments for sewage treatment are on line.

The relative poverty of Varanasi limits the sewage solutions appropriate to this city. In contrast to Madras--which is a major metropolis with a dynamic economy, Varanasi is poor, with a crumbling infrastructure. Winding and unmaintained narrow roads, poor energy supply, and garbage strewn throughout the city in numerous formal and informal dumps as well as problematic sewage and water, interact to reduce waterways quality.

To some extent, cleaning the Ganges at Varanasi is a "public good" whose benefits extend beyond this city to all of India. The grant funding of GAP Phase I reflects this nationwide benefit. GAP Phase II--which promises to provide less funding to Varanasi that under Phase I--represents perhaps the last sizeable outside grant available to improve waterways quality in the foreseeable future. Increasingly, Varanasi must find ways of financing sanitation, particularly operation and maintenance costs, and choose its sanitation investments accordingly.

As a result, Varanasi cannot hope to treat fully and effectively more than a modest portion of current and future sewage with conventional secondary, high-cost methods, such as activated sludge. In this context, expanding primary treatment, conveying sewage downstream to take advantage of the self-cleaning capacity of the Ganges, intercepting sewage before it enters the ghats and other urban waterways, and sewering developing areas represent the main keys to improving waterways quality.

In addition, institutional change must accompany these technical reforms. Ganga Action Plan funding has made the state water/sanitation company, Jal Nigam, the major player in sanitation in Varanasi in the last five years. Decentralization and the decline of GAP funding promise to shift power and responsibility to the Municipal Corporation of Varanasi and the local water/sanitation company, Jal Nigam. The District Commissioner and District Magistrate are also likely to play a greater role. This change offers opportunities for improving accountability and results.

An environmental NGO--Sankat Mochan Foundation (SMF)--has largely motivated waterways and ghat improvement. SMF is strong technically and a model for similar efforts in other part of India in this respect. This NGO has close links with one of Varanasi's major religious organizations and has three local engineering professors as its main members. The organization's technical strength and state-of-the-art water quality monitoring laboratory have given SMF some influence on the macro decisions to be made under GAP Phase II. However, SMF has yet to involve the public in micro projects and create the political will necessary for waterways improvements, and has no staff and little background in working with government. Partly as a result, SMF is at an impasse in its efforts to improve waterways and ghat-area quality. Strengthening SMF's ability to work with government, involving SMF in micro projects, and forming an umbrella NGO organization that includes other temples and other environmental NGOs are important to improving waterways quality.

Thus, the Action Program for improving waterways and the ghat area in Varanasi include the following macro and micro improvements.

Macro improvements:

- Construct a new 100-MLD primary treatment plant and channel the effluent of this plant and Dinapur into new maturation ponds with a 200-MLD capacity. Construct a new pumping station and force main to serve the new STP.

- Inspect and rehabilitate existing main trunk sewer and construct a new relief trunk sewer ("interceptor"), preferably under the ghats

- Clean and repair existing sewers and construct new branch sewers in the old city (Cis-Varuna)

- Construct intercepting trunk sewers along key stretches of the Assi and Varuna Rivers, and dredge the lower Varuna River at its confluence with the Ganges

- Technical assistance and program management

Micro improvements:

- Demonstration garbage collection project

- Demonstration cattle waste and animal carcass project

- Ghat environmental education program

- Industrial pollution monitoring and education project

- Form an environmental NGO umbrella organization

- Surveys of health-care providers, households, and industrial users of water

II. THE CONTEXT OF AND A CONCEPTUAL FRAMEWORK FOR CLEANING URBAN WATERWAYS IN INDIAN CITIES THROUGH SANITATION

2.1 The Context for Improving Urban Waterways

India has four percent of the total average annual run-off of the rivers of the world. Four main river groups exist: the Himalayan, Deccan, Coastal and Inland Drainage Basin rivers. The Ganges River (also called the "Ganga"), which passes through the city of Varanasi, is by far the largest of India's rivers, draining 26.2 percent of the total area of India from the Himalayas through the northern plains into the Bay of Bengal. The rivers of Tamil Nadu state--including the waterways passing through Madras--typify the numerous, small coastal rivers of South India that drain small catchment areas into the sea.

India presents great contrasts in its treatment of its urban waterways. The country has some of the dirtiest, most devastated urban rivers on earth. Yet, it also has made strides in creating the institutional and regulatory environment necessary for clean up.

Accelerating urbanization joined with little sewage treatment have devastated many of India's urban rivers, lakes, and other bodies of water. As of 1995, 27 percent of the total Indian population lived in cities, compared to 17.29 percent in 1950. The vast increase in urban population has loaded the country's urban waterways with contaminants.

Household wastewater causes most of the pollution (BOD, Suspended Solids, Coliform Counts) of urban rivers in India.[2] Indian cities typically treat little of their sewage. Of India's 3,119 towns and cities, only 8 have full sewage disposal and treatment facilities and only 209 have partial facilities. The Ganges River alone carries the untreated sewage of 114 cities, each with 50,000 or more inhabitants. When treatment occurs, it often falls short of official standards.

Finally, many urban households in India lack access to any form of sanitation. Only 38 percent of households in a selected sample of Indian cities had access to adequate sanitation, compared with more than double this figure in other developing country regions--see Table 1.

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[2] Figures ranging from 75 to 90 percent of BOD are used in many reports for India and other developing countries, although no comprehensive study exists of this topic for Indian rivers as a whole. In Madras--for example--sewerage from the municipal water company accounts for over 90 percent of BOD load to the Cooum and Adyar Rivers.

Table 1
Access to Sanitation in Urban Areas in World Regions and Selected Countries, 1988 (percent)

Region or Country	Median Access to Sanitation
Africa	64
Central and South America	85
Asia	84
-China	66
-India	38

Note: These figures are medians of sanitation coverage as estimated by the World Health Organization and the United Nations Children Fund.

Source: World Resources Institute, 1992.

Not surprisingly, international comparisons also show that Indian rivers have strikingly high levels of biological oxygen demand (BOD) and faecal coliform counts.[3] The results shock those who remember the rivers of the near past. As little as thirty years ago, residents of Madras boated and swam in rivers (the Cooum and the Adyar) that now present higher BOD than typical untreated sewage. Rising pollution has dirtied the holy waters of the Ganges, the mother of Indian Rivers, in which Hindu pilgrims swim and drink.

Prompted, in part, by this devastation, the country has made strides in establishing an appropriate institutional and regulatory framework for cleaning up its urban rivers.

State Pollution Control Boards and a body of urban environmental law formed in the 1970s. Phase I of the Ganga Action Plan (GAP)--launched on June 14, 1986--has financed 261 sanitation and river-related projects in 25 of the largest cities (Class-I towns) in the three states (Uttar Pradesh, Bihar, and West Bengal) along the Ganges, at a cost of roughly Rs. 450 crores

[3] Data from the United Nation's Global Environmental Monitoring System show that Indian rivers have some of the highest BOD and Faecal Coliform counts in the world. See Kingsley, Ferguson, Bower, and Dice, 1993.

(US $150 million). The Ganga Project Directorate--a central government entity--has had key decision-making authority under GAP Phase I and channelled funds to state and local government entities.

Over the last three years, privatization--once anathema to bureaucrats--has gained currency. The question among the leading sewer, water, and sanitation companies has now become how to privatize, not whether to privatize.

The Nagarpalika Act--passed in 1994--started the crucial process of transferring revenues and responsibilities from the central government to local governments in India. Up until now, local urban environmental infrastructure finance has consisted largely of ad hoc, politically driven grants from state and central government.[4] In particular, the state government has retained virtually all formal powers of sub-national government. Autonomous local governments typically do not exist. This Act has set the institutional framework for local decision-making and finance of key urban environmental infrastructure necessary for urban waterway improvement--water, sanitation and solid waste.

Capital market liberalization and reforms[5] have reenforced decentralization. They have opened the possibility of systematically financing commercially viable urban environmental infrastructure projects with market-rate debt--in contrast to the ad hoc state and central government subsidies that dominate the current system. The leading sanitation, water, and solid waste agencies have begun to take cost recovery, the pre-condition for market-rate urban environmental infrastructure finance, more seriously.[6]

Although some progress has occurred in cleaning up India's urban rivers, much remains to be made. Many problems have arisen--both institutional and technical. For example, difficulties in implementation of Phase I of the Ganga Action Plan have resulted in direct involvement of the Indian Supreme Court in the planning and execution of Phase II.

Various factors make cleaning up urban waterways a highly complex managerial challenge in India. These factors include fragmentation of power and responsibility, and the lack of

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[4] Most municipal urban environmental infrastructure finance occurs through tightly controlled, ad hoc grants from state government. Alternatively, state government stands a guarantee for loans to municipal corporations, water and sewage Boards, and development authorities from financial institutions such as LIC, GIC, UTI, and HUDCO, but pays back these loans through state government's own budgetary resources. State water supply and sewage Boards receive loans from many of the same subsidized sources, but often face legal and regulatory restrictions on raising their service rates. GOI's Finance Ministry, Planning Commissions, and Reserve Board set the amount, interest rate, terms and conditions and even the date of issue of such debt. In sum, the appearance of debt and bond finance has existed without its reality.

[5] Financial sector reforms undertaken by GOI such as reduction in the SLR will remove much of the subsidized financing previously available to states and localities from LIC, GIC, UTI, and nationalized banks that currently underlies current practices.

[6] Cost recovery--a crucial condition for urban infrastructure debt finance--has been low, averaging 50 percent of operation and maintenance on water projects and 10-15 percent on other types of urban services.

accountability of bureaucracies in charge of urban environmental infrastructure provision.

Traditionally, Indian local governments had responsibility for a wide range of urban environmental services affecting urban waterways. Starting in the 1960s, India took many of these functions from local government and vested them in regional and national parastatals.

Consequently, urban environmental service provision has become fragmented. Typically, a state water/sanitation company makes capital investments in these services. A local water/sanitation company[7] operates and maintains them. Local government has nominal responsibility for solid waste management and storm drainage. A state pollution control board has responsibility for monitoring urban environmental conditions. And a development authority supposedly conducts land-use planning and controls land-use. The many jurisdictions in a large metropolis, over 20 in Madras, further complicate functions that overlap the geographic areas--such as the sewerage necessary to improve river quality.

This fragmentation has created poor incentives for performance. The most distinctive example for urban waterways is that of sanitation/water companies. In many, although not all, Indian cities[8], a state water/sanitation company, the Jal Nigam, contracts the construction of capital projects, and turns them over to local water/sanitation companies, Jal Sansthans, to operate and maintain. Too often, this division of functions means that the entity that builds a sewage treatment plant, pumping station, or collection system has little incentive to make sure it works.

The behavior of bureaucracies that face few incentives to perform well lies at the root of the institutional problem. The delivery of urban environmental infrastructure services takes place in a market and political structure with one dominating characteristic: the absence of accountability.

In economic terms, monopoly dominates urban environmental service provision. Public agencies are typically the sole providers of water, sanitation, and solid waste management services. Indian civil service and other rules greatly hamper the ability of the public managers of these entities to hire or fire workers, adopt suitable technologies, and make the changes necessary for improving performance. Introducing competition[9] represents the key principle for

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[7] Although these companies are local in their sphere of action, state government typically funds and controls them (the Jal Sansthans).

[8] Bombay, Ahmahdebad, and Madras have retained water/sanitation authorities that both construct public works and operate and maintain them. Partly for this reason, these entities reportedly are among the best sanitation and water providers in India.

[9] Although competition potentially offers many benefits, the potential for increasing the number of suppliers depends on the characteristics of the service. Services that resemble public goods (individuals that do not pay can be excluded from the benefits of the service) with few economies of scale (which encourage multiple suppliers) well suit competition. Until recently, most urban infrastructure services have been perceived as purely public goods with high economies of scale. As a result, they were supplied almost exclusively by public entities. Technical and institutional innovations, however, now allow exclusion and a wider range of operational scale.

positive change in this context. In water and sanitation, competition best takes the form of separating these services (sometimes called "unbundling") into components[10] that can be privatized and regulated by the local authority. Unbundling and contracting out water and sanitation services has just begun in India, and deserves strong support.

In socio-political terms, government has little incentive to respond to local people's needs and demands. State governments, in many cities, have suspended elections for mayor and city council for long periods of time. Political appointees from the Indian Administrative Service (IAS) end up governing these localities. These appointees have much less incentive to respond to local needs than elected officials. Since, despite some attempts at reform, elections frequently remain unavailable as a means of influencing local authorities, NGOs and other organizations that can involve local people, mediate their needs, and pressure government, have particular importance.

Social marketing and environmental monitoring can also help increase accountability. Inaction or unresponsiveness to pollution problems is due, in part, to the public's lack of knowledge and access to information.[11] Even when the negative consequences of inadequate environmental protection are pervasive, they are often indirect and urban populations fail to perceive the inter-relationship.[12] Such problems are particularly important when little reliable information exists on river water quality and other environmental problems--the norm in India.[13] Social marketing and environmental monitoring can make city residents aware of urban environmental issues and assist them to take action.

The introduction of competition also depends on location. Capital and secondary cities offer lucrative markets that can attract urban service suppliers. Small, distant municipalities lack these features, and their local governments may well be the only entity capable or interested in paving streets and building water lines at reasonable cost.

[10] Unbundling refers to separating service activities into discrete components and allowing competition in those areas with lower economies of scale and excludability--the characteristics of services most easily privatized. For example, EMOS, the private water supplier for the city of Santiago, has successfully unbundled and contracted out meter reading, maintenance of trunk lines, billing and vehicle leasing (Briscoe, 1993). The city of Santa Fe de Bogota in Colombia has completely privatized solid waste collection.

[11] See Bartone et al, 1994.

[12] The classic examples are sanitation and solid waste. Households appreciate the value of and will pay for water, but often not for adequate sanitation or solid waste management. Studies of the poor shown that many lack an understanding of the importance of adequate sanitation and solid waste management in health.

[13] In part, the lack of good environmental data on river quality and other environmental conditions in Indian cities comes from scarcity of resources--labs, trained personnel etc. In part, it comes from the unaccountability of public agencies charged with providing urban environmental services and monitoring urban environmental conditions. Many such entities are supposed to have labs and monitoring programs, but fail to put much effort into them, resist making any resulting data public, and--sometimes--appear to simply make up data to fit the standards. For example, the Team visited the lab of a sewerage treatment plant that recorded virtually the same BOD5 level for incoming sewerage effluent and for processed sewerage for all the days we examined--a highly unlikely outcome.

Technical issues interact with these institutional ones, especially in wastewater treatment.

2.2 Conceptual Framework for Urban Waterways Improvement in Emerging Countries

Traditionally, city dwellers and infrastructure supply agencies have viewed urban waterways as a highly convenient dump that carries wastes of all types out of the area. Cleaning up rivers, bays, and oceans near cities is a recent concern, both in emerging and industrialized countries. Serious environmental actions began to protect urban waterways in the United States only a little over four decades ago.[14] India's concern began with efforts to clean the Ganges in the late 1980s.

Threats to rivers, lakes, and other bodies of water have galvanized popular and political support for other types of environmental improvement. The environmental movement in the United States spread from efforts to protect the Ohio River[15], San Francisco Bay Area, Lake Tahoe, and other bodies of water to industrial waste, air pollution, solid waste, hazardous waste and urban growth management. Improving urban waterways in emerging countries, cleaning up the beaches and ocean off Rio de Janeiro, de-contaminating Lake Maracaibo, and returning the sacred Ganges to its former purity, promise to be similar catalysts.

Many effective efforts to improve urban waterways have three components. First, a long-range vision must guide actions. Second, a careful consideration of cost--particularly appropriate sewage treatment technologies--and balancing cost with benefits plays a crucial role. Third, the political will and leadership to maintain a long-term commitment must develop. Often, environmental NGOs help create this political will through promoting "micro" projects that involve many local people in numerous small environmental clean-ups to complement the "macro" projects--the heavy investments undertaken by infrastructure operating and environmental improvement agencies.

A useful conceptual framework for urban waterways improvement in India and other developing countries shares these three, inter-related components; vision, balancing costs and benefits, and political will and leadership.

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[14] California enacted the first legislation and established the first special-purpose agencies dedicated to protect urban waterways in the late 1960s and early 1970s. The Bay Conservation and Development Çommission was established to protect San Francisco Bay, while the Tahoe Regional Planning Agency was started to keep Lake Tahoe unpolluted and blue.

[15] The Ohio River Valley Water Sanitation Commission (ORSANCO) was formed in 1948 and pioneered efforts to protect major urban waterways in the United States. In 1972, the Federal Water Pollution Control Act (Public Law 92-500) was enacted by Congress in response to the growing awareness that the Nation's waters were becoming severely polluted.

Setting a Vision

Difficult problems, such as cleaning a highly polluted urban river, require a long-range vision to inspire and orient action. Developing this vision depends on the images and hopes that residents hold for their waterways. In turn, these images and hopes often arise from the prior experience of local people of the waterway in question, and of other waterways.

In this regard, an important datum is that the contamination of urban waterways in developing country cities, including those of India, has occurred only very recently. Massive urbanization, accompanied by huge increases in untreated and poorly treated sewage dumped into waterways, is the principal factor. This increase in sewage discharge has been a direct result of increased potable water supply. Urbanization has dramatically increased only in the last four decades, first in Latin America, and later in South and Southeast Asia and Africa. Before 1960, the rivers, lakes, and oceans near developing country cities, typically, showed very low levels of pollution.

Not surprisingly, the vision that many residents of these cities hold of their waterways dates to this recent past. In Madras, for example, older residents remember swimming in the Cooum and Adyar Rivers and, even, the Buckingham Canal only thirty years ago and they want to be able to swim again in these waterways. Largely because of the pressures of urbanization[16], however, these rivers no longer flow for all but three months of the year and have pollutant levels (BOD, Bacterial counts) two to three times that of typical raw sewage. Achieving water quality suitable for swimming would require huge investments in an attempt to turn back the clock to a different era. Some cities may have the wealth and commitment for such an endeavour, but most, especially in India, will not.

However, other attractive but less ambitious and cheaper images are possible. Fishing and boating in a river requires somewhat lower water quality than swimming. Removing the stench from highly polluted waterways so that residents can take agreeable walks and live comfortably along them, may come at a substantially lower level of water quality and cost than fishing and boating.

An image of waterways and their desired use can emerge from much public discussion or flow naturally from previous experience.[17] Once set, the vision can be translated into quantitative water quality goals and a plan of action that grapples with cost.[18]

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[16] Including diversion of water upstream for agriculture, discharge of greatly increased amounts of municipal sewage into these waterways, and toxic and hospital waste.

[17] In the case of Lake Tahoe bordering California and Nevada, residents, infrastructure supply and environmental agencies, and outside legislators united around the goal of keeping this lake blue.

[18] Keeping Lake Tahoe blue required drastically restricting the flow of organic nutrients into this lake, which--in turn--required restraining development, particularly near the lake.

Cost and Sewage Treatment Approaches

Municipal wastewater typically contributes 80 to 90 percent of pollutant loads to waterways in emerging country cities. Hence, urban waterway quality depends mainly on the extent and efficiency of wastewater collection, treatment, and disposal.

However, treating wastewater to high standards, such as those specified in the U.S., is an extremely expensive task. For example, the incremental cost to treat wastewater (per pound of BOD removed) to tertiary levels (5 to 10 mg\l BOD in the effluent) is about three times the cost to treat the wastewater to secondary levels (20 to 30 mg\l). Because of this high cost, even Western Europe and Japan have gradually and, to date, only partially treated their municipal sewage. As a result, European rivers continue to be the most polluted in the world, in some respects. For example faecal coliform counts in the European rivers monitored by the Global Environmental Monitoring System (GEMS) are an average 1,775 per 100 ml compared to 500 for Asian rivers and 117 in South and Central America rivers.[19]

Conventional biological treatment systems, particularly activated sludge, have become the sewage treatment systems of choice in advanced countries. They have advantages and requirements that well suit conditions in these countries. The treatment systems can achieve consistently high levels of treatment that meet rigorous environmental standards. They need little land. Highly skilled personnel are required for design, construction, and, particularly, operation and maintenance. Finally, the systems are energy intensive, and their capital and operation and maintenance costs are high.

The high cost and exacting operation and maintenance requirements of conventional biological treatment systems make such systems problematic for emerging country cities. However, no straightforward alternative, widely suited to conditions in developing country cities, exists. As a result, an intelligent choice of a sewage treatment technology for cities, such as those of India, requires examination of a range of alternatives and matching its characteristics with the needs and resources of the locality.

An adapted approach to sewage treatment and, hence, waterway quality goes beyond the choice of a treatment technology and depends on two other critical factors.

First is the extent and level of treatment necessary to protect the health of the urban population and ensure the desired level of quality of waterways near the city. Sewage can be treated to three levels--primary, secondary, and tertiary. Sewage can also be intercepted and conveyed downstream of an urban area. Large rivers with rapid flow have a high self-cleaning capacity. Such rivers can absorb and clean considerable untreated sewage. Finally, many common forms of sewage treatment--such as activated sludge--do not remove substantial amounts

[19] See p. 18 in Kingsley, Ferguson, Bower, and Dice, 1994.

of pathogenic (disease-causing) bacteria. Hence, separate disinfection, by chlorine or solar radiation (in ponds), for example, may be necessary.

By varying these factors, cities can intelligently deal with municipal sewage at a fraction of the cost necessary to construct, operate, and maintain conventional biological systems. For example, the cost of constructing and operating a primary treatment plant is about half that for an activated sludge plant. A low-income city on a large river--such as Varanasi--might logically choose to give its sewage primary treatment, and then convey the treated sewage downstream for disposal. A fast-growing, major metropolis, such as Madras, with small, relatively stagnant bodies of water, might well choose higher levels of sewage treatment.

Second, sewage flows differ radically in many emerging country cities depending on the season. Sewage flows in monsoon season in India (from July to September), for example, may be 50 to 100 times those in the dry season.[20] Monsoon flows will overwhelm all but the largest, most expensive sewage collection and treatment systems. Most untreated sewage is discharged into waterways during monsoons. The importance of this seasonal overload, however, may be great or small, depending on local conditions. If a sewage system backs up and floods heavily populated neighborhoods during monsoons, the cost of a larger system capable of relieving the back-up may make sense. Excessive flows may be discharged to the waterways during such periods with the rest (including the first flush) intercepted and conveyed to treatment plants. In sum, cities must choose the level of sewage flow to be intercepted and size their collection, treatment, and disposal systems accordingly.

Figure 2.1 presents an illustrative model of factors critical to vision and cost and, hence, the choice of the heavy investments (which we call "macro" investments) necessary to deal with wastewater and improve waterway quality.

The Y-axis shows different possible visions for the waterway: bathing, fishing and boating, and removing stench.

The X-axis gives different approaches to dealing with sewage including: (1) intercepting only, without treatment; (2) intercepting and treating; and (3) intercepting, treating, and disinfecting. These three approaches can be sized to dry weather conditions, or to wet-weather conditions.

The points on the graph illustrate the relative costs of these different options. (Note: they are not to scale and do not indicate absolute cost.)

For example, the lowest cost strategy is for intercepting dry weather sewage flows to carry them away from urbanized areas and thereby remove the stink from the waterways. The highest cost strategy includes not only dry weather flow interception but also the conveying, storing, and

[20] For example, one inch (2.54 cm) per hour runoff from a rainstorm may contribute 30 to 50 times the average dry weather flow rate. This difference in flow rate has major cost implications.

treating of wet-weather flows sufficient to achieve water quality for bathing at all times of the year. A wide range of options lie between these two extreme strategies.

Political Will; Macro and Micro Projects

Heavy investments in sewage collection, disposal, and treatment systems are key to dealing with the bulk of pollutants and, hence, waterway quality. However, these macro investments depend on the political will and leadership necessary to generate these large sums long-term.

Sustained and effective environmental improvements, worldwide, have required strong public awareness and support. Involving large numbers of people in clean-up activities can sometimes result in greatly improved environmental conditions. Primary garbage collection is one example. NGOs in some cities in South and Southeast Asia (including Madras) and Latin America have succeeded in organizing local people to bag and sort their garbage, and to pay micro-enterprises to pick up this refuse.

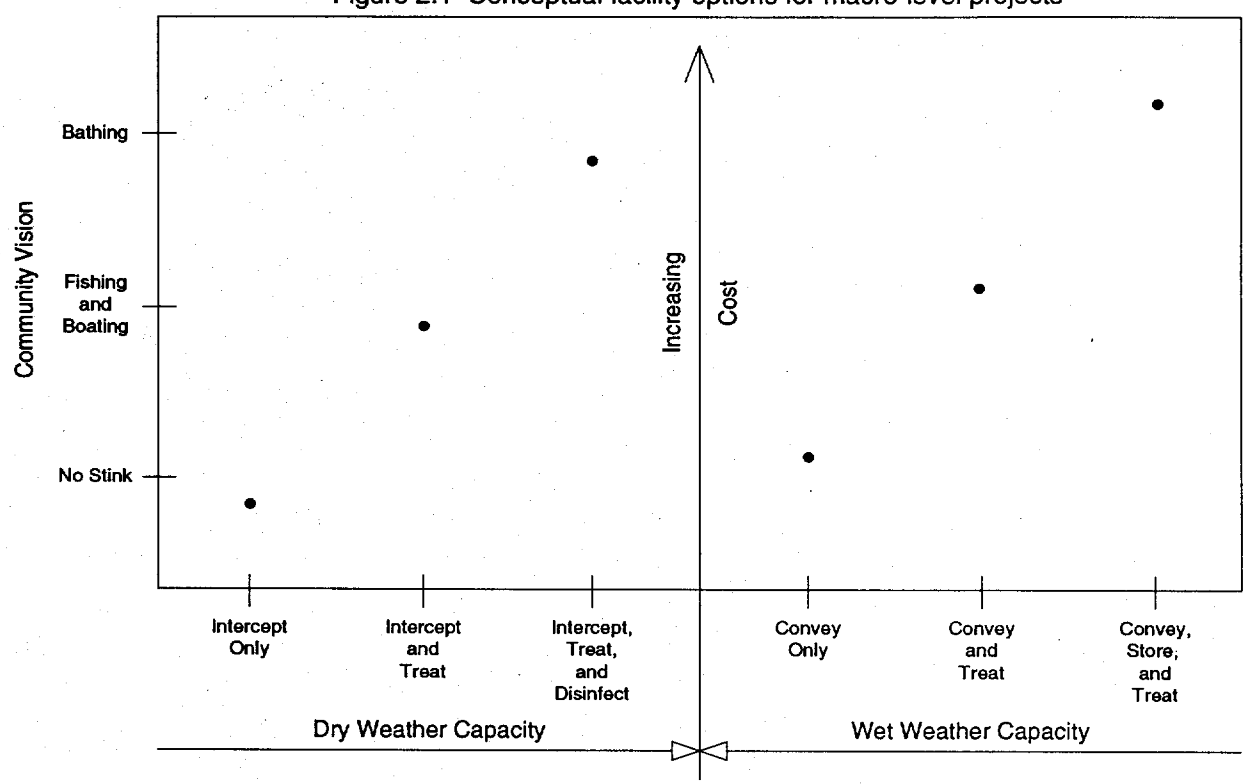
Most importantly, public awareness and involvement often generate the continuing political climate and community leadership necessary to sustain on-going macro investments.

Hence, effective urban waterway improvement pursues two tracks. First, macro investments, that target the major pollutant loads, particularly municipal sewage, are necessary. Infrastructure operating agencies, the government at all levels, international donors, and national financial institutions and capital markets are the likely participants in these macro improvements. Second, micro investments that involve the public, complement the clean-up of macro improvements, and generate the political will for the macro investments are essential.

Micro level projects suited to India cities include the following:

- Removal of garbage accumulations
- Connection of toilets to the sanitary sewer system
- Education regarding the public's role in managing liquid and solid wastes
- Independent monitoring of water quality as a check on results presented by operating agencies and others
- Participation of industrialists in the treatment of wastewater--particularly those whose industries contain toxic and hazardous materials
- Control and proper disposal of cattle wastes
- Removal or proper sewering of informal settlements along river banks
- Reforestation and beautification of river banks
- Self-help upgrading of slums along river banks
- Industrial pollution education and monitoring

Figure 2.1 Conceptual facility options for macro-level projects



- Formation of an environmental NGO umbrella group
- Technical assistance to infrastructure supply agencies, NGOs, and other groups

Macro level projects suited to Indian cities include the following:

- Connecting existing houses, commercial establishments, public buildings, hospitals, industries, and toilets to the public sanitary sewer system
- Inspection, cleaning, repair, rehabilitation, reconstruction, and replacement of the existing sanitary sewer system
- Construction of new sewers to presently unsewered areas
- Construction of new intercepting sewers by either open cut or tunneling methods to eliminate piped discharges of untreated wastewaters into waterways
- Dredging of waterways to remove accumulated contaminated sediments, along with their proper and safe disposal
- Enclosure of waterways deemed to be unworthy of reclamation to acceptable community standards of beauty or safety
- Construction of pumping and conveyance facilities so as to deliver fresh raw sewage to wastewater treatment plants
- Construction of storage facilities or utilization of storage capacity in sewers to temporarily contain excess wet-weather flows of mixed sewage and stormwater for subsequent treatment
- Implementation of industrial wastewater monitoring and pretreatment programs for industries discharging into the public sewer system
- Upgrading the level of treatment and capacity of Sewage Treatment Plants (STP) to meet future flows and loads, such that effluent may be used for industrial process and cooling, groundwater aquifer recharge, low flow augmentation of rivers, crop irrigation, wetlands and wildlife habitat restoration and other purposes,
- Disinfection of STP effluents, as appropriate, to their end uses
- Development and implementation of STP sludge (biosolids) utilization programs such as agricultural land application or energy production
- Construction of alternative sludge disposal facilities when biosolids utilization may not be possible
- Institution of training programs for operation, maintenance and facility management personnel
- Development of privatization or concessionary contracts for construction, operation, maintenance and management for the above facilities.

Typically, environmental improvements including urban waterways clean-up must pursue both macro and micro level project tracks for success in achieving the vision.

Conclusion

In sum, the urban waterways improvement process typically establishes a vision, develops a technical approach to improving water quality that balances cost with benefits, and makes both macro investments aimed at wastewater collection and treatment, and micro improvements that involve local people.

III. DESCRIPTION OF BIOLOGICAL WASTEWATER TREATMENT SYSTEMS

Biological treatment uses bacteria to break down organic material in wastewater. Widely used for municipal and industrial organic wastewater, biological treatment processes remove a large number of constituents including biochemical oxygen demand (BOD5), total suspended solids (TSS) and fecal coliform (bacteria originating in the intestinal tracts of humans and animals).

Biological treatment may occur in the presence of oxygen ("aerobic"), in the absence of oxygen ("anaerobic" or "anoxic"), or in a system of variable oxygen conditions ("facultative"). Useful byproducts of biological treatment include methane gas from anaerobic breakdown and sludge or algae with fertilizer value. The water resulting from effective treatment (called "effluent") recharges aquifers, irrigates crops, and supplies industries.

Municipal wastewater frequently contains materials, other than organic materials, that challenge biological treatment systems. Toxic substances in wastewater such as pesticides and non-organic industrial wastes can damage biological treatment. In extreme cases, the biological system is destroyed (i.e., biological removal of organic wastes may be stopped completely).

Municipal wastewater also contains floating materials (scum and grease), grit (sand type material), rags and large objects, settleable solids (termed "sludge" or "biosolids"), and heavy metals (such as cadmium and chromium). "Preliminary treatment" and "primary sedimentation" protect sewerage equipment from damage by removing these materials and enhancing biological treatment. Both preliminary treatment (screening and grit removal) and primary sedimentation use physical processes. Biological processes are called "secondary treatment" because they come after this primary sedimentation. Tertiary treatment processes follow secondary treatment.

Primary sedimentation most efficiently removes settleable suspended solids. Secondary treatment--that is, biological processes-- most efficiently removes organic substances that are soluble (particle size less than .001 micron) or in the colloidal-size (particle size .001 to 1 micron) range. (Note: 1 micron = .001 mm) Biological treatment processes convert the finely divided and dissolved organic matter in wastewater into flocculent, (increased particle mass) settleable solids that sedimentation basins or clarifiers can remove.

Tertiary treatment, or advanced wastewater treatment, may be required to remove substances unaffected or little affected by primary and secondary treatment processes, such as heavy metals and certain chlorinated hydrocarbons. It may also be required to achieve effluents consistently containing less than 10 to 20 mg/l BOD5.[21] Tertiary treatment is often unnecessary

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[21] Unit operations and processes that have been applied to the tertiary treatment of waste water are classified as physical, chemical and biological. These operations and processes are typically used in combination and include the following:

- air stripping of ammonia
- filtration
- reverse osmosis

and relatively rare in cities of emerging countries.

Some secondary and tertiary processes will disinfect wastewater as well as remove BOD and suspended solids, and other contaminants while others will not.

The contaminants most frequently removed in wastewater treatment systems are Biochemical Oxygen Demand (BOD), Suspended Solids (SS), and Chemical Oxygen Demand.

Typical raw sewage quality, effluent quality for treatment levels, and effluent quality standards are shown in Table 2.

Table 2
Standards for BOD, Suspended Solids and COD Removal

	Concentration (mg/l)		
	BOD5	Total Suspended Solids	COD
Raw Sewage (U.S.)	200	200	500
Treatment Level			
Primary Effluent	140	80	-
Secondary Effluent	10 to 30	15 to 30	-
Tertiary Effluent	2 to 10	0 to 10	-
Standards			
India[22]	30	-	250
U.S.[23]	30	30	250
European Union[24]	25	35	125

- carbon adsorption
- chemical precipitation
- nitrification - denitrification

[22] Environment Protection Second Amendment Rules, 1993 standard for discharge into surface water bodies, for Class B rivers.

[23] Wisconsin, 30-day average, to receiving waters classified as fish and aquatic life.

[24] Official Journal of the European Communities, 30 May 1991.

A fourth parameter has particular importance for human health--faecal coliform counts. Practice in developed countries suggests a maximum of 1,000-2,000 faecal coliform per milliliter (ml.) for waterways used for bathing. The World Health Organization has set a standard of 1,000 faecal coliforms per milliliter as maximum for irrigation water. Disinfection of sewage should also achieve this level. India has yet to establish a standard for bacterial or faecal coliform counts for processed sewage or waterways.

3.1 Conventional Biological Treatment Systems

Three processes -- activated sludge, trickling filters, and rotating biological contactors -- are referred to in this report as "conventional" biological treatment because they are usually the systems of choice in the United States and other developed countries for large cities.

Each process consists of one or more steps that, together, reduce or eliminate the pollution in the water. These steps often include aeration (adding air and/or oxygen to the wastewater) and settling (allowing the solid materials to settle out of the water). Aeration increases the rate at which the bacteria "eat" the organic waste material, and produces a "sludge" which must be removed and disposed. Aeration occurs in basins or tanks that forcibly mix oxygen with the liquid contents of the basins.

Activated Sludge Processes

Activated sludge has become the most common conventional biological treatment system for large cities in developed countries for a number of reasons. First, it can consistently produce the high quality effluent that meets the rigorous standards that rich countries adopt. Second it uses relatively little land. Third, it is very flexible and can be adapted to almost any type of biological waste treatment problem. However, activated sludge also has drawbacks, including high cost (both capital and operation and maintenance) and high skill requirements for operation and maintenance.

Activated sludge has also spread to developing country cities, where its virtues are less easily realized and its drawbacks more serious. Many of India's treatment plants--including most of those in Madras and Varanasi--use the activated sludge process. Hence, an understanding of the activated sludge process is a prerequisite for appreciating wastewater treatment and, hence, the urban waterway quality in these cities.

The term "activated sludge" has come to refer both to a conventional treatment system that depends mainly on this process and to a process that is one of several, component.[25] A treatment

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[25] In addition to conventional activated sludge systems, modifications of this process include:

- Complete-mix

plant that employs preliminary treatment processes, primary sedimentation and the activated sludge process is known as an activated sludge plant. A flow diagram for a typical activated sludge sewage treatment plant is shown on Figure 3.1.

Sludge is referred to as "active" when it contains a suspension of living flocculent microorganisms. Biological systems depend on microorganisms (bacteria, fungi, protozoa and rotifers) that eat the organic matter in the wastewater, and on oxygen to maintain suitable aerobic conditions. The microorganisms tend to settle out in the sludge generated during treatment.

All versions of activated sludge treatment require continuous mixing and forcing air (or oxygen) to provide the proper dissolved oxygen concentrations in the mixed liquor in the aeration basins. "Mixed liquor" is the continuously mixed slurry of primary settled sewage, returned sludge from the secondary clarifier, dissolved oxygen and microbial cell mass. The microorganisms in the mixed liquor eat the organic matter and thrive when the optimum concentrations of food, oxygen and other constituents are present.

"Diffused air systems" introduce oxygen into the aeration basin well below the water surface. Alternatively, mechanical aeration systems (usually surface aerators) infuse atmospheric oxygen into the wastewater.

Some of the sludge (typically 25 to 100 percent) is usually returned to the aeration basins from the secondary clarifiers in order to maintain the proper ratio of food to micro-organisms and prevent bulking (poorly settling and thickening biomass). Excess or waste activated sludge is removed from the system. Upon removal, the sludge requires "stabilization" to assure its safe disposal or utilization. Stabilization may consist of anaerobic digestion, aerobic digestion, incineration, composting, drying, advanced alkaline stabilization or other processes.

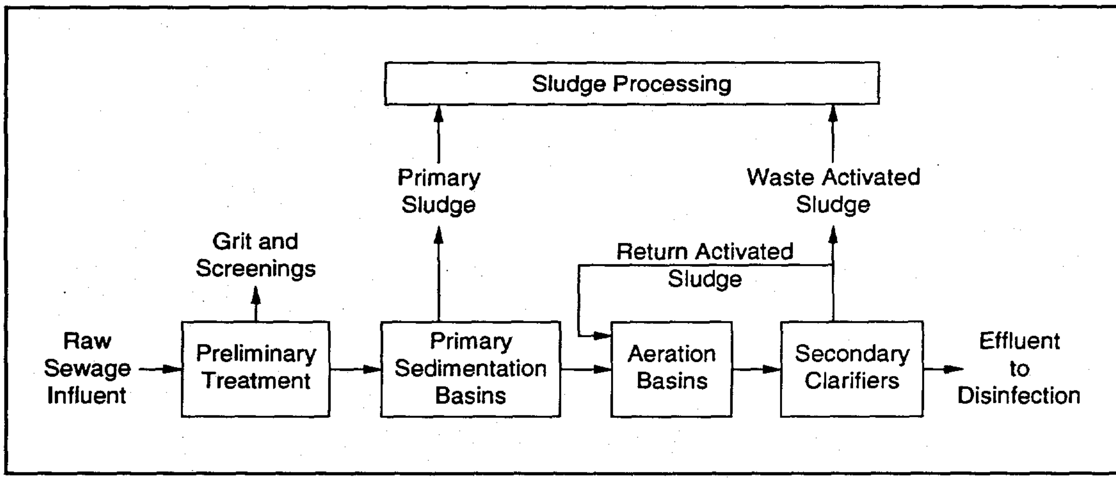
The activated sludge process has decided advantages:

- Can produce high quality effluent
- Little land area required
- A proven track record
- High potential for utilization or recycling of treated effluent.

Activated sludge has become the dominant form of sewage treatment in the U.S. and Western Europe because these virtues well suit conditions in these countries. In particular, these countries are energy rich, and their cities have relatively high maintenance capability.

- Step-aeration
- Contact stabilization
- Extended aeration
- Pure oxygen systems

Figure 3.1 Typical activated sludge sewage treatment plant flow diagram



However, activated sludge also has disadvantages:

- High energy requirements (aeration is the largest cost)
- Requires high skill levels, including highly trained personnel for design, construction, equipment installation, operation, maintenance, control, laboratory analysis, and management
- Vulnerable to shock loads (i.e. unexpected peaks in BOD levels)
- Produces large sludge quantities
- High capital and operation and maintenance costs
- Requires separate sludge stabilization
- Effluent requires separate disinfection (disinfection is not considered to be an integral part of the activated sludge process)

These drawbacks of activated sludge make this process far less suitable for cities of emerging country than those of rich countries.

These disadvantages contribute to a number of serious operational problems frequently encountered in activated sludge plants in the developing world that can greatly reduce the efficiency of these plants, the quality of treated effluent and the quality of urban waterways into which these plants discharge. They include:

- "Retention" for too long a time in primary and secondary sedimentation basins, leading to septic conditions and poorly settling sludge
- Inappropriate levels of dissolved oxygen and mixed liquor suspended solids concentrations in the aeration basins
- Lack of scheduled equipment maintenance and tank clean out that minimizes equipment wear and tear and prevents clogging of diffusers and other equipment.

Trickling Filters

Trickling filters are also used in developing country cities, although less commonly than activated sludge. The Koyambedu sewage treatment plant in Madras, for example, was recently converted from high-rate trickling filters to activated sludge to conform to Madras city's current policy of using only activated sludge.

Trickling filters bring the wastewater into direct contact with bacteria by having the wastewater flow down over large stones or other "media." The media provide surfaces on which bacterial colonies grow in an aerobic environment, continually fed by organic matter in the incoming sewage.

Two types of trickling filters exist. Low-rate trickling filters do not recirculate effluent. High-rate trickling filters employ various patterns of recirculation to achieve optimum performance. Low-rate trickling filters are seldom constructed today because they require large land areas and because they cause more odor and fly problems than high-rate trickling filters.

In the high-rate trickling filter, recirculation of the effluent allows for handling higher organic loadings--that is "stronger" sewage with larger amounts of BOD. For example, recirculation of effluent from the trickling filter clarifier (sedimentation basin following the filter) permits the high-rate filter to achieve the same removal efficiency as the low-rate filter in much less space.[26] High-rate trickling filter flow sheets, with various recirculation patterns, are shown on Figure 3.2.[27]

Trickling filter processes share some advantages and disadvantages with activated sludge. Both approaches:

- Have a proven track record for cities with good operation and maintenance capability
- Can produce high quality effluent
- Require separate sludge stabilization
- Require separate sludge disinfection

Advantages of high-rate trickling filters, in comparison with the activated sludge process, include:

- Less skilled operation and control required
- Lower energy requirements
- Lower sludge quantities produced
- Process less vulnerable to overloads and shocks
- Lower capital, and operation and maintenance costs

Disadvantages, in comparison to activated sludge, include:

- Effluent quality varies somewhat more with the season of the year
- May require somewhat more land area than activated sludge

In emerging countries such as India, trickling filters offer many advantages for producing secondary-treatment effluent quality because of the technology's simplicity and low land-area

[26] Recirculation of filter effluent also returns some of the viable organisms to the filter tank, which often improves treatment efficiency. Furthermore, recirculation aids in preventing ponding in the filter and in reducing the nuisance due to odors and flies. Finally, the use of newly developed plastic filter media (such as the cross-flow type) provides greater consistency in BOD5 and TSS removals while allowing deeper tanks which require less land area than the older stone media filter beds.

[27] The ratio of recirculation rate to design average flow ranges from 0.5:1 up to 4:1. Multi-stage trickling filters are used where needed to meet more stringent effluent standards.

requirements. However, cities in these countries only infrequently use trickling filters, perhaps for a number of circumstantial reasons. Marketing of equipment manufactured or provided by developed countries tends to focused on equipment-intensive technologies, such as activated sludge, rather than simpler, more appropriate technologies, such as trickling filters. Activated sludge may have gained the status of "state-of-the-art" and have more prestige than trickling filters.

Rotating Biological Contactors

Rotating biological contactors (RBCs) represent a hybrid form of biological treatment that incorporate elements of both activated sludge and trickling filters. Similar to activated sludge, RBCs rely on energy consuming mechanical devices to assure the oxygen and food that bacteria need to thrive. As trickling filters, RBCs provide a surface which has a two-fold purpose. It is a surface that bacteria can adhere to and it brings food and oxygen to nourish them.

The "contactors" are mechanically driven discs covered with a filter medium. These discs and their filter medium rotate in a circle. While these discs rotate, wastewater passes through the filter medium. Bacterial colonies that grow on the filter medium consume the organic matter in this wastewater, which is continuously fed into the disc. The rotation of the discs also provides the oxygen necessary for the bacterial colonies to thrive. This rotation can be adjusted to fit conditions.

RBCs can provide high quality effluent comparable to that produce by activated sludge. Advantages of RBCs over activated sludge include:

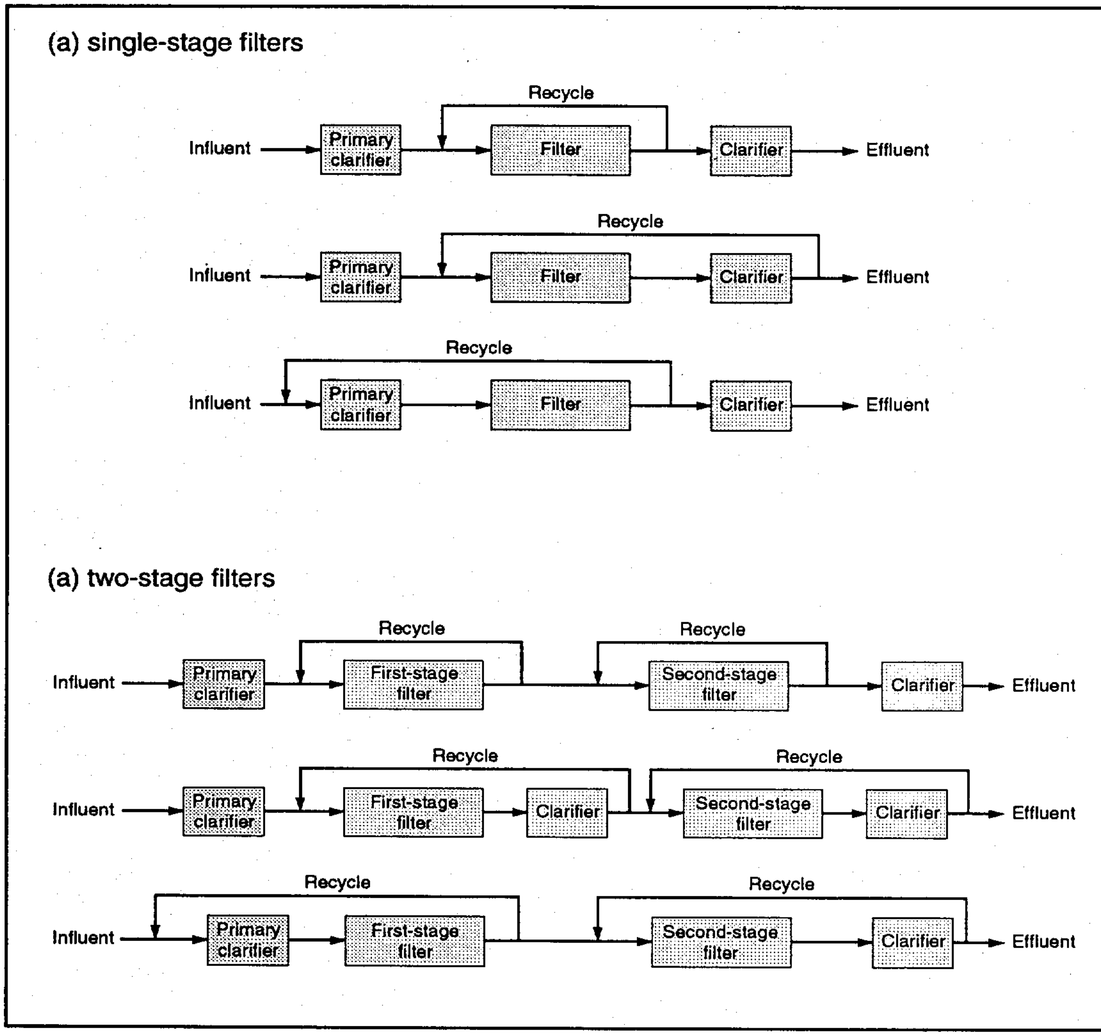
- Lower energy costs (but higher than those for trickling filters)
- Less skilled operation required
- Process not easily upset
- Less sludge produced

Disadvantages include:

- Highly mechanical and, hence, high O & M costs
- Requires highly skilled maintenance
- Sludge requires separate stabilization
- Effluent requires separate disinfection

RBCs are rarely used in emerging country cities. As trickling filters, RBCs may lack state-of-the-art status with engineers in developing countries. In addition, RBCs' heavy mechanical nature renders them inappropriate for use in most developing country contexts.

Figure 3.2 High-rate trickling-filter flowsheets with various recirculation patterns



3.2 Non-Conventional Biological Treatment Systems

We examine two types of non-conventional biological treatment systems: upflow anaerobic sludge blanket systems and land-based pond systems.

Upflow Anaerobic Sludge Blanket System (USAB)

Dutch engineers developed the UASB and have marketed this system internationally as a low-tech biological treatment process requiring little maintenance. Generally, it has low pumping and aeration requirements. The UASB system has succeeded in treating relatively small amounts of industrial sewage. However, its application to large municipal systems remains largely untested.

The UASB process is a combination of physical and biological processes. The main features of the physical process are the separation of solids and gases from the liquid, and the decomposition of organic matter under anaerobic conditions. No primary treatment (sedimentation) is provided prior to the UASB reactor, where the organic matter is broken down by microbial action.

A process flow diagram of a UASB plant near Varanasi in the town of Mirzapur is shown on Figure 3.3.

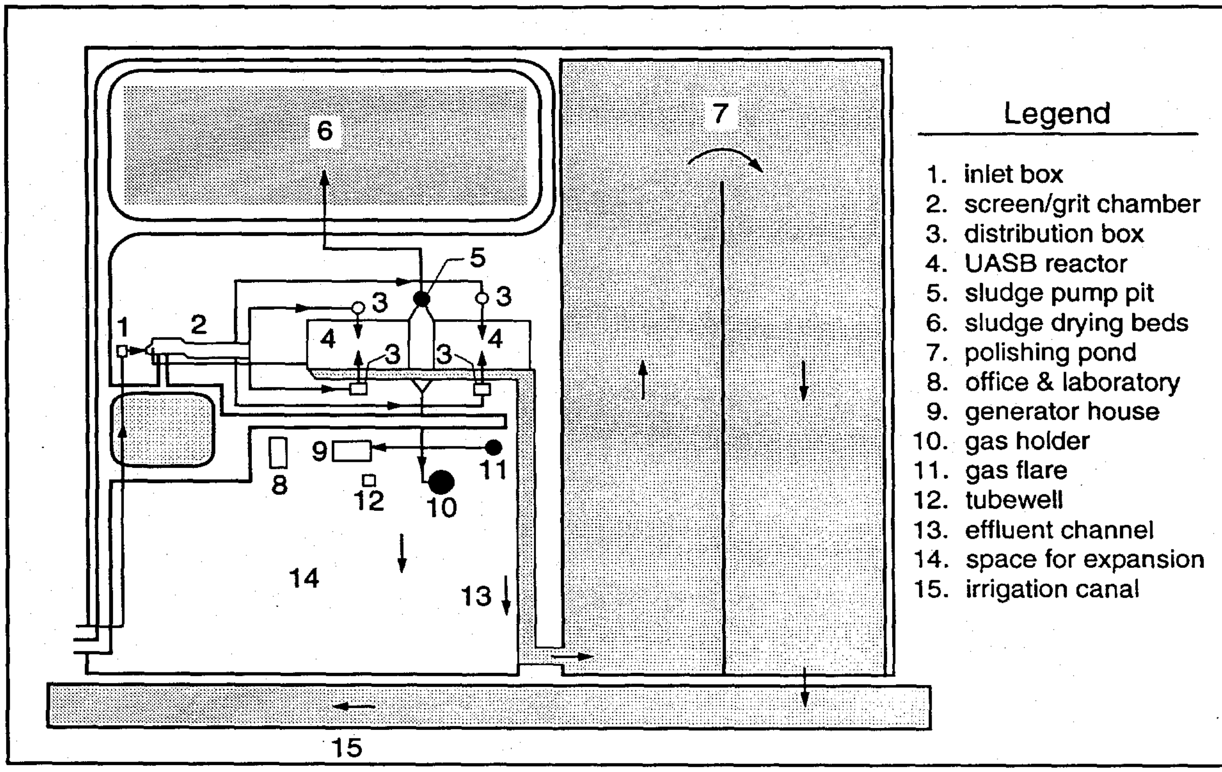
Wastewater enters through the bottom of a UASB reactor and travels upwards. The inlet system spreads the wastewater uniformly over the bed of the reactor. The lower part of the reactor ("the reaction compartment") contains a layer of active (alive with microbes) sludge. When the wastewater comes in contact with the sludge, the unstable (decomposing) organic matter present in the wastewater is digested anaerobically, resulting in end-products mainly consisting of methane and carbon dioxide. These gases are collected in a "gas hood" above the reaction compartment (called the "solid-liquid-gas separator")

The excess liquid overflows into the "settler zone" where solids settle, and then return to the reaction compartment. No intended recirculation of the liquid component occurs. The treated effluent is collected in the effluent channels and transported out of the reactor.

To date, UASB facilities are small. Hence, large numbers of such plants (10 to 15 initially) would be required to serve a large city such as Varanasi. Separate disinfection of effluent is necessary, similar to that of conventional biological systems.

A team member reviewed and visited the pilot UASB facility in Cali, Colombia in 1988 where 13 or more UASB systems were being proposed to serve the city, which was comparable in population to Varanasi. Observations included:

Figure 3.3 UASB plant lay-out and process flow diagram



- Close operational control is required; sludge volumes and return rates must be carefully controlled to assure maximum effectiveness and avoid nuisance conditions; sludge pumping is required.
- Despite special attention paid to its operation and maintenance, housekeeping deficiencies and corrosion were evident.
- Some pumps and other mechanical equipment are required
- Operating results in terms of BOD5 and TSS fell short of consistently meeting discharge standards
- The large number of plants required present a potential operation and maintenance nightmare

A UASB plant in Mirzapur, Uttar Pradesh appears to share some of these limitations. Results presented for operation of the Mirzapur STP show effluent qualities consistently worse than the required BOD5 levels of 30 mg/l (ranging from 31 to 127 mg/l in the data available to us). BOD5 removal efficiencies range from 65 to 91 percent with an average of about 75 percent. Fecal coliform counts reported for the Mirzapur, India wastewater treatment plant (STP) effluent (even after the polishing pond which receives the UASB effluent) were 7.4 million per 100 ml on March 2, 1995--an extremely high and dangerous condition. These results show that treatment levels well below those normally expected of secondary or biological plants.

The potential problems associated with scale-up, from a pilot facility, such as that of Mirzapur, to numerous larger plants, are unknown, but certainly significant.

Land-Based Pond Systems

Land based systems are generally low tech and make use of relatively large land areas for performing their pollution reduction functions. In contrast, conventional systems and the UASB system confine treatment processes to small areas.

Land-based or pond systems may provide an attractive option where adequate land area is available, electrical energy is in short supply or erratic supply, and little or no experience in the operation and maintenance of treatment systems exists.

<u>Stabilization Ponds.</u> Wastewater stabilization ponds are the simplest form of pond or lagoon system. They are also known as oxidation ponds and have been in use for many years, in many countries, primarily in small and rural communities.

Their virtue lies in their simplicity. They consist of a "single cell", or of multiple pond cells arranged either in series or in parallel. Pond cells are usually earthen embankments and are lined with impermeable membranes of either plastic or clayey soils to prevent leakage and possible groundwater contamination. Multiple cells are interconnected and may have gates or valves to control and adjust the gravity flow patterns, and to allow the draining of cells (cell "dewatering") for cleaning or maintenance.[28]

Wastewater passes through these cells by gravity. This wastewater must remain in stabilization pond systems for relatively long periods of time--typically up to 30 days for effective treatment. Hence, stabilization ponds require large land areas in order to retain large volumes of wastewater for long periods. Ponds are sometimes preceded by screening and grit removal, but rarely by primary sedimentation and seldom followed by separate disinfection.

Stabilization pond systems should operate only in an aerobic condition. Hence, BOD levels[29] must be relatively low (i.e. "loaded" lightly) to assure that natural aeration from the atmosphere and photosynthesis is always sufficient to maintain this aerobic condition.[30] If a system becomes overloaded (i.e. the incoming wastewater require more oxygen than the system can produce), anaerobic or septic conditions develop, causing unsightly and odorous conditions.

Algae and aquatic plants, including water hyacinth, thrive on the nutrient-rich liquid in ponds and can be harvested for use as fertilizer. Ponds are commonly 1 to 1.5 meters (m) deep to prevent rooted aquatic growth from developing and to permit light penetration through the entire depth of liquid. Rooted vegetation does not develop if such depths are maintained.

Stabilization pond systems can produce acceptable effluent if maintained in a continuously aerobic state. However if overloaded, they can quickly become anaerobic, begin to stink, and cause problems. High land-area requirements render stabilization pond systems impractical for most major cities. The total pond surface area required would be 200 to 500 ha. for a city of one million people. Additional area would be required to allow for future population growth, access roads, embankments and other facilities.

The simplicity and ease of operation of stabilization ponds make them very attractive for developing country cities, either alone or in combination with other processes. These ponds may be the process of choice where adequate suitable land area is available.

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[28] Pond cell embankments are commonly planted with grasses for erosion protection, and periodic inspection and mowing are necessary to prevent embankment failure and an overgrown condition. Embankments may also require protection from wind-induced wave action which can cause erosion; rip-rap (placement of large rocks) may be needed where winds have a long reach of open water in which to set up significant wave action. Pond cells are placed in series to enable sedimentation of sewage solids to occur in the first cell. Subsequent cells yield progressively higher quality effluents due to continued bacterial assimilation of organic matter. In parallel cells or in single stage pond systems all bacterial decomposition occurs in one cell or stage thus requiring longer quiescent settling conditions than for series ponds in order to achieve comparable results. In both series and parallel pond systems long detention times (usually months) and prolonged exposure to sunlight provide effective disinfection to reduce concentrations of pathogenic bacteria (as measured by fecal or total coliform counts) to acceptable levels.

[29] Organic (BOD5) loading rates for conventional stabilization pond systems are commonly around 2000 persons per hectare (ha) per day or between 34 and 50 kg per ha per day.

[30] Loading must take into account that algae enter their respiratory phase (in which they utilize rather than produce oxygen) during the night time hours.

Aerated Lagoons. Aerated lagoon systems are modifications of stabilization ponds. They use surface or submerged forced aeration to supplement natural aeration processes. Aeration may be provided by electrically driven air compressors--which feed air under pressure to a system of tubes resting on the bottom of the aeration cell--or by mechanical surface aerators.

Pond cells are earthened and lined similarly to stabilization ponds. The aerated cells may be preceded by a separate primary sedimentation stage, to prevent clogging of the aeration system and reduce loading, and/or by screening and degritting. Flow from the aerated cells commonly passes by gravity from the aeration cells to secondary and tertiary ponds for settling and disinfection. Pond cell embankments may require the same types of protection as stabilization ponds.

Aerobic lagoon systems are operated in a continuously aerobic condition. Supplemental forced aeration helps assure this condition, reduce surface-area requirements, and introduce an element of control over dissolved oxygen concentrations in the system for optimum performance. Such control reduces the possibility of anaerobic conditions developing, either at night or when unexpectedly heavy loads occur. The depth of liquid in aerated cells may vary from about three to five meters depending on the type of aeration devices used.

Secondary and tertiary ponds in series following the initial aerated cells can be much smaller than those required for stabilization ponds because of this greater efficiency--that is, loadings that enter the secondary and tertiary pond from the primary pond are much lower. The total surface area required for an aerated lagoon for a city of one million would be around 100 to 300 hectares, or about half the area required for stabilization ponds.

Aerobic lagoons are capable of producing a more consistently acceptable effluent quality than stabilization ponds. However aeration requires energy consumption, equipment maintenance and support. The system must function continuously to prevent anaerobic conditions from developing. Power failures can result in rapidly overloading the system and unacceptable effluent quality.

Aerated ponds are an attractive option for cities in developing country, with adequate and stable electrical energy. In comparison with other land-based systems, aerated ponds conserve land area, which is frequently scarce near large cities.

Advanced Integrated Wastewater Pond Systems (AIWPS). Advanced Integrated Wastewater Pond Systems (AIWPS) are an innovative, relatively untested improvement on older land-based pond treatment systems. By joining a series of different types of ponds, AIWPS seek to shorten the time required for treatment ("residence time") and, thus, greatly reduce the land area necessary for the treatment facility. However, AIWPS retain the advantages of other land-based pond systems over conventional biological treatment systems--including much lower capital cost (less than a tenth of the capital cost of activated sludge) and operation and maintenance cost, very low energy use, and relatively low skill and personnel requirements. In short, AIWPS seek to have the best attributes of both conventional biological treatment and land-based pond systems.

A flow sheet for advanced integrated wastewater pond systems is shown on Figure 3.4.

AIWPS incorporate, in a series of at least four ponds, special environments for methane fermentation (anaerobic decomposition) and photosynthetic oxygenation (algae oxidation) of sanitary sewage and organic industrial wastewater. These systems can achieve secondary and even tertiary levels of treatment. When properly designed, located, constructed and operated, the systems produce little sludge, use little electric power, require less land than conventional stabilization ponds and are claimed to be more reliable and economical than mechanical systems of equal capacity.

In their most effective and reliable form, AIWPS consist of at least four ponds in series, each designed to perform one or more basic treatment processes:

- Facultative pond (FP) with an aerobic (with oxygen) surface and an extremely anoxic (without oxygen) internal pit for sedimentation and fermentation.

- High rate pond (HRP), a paddlewheel-mixed shallow raceway in which microalgae grow profusely releasing oxygen by photosynthesis.

- Algae sedimentation pond, in which algae carried over from the HRP are allowed to settle.

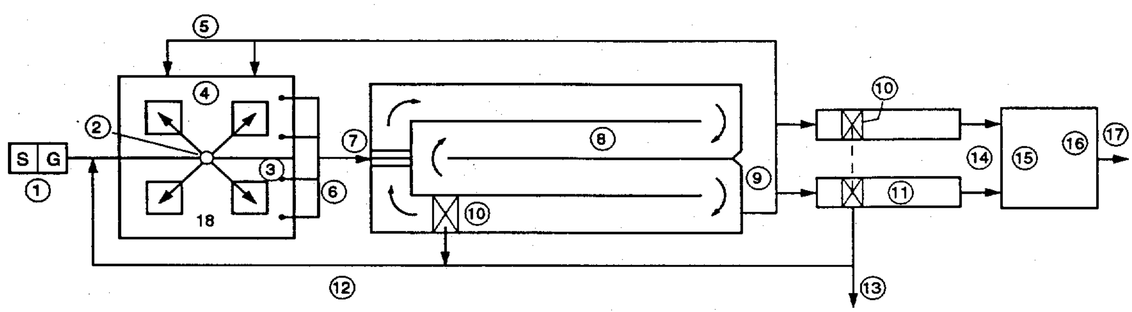
- Maturation pond, which provides added disinfection and storage for irrigation.

In contrast to aerobic lagoons and stabilization ponds--which are only aerobic--AIWPS join both aerobic and anaerobic treatment.

The first pond--the facultative pond (FP)--achieves the bulk reduction of various pollutants (BOD, Suspended Solids). Residence time in this pond is 8 to 16 days. Following the facultative pond, effluent is drawn from a depth of 1.2 meters below the surface and introduced into the paddle wheel-mixed HRPs. The HRPs are comprised of raceways or channels each of which has a surface area of about 0.1 hectares.[31] The normal operating depth for the HRPs is 30 cm, and the hydraulic residence time in the HRPs is 3 to 4 days. Longer residence times cause excess algal growth and aging, with the resultant release of nutrients from the sludge.
Effluent from the HRP's is drawn from the surface at a point about 6.1 meters upstream of the

[31] Flow velocity in the raceways is maintained at 15 centimeters per second, a velocity sufficiently high to prevent thermal stratification and to maintain algal suspension, and sufficiently low to avoid lifting the flocculent bacterial phase into the high pH surface waters.

Figure 3.4 Flowsheet for advanced integrated wastewater pond systems



Legend

1. screening/grit removal
2. distributor
3. fermentation pits
4. facultative pond
5. oxygenated water return
6. low-level transfer
7. paddle wheel mixer
8. high-rate pond
9. high-level transfer
10. algae subsidence chambers
11. algae settling ponds
12. settled algae return
13. algae harvest
14. low-level harvest
15. maturation pond
16. high-level transfer
17. water reuse/effluent
18. supplementary aeration

paddlewheels.[32]

HRP effluent is directed into the algae sedimentation pond. Because of their small size, these units may be constructed of concrete rather than earthwork. Hydraulic residence times in these settling units can be varied from 2 hours to over 1 day. Overflow from the settling units is drawn through a series of parallel holes at the far ends of the units into the maturation pond. To harvest the settled algae, the supernatant liquid is decanted and the thickened algae is removed by pumping.

The University of California has constructed and operates an experimental AIWPS in Richmond, California, that processes household waste from a nearby community. The results[33] are satisfactory for Indian conditions, but potential scale up problems to a large full-scale facility could be significant.

Small scale installations have shown treatment effectiveness of AIWPS comparable to conventional biological processes, but without their large energy requirements. This result holds great promise for developing country cities, especially smaller ones. Significant drawbacks are the systems' large land requirement and the potential for scale-up problems to accommodate large cities. Dr. Oswald--an authority on AIWPS--has estimated that 9 km2 of land area would be required to treat the wastewater from the presently estimated 1.2 million people in Varanasi. Future urbanization would have extreme land-area requirements. At its present stage of development, the AIWPS appears best suited for cities and towns of under 500,000 population, or where land represents little problem.

Constructed Wetlands. Constructed wetlands, an emerging land-based technology, treats wastewater using emergent (rooted to the bottom) plants such as cattails, reeds and rushes. The flow path of the applied wastewater can be either above or below the soil surface. Constructed wetlands have been used in several small U.S. cities. Because the technology is still developing, pilot plant operations are often established and tested before moving to full scale.

Two types of constructed wetlands exist: subsurface flow (SF) systems, and free water surface (FWS) systems. Subsurface systems consist of beds or channels filled with gravel, sand, or other permeable media, (0.5 to 0.75m deep) planted with emergent vegetation. Other names for sub-surface systems include "rock-reed filters" and "vegetated submerged beds." Filtration is a major mechanism for suspended solids removal in subsurface systems.

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[32] By drawing from the surface, the removed water has a high pH and has been irradiated by the sun. Each of these phenomena enhance disinfection of pathogenic organisms.

[33] Operating results at Richmond (capacity between 1894 and 7576 m3/day) show total BOD5 removal of about 80% and TSS removal of about 16%. The suspended solids content is reported to be primarily algae and not sewage solids. Fecal coliform are reduced from 90 million to 170 MPN per 100 ml.

Free water surface systems consist of beds of medium to coarse sand. FWS systems remove BOD using bacteria attached to plants and vegetative litter. This vegetation traps suspended solids, which also settle out.

Nitrogen removal can be effective in both types of constructed wetlands, depending on the pre-application treatment given to the wastewater, detention times and loading rates. Phosphorus removal in most FWS systems is ineffective. The potential for phosphorus removal is greater in FS systems.

Constructed wetlands require more land than stabilization ponds and about the same as AIWPS. For example, four to 15 square kilometers of land area would be required for a million people, almost the present population of Varanasi.[34]

Constructed wetlands have achieved BOD5 reductions of 64 to 86 percent and suspended solids reductions of 28 to 93 percent based on low strength domestic wastewater. Preliminary treatment and sedimentation must precede the constructed wetlands to assure effective performance. Mechanical equipment is required for preliminary treatment, sedimentation and sludge processing.

Wastewater from the city of Calcutta reportedly flows into a large wetland for treatment. The study was unable to find data on the effectiveness of that system and its operation and maintenance requirements. However, simply running raw wastewater into an existing wetland area fails to constitute proper constructed wetlands technology. If uncontrolled, use of an existing wetland area may create an environmental health hazard through the contact of people with raw sewage over a large area. Considerable construction of facilities and earthmoving are required to assure control over the process and conduct flows appropriately through the facility.

The great land-area requirements and difficulty of controlling the inflow of raw sewage to such a facility make the use of constructed wetlands largely inappropriate for large cities in India.

<u>Root Zone Systems.</u> Root zone systems are both land-based and use land to treat wastewater. "Land treatment" is the controlled application of wastewater to the land at rates compatible with the natural, physical, chemical and biological processes that occur on and in the soil.

The three types of land treatment systems are slow rate, overland flow, and rapid infiltration. Of these three, overland flow--which emerged in the 1970's--appears most promising

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[34] Hydraulic surface loading rates--the key variable for land-area requirement--for constructed wetlands vary between 400 and 1500 m3/ha-day.

for developing country cities.[35]

Use of a partially aerated pond has proved successful for overland flow. The pond precedes land application, serves to remove large solids, and adds dissolved oxygen to the wastewater. The short detention time retards the growth of algae, which otherwise could not be removed efficiently. The land application technology is very similar to that for crop irrigation, varying from sprinkler to surface application. Screening or comminution (grinding of solid materials and debris) plus aeration to control odors during storage or application is acceptable for urban locations with no public access.

Overland flow systems can treat sewage to secondary levels, by removing significant amounts of BOD5, suspended solids and nitrogen.[36] However, overland flow is less efficient at removing phosphorus, trace elements and pathogens. For the present population of Varanasi the land area requirement would be between 3 and 20 km2.[37] Overland flow is best suited to slowly permeable soils that can be graded to mild slopes (2 to 8 percent) and planted with water-tolerant grasses which can be harvested or left on the slopes.

Conclusion

Table 3 summarizes, compares and contrasts the biological treatment systems discussed above. The final column contains an overall ranking for the use of each technology in India.

A number of salient points emerge from this table and its review of technologies:

The choice of a wastewater treatment process best occurs through carefully examining a range of technologies and, then, adapting one or more to local conditions. Four conditions have particular importance for this choice in major cities in India: energy consumption, land requirements, operation and maintenance capacity and needs, and disinfection.

Typically, wastewater treatment represents by far the largest cost component of waterways improvement programs. Greater degrees of treatment rapidly escalate cost. Secondary treatment capital costs are twice those of primary treatment. The incremental cost of tertiary treatment is three times that of secondary treatment and, hence, tertiary treatment is seldom used in cities of emerging countries. Even secondary treatment of all wastewater represents an unaffordable

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[35] Slow rate systems require an extraordinarily large land area which for Varanasi could be as much as 100 km2. Rapid infiltration is appropriate technology for groundwater recharge, but because its intent is to pass treated waste water quickly into the subsoil it is not appropriate to the purpose of growing crops or other vegetation. Rapid infiltration is appropriate for ground water recharge but not for the growth of vegetation.

[36] Effluent can be better than secondary quality, depending on the application rate. However, huge land area requirements exist for reaching better than secondary quality levels.

[37] Hydraulic loading rates range from 3 to 20 meters/year. Land area needed is 7 to 46 ha/mgd or per 3785 m3/day.

Table 3. : Summary Analysis of Biological Treatment Systems

Biological Treatment Systems[2]	Effectivness of Treatment[3]	Recyclability of Output[4]	Environmental Impact[5]	O&M Sophistication[6]	Costs[7] Capital	Costs[7] O&M	Comparison with Conventional[8]	Total[9]
	Analysis Factors[1]							
Conventional Systems								
Activated Sludge	1	2	3	5	5	5	-	-
Trickling Filters	2	3	2	3	4	3	-	-
Rotating Biological Contactors	2	3	2	4	4	4	-	-
Upflow Anaerobic Sludge Blanket (UASB)	3	4	2	4	4	3	5	21
Natural Systems								
Conventional Stabilization Ponds	2	1	4	1	1	1	4	10
Aerated Lagoons	2	1	3	3	3	3	3	15
Integrated Ponds Systems	3	1	2	2	2	2	4	12
Constructed Wetlands	3	2	4	1	1	2	5	13
Root Zone Systems	3	2	4	1	1	2	5	13

Notes:

[1]Rating scale for analysis factors: 1 = best, 3 = moderate, 5 = worst. These ratings are for the individual systems only; that is, the ratings are based on the assumption that the systems are not used in conjunction with one another.

[2]Ratings for each biological system assume that preliminary treatment (screening and grit removal) and primary treatment (sedimentation) were carried out beforehand.

[3]Effectiveness of treatment considers effluent quality in terms of both 5-day biochemical oxygen demand (BOD5), total suspended solids (TSS), and fecal coliforms, as well as system reliability based on experience in comparably sized cities, including consideration of scale-up.

[4]Recyclability of output includes considerations of:

- quality of treated effluent for irrigation of crops, industrial reuse, or body contact activities without separate disinfection systems
- quality of sludge or algae produced relative to its land applicatiion
- potential for either effluent, sludge, or algae to be utilized

[5]Environmental impact elements include:

- energy utilization
- utilization of existing facilities
- minimum land area required for treatment processes
- compatibility with the sacredness of rivers in terms of using them as treatment sites

[6]Operation and maintenance sophistication refers to the low or high technology nature of the process, the need for highly trained and skilled staff, and the need for extensive spare parts and equipment support. This factor also considers the need for multiple treatment locations.

[7]Highest costs equate to the worst rating.

[8]Comparison with conventional processes relates to an overall assessment of the advantages or disadvantages of the other systems, including land requirements for major cities.

[9]Ratings for UASB and natural systems only; only the first six columns of analysis factors are included in the totals.

option for most low-income cities. Such cities must rely on primary treatment and conveying the sewage outflow downstream of population centers and away from vulnerable stretches of waterways, in order to use rivers' self-cleaning capacity.

Activated sludge processes well suit developed-country cities, but not particularly those in emerging countries. Relatively large and prosperous cities in developing countries can best justify the cost of activated sludge. Where activated sludge is already the biological treatment process chosen by local officials, reforms should seek to save energy, evaluate and optimize plant operation, and disinfect sewage through maturation or polishing ponds.

In addition to activated sludge, a number of other technology imports from developed countries appear to have little to modest use in developing country cities. Rotating biological contactors (RBC's) appear inappropriate to less developed country cities. Upflow Anaerobic Sludge Blanket (UASB) systems fail to provide a practical alternative to conventional biological treatment systems for large cities, either in developed or emerging countries.

Other technologies appear better suited to most cities in emerging countries than activated sludge. When properly operated, high-rate trickling filters fit developing country cities that have unstable or erratic electric power.

Pond systems offer distinct advantages for Indian cities where adequate, suitable land is available. Pond systems: (1) have relatively low capital and operation and maintenance costs; (2) can disinfect; and (3) require much less land area if joined with preliminary treatment, primary sedimentation, and high-rate trickling filters--indeed, this combination of processes appears to suit Indian cities well.

IV. MADRAS

4.1 Description of Urban Waterways in Madras

Madras is on the eastern coast of India, located on flat land that falls about 3 meters from the western limits of the city 20 kilometers to the sea. Two small river estuaries divide the city, that of the Cooum and of the Adyar. Both rivers have small catchment areas, of roughly 283 square kilometers and 847 square kilometers respectively. In addition to the Cooum and the Adyar Rivers, two other urban waterways exist in Madras--the Buckingham Canal and the Otteri Nullah. These four waterways inter-connect.(Refer to map of Madras)

Two basic conditions distinguish the urban waterways of Madras from those of Varanasi and most other cities in India. First, none of these urban waterways now flows throughout the year. Except during the monsoon season from October to December, these urban waterways are stagnant and fed largely by treated and untreated sewage.

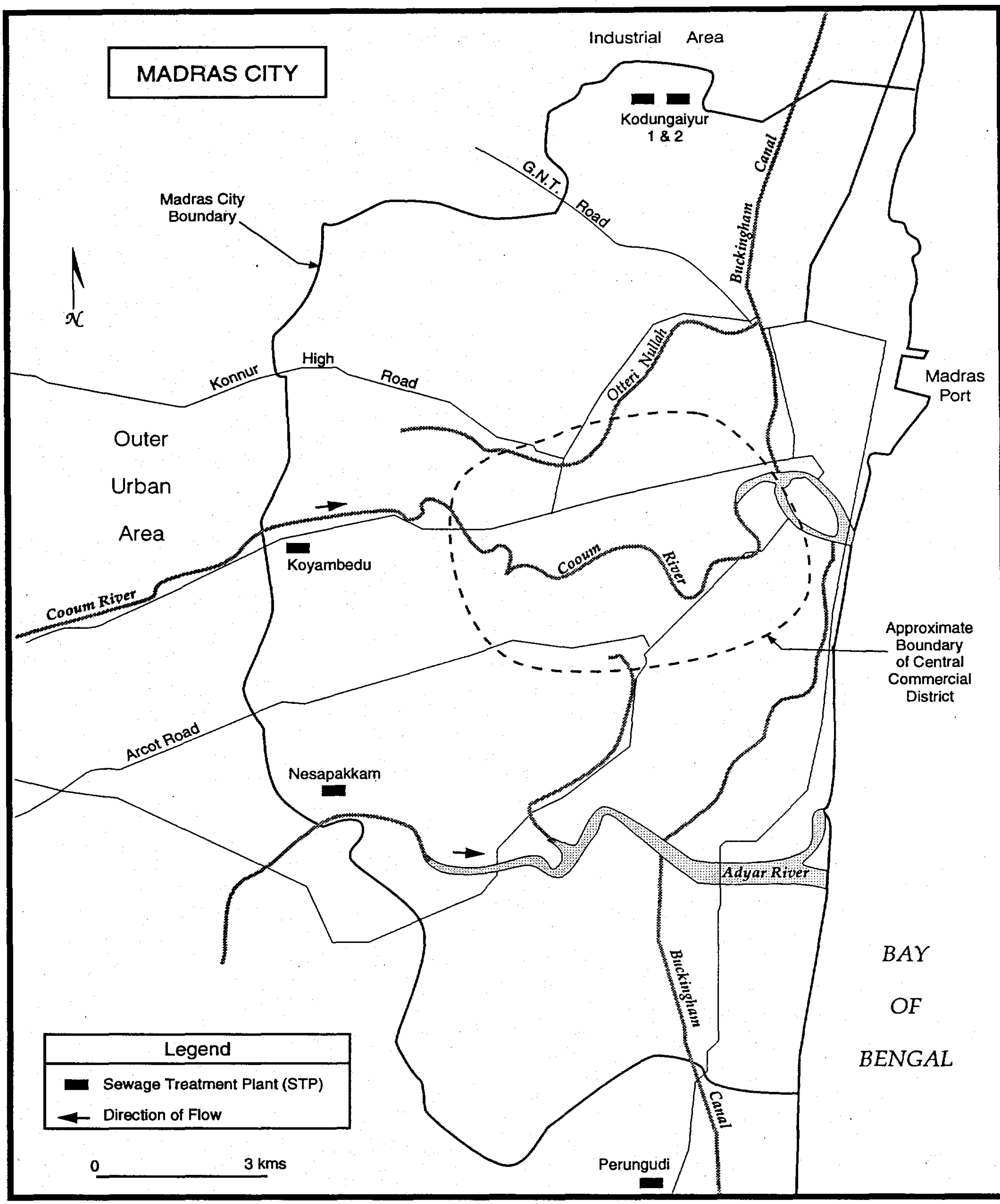
Second, the Madras region has less piped water per capita than any other major metropolitan area in India--ranging from 30-79 liters per capita per day, compared to the Indian standard of 140. As a result, the flow of the Adyar and Cooum has been diverted for agriculture and to replenish reservoirs that supply the city before entering the central urban area.

The pollution of these waterways joined with accelerated population growth has occurred largely in the last four decades. Now, partly because of the extreme scarcity of water in the Madras region, pollution loads in these waterways, such as Biochemical Oxygen Demand (BOD), are extraordinarily high (BOD averaging 200-600 mg/liter)--equal or above that of typical Indian raw sewage (200 mg/liter). Household sewage contributes the great bulk--85 to 90 percent--of this BOD.

The BOD from household sewerage enters these waterways in various forms including: partially treated effluent discharged from Madras' three sewerage plants; diversions of raw effluent from these sewer plants and from pumping stations, particularly during the monsoons when these facilities virtually shut down; and direct discharge from unsewered large buildings and facilities (hospitals, a train station, government buildings), from unsewered formal-sector households, and from squatter settlements along the banks of these waterways (which contain roughly 50,000 people).

Comprehensive analysis of the sewage discharges into the waterways has yet to occur. However, the BOD load from the sewerage plants and pump stations are, almost certainly, the most important.

Older residents of Madras remember boating and swimming in the Cooum, the Adyar, and--even--the Buckingham Canal. The vision they hold of these waterways dates to a different time, before the massive diversion of water and before the heavy pollution of these rivers.


MADRAS CITY
Industrial Area
Kodungaiyur 1 & 2
G.N.T. Road
Buckingham Canal
Madras City Boundary
N
Konnur High Road
Otteri Nullah
Madras Port
Outer Urban Area
Cooum River
Koyambedu
Approximate Boundary of Central Commercial District
Arcot Road
Nesapakkam
Adyar River
BAY OF BENGAL
Legend
Sewage Treatment Plant (STP)
Direction of Flow
0 3 kms
Perungudi

Cooum River

The Cooum flows through the key residential and commercial parts of the city. The watershed of the Cooum nourished the early commercial and residential growth of Madras City. Various important urban landmarks line the Cooum.

Currently, the Cooum is a drainage course that collects the surpluses of several reservoirs. Much of the flow of the Cooum also gets diverted into a reservoir, the Chembarambakkam Tank, which is used for irrigation. Given the great scarcity of water in Madras, reducing the Cooum's inflow into this reservoir in order to augment this river's flow is highly unlikely. The river meanders roughly west to east for 16 kilometers through Madras before reaching the sea. Near the Cooum's mouth, the Buckingham Canal connects. A sand bar covers the mouth of the Cooum, which further hinders flow.

The pollution of the Cooum began in the nineteenth century. Efforts to clean it date at least to the 1930s. From 1967 to 1972, the government of Tamil Nadu undertook a major improvement scheme. This project included channelling, excavation and lining of the central channel, and construction of boat jetties and other amenities. These efforts failed mainly because they neglected to target the pollution entering the river.

Little appears to have changed since then. Many proposals for removing the sandbar have been made, although a consensus exists that the sandbar is a natural feature that would re-build quickly if removed. Meanwhile, the main problem, pollution, has grown much worse. After the Buckingham Canal, the Cooum is the most polluted of Madras' waterways. The main contributor to the Cooum's pollution is the Koyambedu Sewage Treatment Plant, which discharges 34 million liters per day into this river. This discharge has led to an accumulation of sludge on the river bed.

Adyar River

The course of the Adyar runs 40 kilometers from its catchment area, west to east through Madras. Similar to the Cooum, much of its flow has been diverted. The surplus from the Chembarambakkam tank and 200 smaller tanks drain into it. A number of large drains that carry sullage and storm water also flow into the Adyar, contributing to its pollution load. The Nesappakaam Treatment Plant and several hundred industrial establishments discharge wastes directly into this river, and are the other main source of its pollution.

Nonetheless, the Adyar is less polluted than the Cooum River, the Buckingham Canal, and the Otteri Nullah. The maximum BOD measured from September 1991 to October 1993 was 290 mg/liter.

The estuary of the Adyar still attracts a wide variety of birds.

Buckingham Canal

The Buckingham Canal is a salt water canal excavated in 1806 through strips of land and shallow back water. The Canal was used actively for navigation until cyclone damage in 1966 and 1976 first curtailed and then ended this practice. It runs from north to south 420 kilometers, 315 kilometers north of Madras and 105 kilometers south. The Buckingham Canal intersects both the Cooum and the Adyar on their way to the coast.

The Buckingham Canal is the most polluted waterway in Madras, having extraordinary levels of BOD--as high as 1,170 mg/liter. Septic conditions prevail in much of this waterway.

Effluent from a sewage treatment plant, unsewered residential areas, and a prawn factory contaminate the southern part of this canal. Diverted flow from various pumping stations and hospitals pollute the central stretch. A government hospital, the central train station, metro water pumping stations, and various factories are largely responsible for polluting the northern stretch.

Otteri Nullah

The Otteri Nullah is the surplus drainage course of a number of tanks (small reservoirs). The total length of the river is about 12 kilometers with a catchment area of 38.40 square kilometers. The Villivakkam sewage treatment plant and 80 sullage outlets contribute to the heavy pollution load of this waterway.

4.2 Urban Development Assessment

In many ways, Madras is a unique city whose economic characteristics and urban development present challenges for improving the quality of its urban waterways. Among the features that distinguish Madras are:

- The lowest supply of drinking water among the major cities of India. The drinking water supply is only 35 liters per person per day.

- An estimated one million people who have no access to any form of safe and dignified sanitary facilities.

- All but one of its main waterways are polluted to a degree that has few parallels, with BOD5 levels running at 100-600 mg/l. In contrast, treated sewage should be 20-30 mg/l before it is discharged.

- Failure of sewerage planning and investment to keep pace with the planned expansion of the water supply system. The amount of publicly provided water is planned to increase from 330 million liters per day (MLD) currently to 1,164 MLD by the year 2011, (once the Palar and Krishna water projects are completed). The current sewage collection system covers about 85 percent of the City's population. In contrast, the treatment system has a capacity of about 260 MLD--about 22 percent of the anticipated water supply in 2011. No investments are underway or in an advanced planning stage to remedy this imbalance.

- Much greater resources and a stronger economic base (consisting of industry and agricultural distribution) than most small and medium-sized Indian cities, such as Varanasi. However, fewer resources and a weaker fiscal position than other major Indian metropoli. Madras has the lowest municipal budget (Rs.50 crore in 1990) and the lowest per capita income of the four largest metropolitan cities in India (Rs.425 per month in non-slum areas and Rs.134 per month in slum areas).

Population and Standard of Living

Both the number of people and population density stress waterway quality.[38] The population of Madras City has grown by over a factor of six in this century, from 553,000 in 1901 to 3,276,000 in 1981 and to an estimated 4 million in 1991. The bulk of this growth has taken place since 1950.[39]

The area of Madras City has increased by a factor of 1.4 between 1901 and the present, from 71 square kilometers to 172. Hence, density has increased from 78 persons/hectare in 1901

[38] Each waterway has a capacity to handle waste, governed by certain characteristics of the waterway. For example, the more water in the waterway and the faster the water is moving, the greater its capacity to handle waste. At some point however, the population increase and density overloads this capacity and significant degradation of the water quality occurs. The carrying capacity of the waterways in Madras is quite small. For most of the year, the waterways have little flow. One of the main reasons for the existence of the Cooum and Adyar Rivers is to drain the large amounts of water that are temporarily available during the monsoon months. During most of the rest of the year, these rivers do not flow since much of the water is diverted, upstream from Madras, for irrigation and water supplies. Increases in density also result in more of the ground area covered with impervious materials (such as pavement and buildings), which prevent water from percolating down through the soil and entering the natural underground water systems gradually. Percolation helps to clean the water before it enters either the underground aquifers or the waterways. Instead, rapid runoff occurs, which may momentarily increase flows while carrying large amounts of pollution.

[39] From 1900 to 1920, the population of Madras City grew only slightly (4.0 percent from 1901-1911, and 3.0 percent from 1991-1921). Decadal growth rates increased substantially, however, in the following periods. Growth rates were: 24 percent in 1921-31, 20 percent in 1931-41, 28 percent in 1951-61, and 42 percent in 1961-71. The decade with the highest growth rate was 1941-51, at 61 percent. This figure is deceptive, however, because the City also increased its physical area by 72 percent during that decade. Similarly, the growth rate of 27 percent in the 1971-81 period occurred at the same time that the area of Madras City increased by 33 percent. Based on the available data, it is not possible to correct for these changes in area of the City.

to 190 persons/hectare in 1981 and an estimated 232 persons/hectare in 1991.[40] Densities vary considerably across Madras City, ranging from about 50 persons/hectare all the way to 590.

While population densities in the Madras Metropolitan Area outside the City are still quite low, these areas have also experienced substantial population growth and increases in density in the last 30 years. In 1981, the population outside the City was about 1.3 million and the density was 14 persons/hectare.[41] The 1991 population in the Madras Metropolitan Area outside the City was estimated to be 1.9 million with a density of about 20 persons/hectare. Growth rates in these outlying areas have exceeded those of the City during the last 30 years.[42]

Available evidence indicates that about 30 percent of Madras households live in slums, squatter settlements and on pavements, perhaps the highest proportion of the major metropolitan areas of India.[43] Most of these areas lack proper sanitation facilities and lie along the waterways.

The per-capita income in Madras is among the lowest among major metropolitan cities for both slum and non-slum dwellers. The average per capita income in non-slum areas is Rs.425 per month. In slum areas it is Rs.134 per month.[44]

Living conditions in Madras are on a par with those of other major metropolitan areas in India and South/Southeast Asia--see Table 4. By all measures, living conditions in Madras are better than in Calcutta. By all measures except infant mortality rates, they are somewhat better than in New Delhi. In terms of amount of education and infant mortality rates, Madras is worse off than Bangkok, but better off in terms of more direct economic measures of living conditions.

The density in 1971 was actually greater than in 1981, due to the annexation of 43 sq.km. during the 1971-81 decade. The density in 1971 was 199 persons/hectare.

41 Data provided in Madras - 2001: Policy Imperatives, An Agenda for Action, Madras Metropolitan Development Authority, October 1991, gives various figures for the 1981 population outside the City, ranging from 1,290,000 to 1,353,000. The lower figure is used by the MMDA in their projections of future population.

42 Fifty-six percent in 1961-71, 60 percent in 1971-81 while the area was decreasing due to annexation of area by the City, and an estimated 46 percent in 1981-91. Madras - 2011: Policy Imperatives , An Agenda for Action, Volume IV-A, A New Perspective for Metropolitan Management, Madras Metropolitan Development Authority, October 1991, Appendix Table 1, p. IV-A.44.

43 During the 20-year period 1961-1981, both the number of people living in slums and their proportion of the total population of the City increased. The slum population in 1981 was estimated to be about 1 million people, which was 31 percent of the population of the City. According to the 1991 Census, 27 percent of housing in the City was classified as kutcha and semi-pucca. The corresponding number for the rest of the Madras Urbanized Area is 43 percent.

44 These low averages are due in large part to the low formal-sector employment rate of 29 percent. About 534,000 people (58 percent of the labor force) are dependent on the informal sector for their livelihood.

Table 4
Madras Compared with Three Other South Asian Metropolitan Areas

	Madras	New Delhi	Calcutta	Bangkok
Population (millions)	5.6	9.8	12.8	7.0
Percent of income spent on food	33%	40%	60%	36%
Number of Persons per Housing Unit	1.2	2.4	3.0	3.2
Percent with Electricity	82%	66%	57%	76%
Percent with Secondary Education	56%	49%	49%	71%
Number of Infant Deaths per 1,000 Live Births	44	40	46	27

Source: *Cities: Living Conditions in the 100 Largest Metropolitan Areas*, Population Action International.

Water and Wastewater

Madras currently suffers from an acute water shortage. Its major source of water is rain-fed reservoirs that get most of their supply during the September to December monsoons. These reservoirs yield about 200 million liters per day (MLPD). Six well fields that yield about 120 mlpd supplement these reservoirs. Miscellaneous other sources bring the current total safe yield to about 330 mlpd. In per capita terms, the current supply of water averages about 32 liters per day--about one-fifth of the Indian standard for urban areas of 150 liters per day per capita (LPDC).

Due to this low supply, water is available for only about three hours, every other day. Households supplement piped water with wells and water purchased from private sources.[45] Tube and dug wells provide unprotected water, used for non-drinking purposes.

The water shortage has inhibited economic growth by restricting the amount of industrial expansion that can occur. Some large industries in the northern Madras area are developing water

[45] About 5,700 shallow tube wells (depth of up to 8 meters) and 4,240 deep wells with hand pumps (depth of up to 22 meters). These wells yield an estimated 50 mlpd. In addition, most houses have an ordinary dug well equipped with a 0.5 horsepower pump. Private contractors do a big business by supplying water in tankers. This water is trucked up from groundwater sources south of the City. In 1988, about 1,100 private tankers in operation in Madras City.

reclamation facilities.

In addition to inhibiting economic development, the water shortage has resulted in public health problems. The small amount of water available to many households plays a critical role. Lack of water join with poor personal hygiene to create conditions favorable to the spread of disease.[46] One study showed that infant mortality rates were higher in Tamil Nadu, the state in which Madras lies, (and accounts for much of the population) than in neighboring Kerala, irrespective of the source of the drinking water. The author concluded that, in terms of lowered infant mortality rates, the availability of an adequate supply of water and proper hygiene are probably more significant than access to drinking water.[47]

Madras City is expected to grow from about 4 million persons in 1991 to about 6 million in 2011, while the Madras Metropolitan Area (MMA) outside the City is expected to grow from 1.3 million persons in 1991 to 3.6 million in 2011.[48] In other words, the population of the total MMA is expected to double in this 20 year period. At the same time, the density of the City will increase to about 351 persons/hectare and the density in the surrounding areas to about 37 persons/hectare. These increases in the number and density of people will put additional burdens on both the water and the sewage systems.

The water supply for Madras will greatly expand over the next few years, assuming the Krishna River Project is completed. Involving two states (Tamil Nadu and Andhra Pradesh), the first phase--scheduled to be commissioned in December 1995--will bring an additional 230 MLD of water to the Madras area. Two additional phases will bring an additional 230 MLD if completed. Assuming all three phases are implemented, they will greatly relieve the water shortage, but will fall short of entirely solving the long-term problem.

For planning purposes, a water consumption rate of 140 liters per capita per day (LPCD) in Madras City and 90 LPCD in areas outside of Madras are forecast. Using the population forecasts for the year 2011 presented above, Madras needs 840 MLD and the surrounding areas another 324 MLD, for a total of 1,164 MLD. The entire water supply from the Krishna Project, plus the current water supply, equals 915 MLD. Although this total will not meet the projected demand (even without allowing for increased industrial use), it represents a dramatic improvement over current conditions.

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[46] The infections in this group also depend on the lack of proper human waste disposal, and include such diseases as: scabies, leprosy, trachoma, conjunctivitis, dysentery, enterovirus diarrhea, and hookworm.

[47] Nagaraji, K. (1986) "Infant Mortality in Tamilnadu", MIDS Bulletin, Vol.16, No.1, pp. 27, 68; as reported in Paul Appesamy (1989) "Managing Pollution in the Waterways of Madras City: An Initial Assessment", Working Paper N. 88, p. 41, Madras Institute of Development Studies.

[48] These projections have been made by the Madras Metropolitan Development Authority, as published in October 1991. Madras - 2011: Policy Imperatives, An Agenda for Action, Volume IV-A, A New Perspective for Metropolitan Management, Appendix Table 4.

This increase in water usage should require a substantial investment in the sewage collection and treatment system of Madras. Roughly 70 percent of water supply ends up as wastewater. Using this figure, the current sewage treatment capacity of 260 MLD is less than a third of the sewage to be generated in 2011.

However, little planning and investment, however, appears underway to increase the capacity of the sewage treatment system. Metro Water has proposed to provide sewage collection to the remaining unsewered areas of the city proper by the end of this year.[49] In addition, Metro Water is modernizing two of the five treatment plants and 14 sewage pumping stations. This company has also commissioned some small pumping stations in densely populated and low-lying pockets.

While these improvements are useful, they fall far short of addressing the magnitude of the problem. If current water supply projects come on line as planned, sewage flows in 2011 will be 3.5 to 4.5 times current flows (increasing from 260 MLD to between 915 and 1,164 MLD). Existing treatment plants fall far short of handling the current sewage flows and have far less capacity than needed to handle these anticipated flows.

This situation deserves to be called a "crisis". Metro Water--the state government entity responsible for providing water and sanitation in MMA--is at its crux.

Land Use Along the Waterways

Land use along waterways frequently has a direct impact on the quality of waterways since it is easy to discharge waste directly into them. A recent study conducted by Exnora International of segments of the rivers found 30 major outlets discharging into the Cooum River and 27 major outlets discharging into the Adyar River. The principle sources of discharge were: major developments such as hospitals, colleges and hotels, small industries; and unsewered slums and squatter settlements, and sewage from defective sewer systems and sewage overflows.

Many slum dwellers use the waterways as toilets and sewers. Madras slums tend to be concentrated along the waterways because this land is, typically, public and floods with the monsoons. A TNSCB study a few years ago estimated that 35,450 families have put up residences along the four waterways, including the Otteri Nullah.[50]

[49] As reported in a recent article, in 1991, about 86 percent of the total area was covered under the system, and in 1994, about 95 percent. The article goes on to assert, however, that 40 percent of households will still be without a sewer line at the end of this year. "Madras: Is a Clean City a Utopia?", Survey of the Environment 1995, The Hindu, pp. 86-87.

[50] In 1992-93, there were 38 clusters along the Cooum with a population of 6,500, 30 clusters along the Adyar with a population of about 7,500, and 16 clusters along the Otteri nullah with a population of 3,400. There were about 58 clusters along the Buckingham Canal, with a population of over 12,000, but most of these have been shifted to alternative sites to make way for the Mass Rapid Transit System alignment along the canal. As reported in "Madras: Is a Clean City a Utopia?", Survey of the Environment 1995, The Hindu, p.88.

The Tamil Nadu Slum Clearance Board (TNSCB) has provided toilets in slum areas, at a rate of one toilet for every 20 persons. However, many of these toilets are poorly maintained and in bad conditions. As a result, about one million residents of Madras have no access to safe and dignified sanitary facilities. Technical problems (such as laying sewer lines along narrow, highly congested streets) make providing sewers in slum areas difficult. Even more importantly, the government tends to channel the limited resources available to higher income households.

Land-use along the Cooum River stands out. Madras developed largely along this river. Thus, many important commercial and government buildings lie along it. Although all four waterways of Madras are inter-connected and, hence, any solution to their pollution problems should be universal to all four, the Cooum deserves some priority because of its importance to Madras' urban development and heritage.

Implications for the Action Plan

- The great increase in water supply planned for Madras, a tripling by 2011, will result in a dramatic rise in sewage. Unfortunately, no coherent plan for treating this wastewater exists. The action plan should place investments within a long-term vision capable of dealing with this crisis.

- The poor water quality of Madras' waterways and the mismatch between water supply and sewage treatment has developed over decades, and cannot be reversed overnight. Credible solutions for Madras require a long-term commitment and massive investments commensurate with the city's importance as the fourth largest metropolitan area in India.

- Although all four waterways and, hence, the solution to their pollution problem are inter-connected, the Cooum River deserves special focus because of its central place in the life of the city.

4.3 Water Quality and Sanitation Technical Assessment

The extent and effectiveness of wastewater treatment underlies the pollution of Madras' waterways.

The sanitation system of Madras city consists of the following components:

- Four wastewater treatment plants
- About 110 sewage pumping stations
- Several thousand kilometers of sanitary sewers
- Storm drains covering about 110 km2 of Madras city
- The four principal waterways
- Solid waste collection and disposal
- Public toilets

The four wastewater treatment plants are:

- Nesapakkam
- Koyambedu
- Kodungaiyur
- Perungudi

We visited the Nesapakkam plant and, hence, describe its operation in greater detail. The Nesapakkam wastewater treatment plant has a capacity of 23.5 million liters per day (MLD). This activated sludge plant was receiving about 24 MLD at the time of the team's visit on May 26, 1995. The maximum flow rate to the plant was stated to be 92 MLD. The plant contains the following process units:

- Screening (hand cleaned) and grit removal
- Primary sedimentation
- Aeration with mechanical surface aerators
- Secondary or final sedimentation
- Open sludge drying beds for waste sludge
- Sludge digesters

All process units, except the digesters, appeared to be functioning during our visit. The operating staff refuses to visit the digesters because of snakes in the overgrown underbrush around these units. Considerable material on scraper arms, baffles, and weirs have built up, indicating that the tanks and equipment receive less than sufficient maintenance.

Farmers take only about six truckloads of sludge as fertilizer out of a monthly production of about 200 truckloads. The operating staff of the STP spread some of the remaining sludge on an on-site teak tree farm.

BOD5 (biochemical oxygen demand) concentrations are recorded in the Nesapakkam plant's laboratory. A review of this data over the previous three months showed highly improbable regularity. The readings ranged from 40 to 45 mg/l (milligrams per liter) in the effluent and 300 to 340 mg/l in the influent for virtually the entire period. Even on accepting these values--which lack the variation of real measurements--this plant would be failing to achieve the required BOD5 level of 30 mg/l.

Other studies have delved further than the observations possible in our field visit. The 1989 Severn Trent report stated that internal bypass of raw sewage within some of Madras' sewer plants make quality of effluent little different from that entering the plant. The Nesapakkam Plant discharges into the Adyar river near the western boundary of Madras city.

The Koyambedu wastewater treatment plant is a 34 MLD activated sludge plant reported to be well operated and producing an effluent quality meeting standards. It is understood that this plant was converted from a trickling filter process, recently. This plant as well as the two plants discussed below were not visited by the team. The plant discharges into the Cooum river near the western boundary of Madras city.

The Kodungaiyur wastewater treatment plant consists of two parallel activated sludge process trains, each with an average daily design flow of 80 MLD. This plant lies near the northern boundary of Madras city and channels its effluent to a water-starved industrial complex in the north of the city.

The Perungudi wastewater treatment plant is a primary treatment plant with an average daily design flow of 45 MLD located south of the Madras city boundary. Thus, this plant removes only coase and bulky materials from raw sewage, without substantially reducing other pollutant loads.

All four of these plants create a number of problems for waterway quality. None of the plants have provision for effluent disinfection. The plants receive raw sewage with strengths ranging from 1.5 to 3 times those normally found in the U.S. The raw sanitary sewage in Madras contains extraordinary amounts of grit, hay, and fiber which often overwhelm the degritting facilities and lead to malfunctions in following process units.

Overall, the existing sewage treatment system requires substantial expansion and reform. A positive is that all four STPs reportedly have ample site area to accommodate expansion and reform.

Other elements of the Madras sanitation system present challenges:

The system's designers chose to deal with the extremely flat topography of the area by building a very large number of sewage pumping stations--110 altogether--to convey sewage flows to the treatment plants. Even in the best circumstances, this large number represents an operation and maintenance nightmare. These pumping stations suffer from constant emergencies and failures caused by overloading, power fluctuations and outages, age, inadequate spare parts and support and economizing on power consumption.

Metro Water has privatized the operation and maintenance (O&M) of about 35 pumping stations in order to improve their performance--see Box 4.1 for more details. Management plans to privatize many of the remaining pumping stations are underway, as circumstances allow. These privatization efforts can best improve performance if joined with technical assistance in the operation of pump stations and some systemic reforms that reduce their number.

Currently, for example, private pump station contractors have an incentive to bypass sewage directly into waterways in order to economize on electricity use. Regulations, performance incentives, and penalties must join to make such bypassing unattractive.

Systemic reforms must avoid the proliferation of the pumping stations and phase out as many of the existing ones as possible. One option is construction of new sewage trunk lines ("interceptors") at sufficient depth to permit the collection system to drain by gravity to them. Flows then could then be lifted to each plant by a relatively large single pumping station.

The sanitary sewer system of Madras fails to receive effective routine inspection, cleaning, rehabilitation and maintenance. Clogged sewers[51] are common because of excessive loads of grit, organic solids and solid wastes dumped put into them. Most sewer lines have minimum grades caused, in part, by the flat topography and the long-established practice of laying sewers to depths of no more than 6.5 meters to avoid excessive ground water intrusion into the sewers. With the pipe and pipe joint systems now readily available, however, this restriction no longer makes sense.

Storm drains now cover about two-thirds of the city. An estimated 500 interconnections exist between the sanitary sewer system and storm drains. The sanitary sewer and storm drain systems function as a combined system.

This condition is common to large older cities in other countries. Attempts elsewhere to segregate the two systems have proved infeasible and problematic. To do so in Madras would require an unprecedented effort to separate plumbing systems in all buildings and keep them apart, identify and sever all interconnections, and prohibit and prevent new interconnections.

In sum, the sewerage system fails to work as designed in many ways. However, even if the current sewerage system were working properly, a number of serious problems challenge waterways quality:

Foremost is the partial coverage and lack of disinfection of the sewer system. The sewerage system fails to cover roughly 15 percent of the population of Madras City. Most of the

[51] Which are primarily vitrified clay.

informal settlements of this area lie along the banks of the four waterways, and discharge directly into them. In addition, sewerage is virtually absent in the fast growing areas outside the city--the Outer Urban Area.

However, even the modest share of wastewater that receives treatment lacks disinfection. All four sewage treatment plants are activated sludge--a system that removes BOD, suspended solids, and some other contaminants, but requires separate disinfection. As no separate disinfection occurs, the treated effluent of these plants has astronomical bacterial levels--in the hundreds of thousands and millions per 100 milliliter, compared to a standard of 1,000-2,000 per ml. in developed countries.

Industrial pollution is growing fast. In the absence of an effective industrial wastewater control program, many industries discharge their wastes without any treatment. For example, 400 tanneries reportedly discharge untreated wastewater in and around Madras.

A number of public buildings are reportedly discharging directly into the Cooum river and the Buckingham Canal. Many of these buildings are located in the city center--for instance the General Hospital, Madras University, the Central Station, Public Works Department offices, Presidency College and Queen Mary College.

Municipal solid waste accumulations along river banks, in streets, and in yards contribute significantly to contamination of the waterways. Garbage enters the waterways either by flushing of land surfaces during monsoon rains or by direct deposition.

An estimated 50,000 to 60,000 licensed and unlicensed cattle in the city deposit their wastes around the city. Such wastes have the BOD of over a half million people.

Sludge deposits from many years of unchecked discharges from all sources reside in the waterways along with construction debris. In the case of the Buckingham Canal, piers and facilities related to the rapid transit system--which has been started but not completed--and old navigation locks also obstruct flows.

Sand, continually deposited by the littoral currents, blocks the mouths of the Adyar and Cooum Rivers at the Bay of Bengal. These sand bars reportedly prevent the tidal flushing of the lower basins of both rivers and break only during flooding monsoon rains.[52]

The four principal waterways themselves now form an essential sanitation function in Madras. They serve as the primary receptors for all the wastewater and much of the solid waste now generated in Madras. Extensive deposits of contaminated sludge and silts from past pollution negatively impact water quality and quality of life independent of current discharges.

[52] The tide range is about one meter.

Solid waste collection disposal falls short of that typical for a city of the size and importance of Madras. In particular, two unsanitary landfills now serving the city are at or near capacity.

Effect on Waterways Quality

Around 80 percent of the waste load entering the waterways of Madras reportedly comes from wastewater treatment plants and sewage pumping stations. Other sources contribute the remaining 20 percent, including garbage, dumping of human and animal waste directly into waterways from many sources (squatter settlements along waterways, industry, unsewered public and private formal-sector buildings etc.), and storm drains.

These other sources are relatively minor. For example, the State Pollution Control Board estimates that only about four percent of the pollution contributed to the waterways comes from industry. Squatter settlements are said to contribute perhaps five percent of pollutants.

The modest information available on the waterways of Madras shows water quality to be the equivalent of raw sanitary sewage. Samples of Adyar River water showed BOD5 concentrations of 230 to 330 mg/l. Both the Buckingham Canal, the Cooum river and the Otteri Nullah are more polluted than the Adyar river.

Over the years, various proposals have been made to clean up the waterways:

- Build a breakwater or groyne south of the Cooum mouth so that the littoral drift (of sand) does not result in the formation of the sand bar.
- Discharge cooling water from the Ennore thermal power station into the adjacent Buckingham Canal to be carried south into the Cooum to improve flushing.
- Remove the sandbar at the mouth of the Cooum, to enable tidal flushing of the estuary.
- Pump fresh sea water or ground water in pipes laid along the Cooum bank up to Harris bridge.
- Remove organic and other pollutants by using the accreted sand (sand bar) as a filter bed.
- Let the Cooum estuary perform biological treatment by involving the use of "exotic culturable species".
- Pump seawater as far upstream on the Cooum as the Koyambedu wastewater treatment plant to provide constant flow and flushing of the river.
- Pump 100 cubic feet per second (cusecs) of seawater to a point 2 km east of the entry point of the Cooum into the city, and construct sluices to hold the water at 5 foot depth in the river; line the bed of the Cooum with polythene sheets to prevent intrusion of brackish water into neighboring aquifers.

None of these proposals has addressed the problem of water quality in a comprehensive manner. Instead, they have relied mainly on flushing or diluting wastes rather than on pollution reduction. Such proposals may have merit after water quality is improved. However, efforts should start by reducing pollution, rather than diluting, flushing or transporting it to the sea, where it may it may then pollute Madras' famous and beautiful beaches.

Implications for the Action Plan

Household waste contributes the great bulk of pollution. Hence, dealing with this waste in various ways must have the highest priority for waterways clean-up:

- Expanding and reforming sewage treatment capacity, intercepting wastewater flows into rivers and canals, and extending sewers to new areas are the macro investments necessary to reduce pollution of the waterways of Madras

- Better management and reduction of cattle waste and sanitary upgrading of slums along waterways, and establishment of a greenbelt and walkways along waterways are worthwhile micro improvements that can complement these heavy investments, involve local people, and help generate the political will necessary for reform

- Dredging sludge from the most highly polluted stretches of waterways must complement reduction in discharges

4.4 Institutional Assessment

Improvement of the waterways of Madras--as in most Indian cities--presents some complex managerial challenges. Many organizations are involved in principle or in fact in influencing water quality in the rivers and canals. The main ones are the Madras Metropolitan Water Supply and Sewerage Board, the Tamil Nadu Water Supply and Drainage Board, Local Governments, the Tamil Nadu Housing Board and Slum Clearance Board, the Irrigation Branch of the state Public Works Department, the Madras Metropolitan Development Authority, and various NGOs. Although many organizations are involved, none has overall responsibility for coordinating river clean up.

However, one organization has by far the greatest impact on river quality--the Madras Metropolitan Water Supply and Sewerage Board. Household sewage--which is the responsibility of this organization--contributes the great bulk of pollutants--for example, 85 to 90 percent of BOD5--to these waterways. Hence, the effectiveness of this organization has critical importance.

Madras Metropolitan Water Supply and Sewerage Board

This entity (commonly called "Metro Water") has responsibility for the planning, designing, financing, implementation, and operation and maintenance of the water supply and sewage systems for the Madras Metropolitan area. However, the Board has restricted its operations so far to the city of Madras--the Tamil Nadu Water Supply and Drainage Board supposedly provides these services in others towns in the metropolitan area.

Formed in 1978, Metro Water is under the administrative control of the Department of Municipal Administration and Water Supply of the state of Tamil Nadu.

Metro Water appears to be one of the more efficient and entrepreneurial water/sanitation providers in India. Part of the reason may involve the long organizational culture of the state of Tamil Nadu--one of the original British capitals in India.

However, a key structural factor plays a role. In many areas of India, a state water/sanitation board designs and contracts the construction of projects, and then hands them over to a local water/sanitation board to operate and maintain. In contrast, Metro Water both builds, and operates and maintains its projects. Joining these functions within one organization creates better incentives than separating them. For example, Metro Water has an interest in building well because it must make the resulting project work.

Metro Water also appears to be at the forefront of reforms to improve operating efficiency in India, particularly privatization. Over the last two years, MMWSSB has successfully contracted out the operation of 40 of its 110 pumping stations, and is planning to tender the remainder--see Box 4.1 for details.

Operation of pumping stations is a small, discrete function easily isolated from much of the rest of the sewage system. Metro Water has also privatized sewer cleaning--another discrete function.

However, Metro Water is also actively pursuing privatization of large, systemic phases of sanitation, including the operation of its sewage treatment plants. Taking privatization to this level would raise questions, unanswered in the Indian context: how to pay and how to regulate the operation and maintenance of such a large facility.

Other aspects of Metro Water's operation appear less promising for the quality of urban waterways of Madras.

Foremost is this agency's focus on water, and relative neglect of sanitation. Metro Water, in tandem with other state agencies, has embarked on two water supply projects that will greatly expand supply, if completed, from 70 liters per capita per day for the current city population of 3.5 million to close to 140 liters per capita per day for nearly double this population (7 million) by 2011. Much more water will generate much greater quantities of sewage. Yet no contracts have been let to expand sewage treatment capacity substantially. This problem reflects the urgent need for integrated planning and implementation of water and sanitation, which has yet to occur in the Madras Metropolitan area.

Metro Water has also neglected sanitation and waterway quality in its own operations and maintenance. The agency has allowed pumping station operators to discharge raw sewage directly into waterways, rather than pump it to treatment plants. A visit by this consultancy to one of the water treatment plants suggests that quality of the sewage inflow and effluent remains largely unmonitored. While monitoring data is recorded at the site, this data showed a highly improbable consistency in the BOD5 readings throughout a number of months, both in for inflow and effluent concentrations. In reality, BOD5 levels vary across days and across seasons, depending on several factors such as of amount water used.

Box 4.1--Privatization of Sewage Pumping Station Operation in Madras

Metro Water of Madras (MMWSSB) is, reportedly, the first public entity to privatize the operation of pumping stations in India. The process is instructive and has lessons for water/sanitation companies elsewhere in India. Essentially, MMWSSB issued a request for proposals from certified engineers. Metro Water received an excellent response from local engineers--many of whom, as in the rest of India, are unemployed--including some retirees of Metro Water. The winning candidates hire five to ten local workers, train them to operate these pump stations, and supervise them. MMWSSB pays these contractor/operators based on the amount of time their pumping station maintains a negative head--a good proxy for the amount of sewage pumped through these stations. The contractor/operator must keep an hourly record of pump operations. In addition, Metro Water inspectors make announced and unannounced visits to these pump stations.

Overall, the results have been highly positive, and a substantial improvement over Metro Water's direct operation of these facilities. Because of Civil Service rules, Metro Water is often unable to find certified Engineers internally to operate its pump stations. Its wage and benefits structure are also high. In addition, MMWSSB has little means of encouraging its staff to perform. In contrast, private contractor/operators of these pumping stations can hire workers at lower wages and have a strong incentive--payment based on performance--to work more efficiently. The small scale of operation--one pump station--allows easy entry by small local contractors.

An important bottleneck to privatizing the remaining pumping station has been Metro Water's reluctance to displace its employees, which the company must pay whether they work at a pump station or not. Metro Water has avoided this problem by starting with privatizing the operation of newly constructed pumping stations. Many of the contractors that built these pumping stations competed to operate them. In subsequent phases, Metro Water plans to privatize most of the remaining pumping stations, and reduce its employees gradually through attrition.

Finally, the cost recovery of Metro Water has declined steadily. Its water and sewerage tax revenues are based on the property tax, which has remained the same for 14 years in Madras. Not surprisingly, the Board's income from sale of water and the sewerage tax has declined in real terms since the early 1980s. Its water and sewer rates were lower than those of water/sanitation providers in India's other three largest cities (Bombay, Delhi, and Calcutta). The company depends mainly on charging industry (66 percent of water revenues in 1990-91) for current income. Metro Water relies increasingly on ad hoc grants from the state government to finance capital investments. As of 1991, government grants financed 50.07 percent of Metro Water's annual capital investment, while government loans financed 49.93 percent.

Supporting Metro Water in meeting these challenges represents one of the best means for improving the quality of Madras' waterways.

Madras Municipal Corporation

From its founding in 1841 until 1970, the Madras Corporation had responsibility for a wide range of urban environmental and other local services, including water, sanitation, electricity, housing and slum improvement, roads, solid waste management, land-use planning, and primary and secondary schools. The powers and responsibilities of the Madras Corporation have steadily declined since then.[53]

In 1970, the primary responsibility for slums was vested with Tamil Nadu Slum Clearance Board. In 1974, the Madras Metropolitan Development Authority took over the planning and development control functions of this local body. In 1978, Metro Water took control of water and sewerage. Primary and secondary education were transferred to the Education Department of the state government in two stages, in 1987 and 1990.

The Corporation retains two functions important to urban waterway quality. First, it continues to have responsibility for solid waste management. Second, the Municipal Corporation is supposed to construct and maintain storm drains.

However, this local government, as many in India, has seen its revenues and political legitimacy as well as its powers erode. The property tax, the Corporation's major source of income, is based on assessments that have remained the same since 1977.[54] State government has suspended elections for mayor and city council ("corporators") since 1973. No elections have occurred since 1970. An appointed commissioner from the Indian Administrative Service (I.A.S.) has administered the Municipal Corporation.

These problems have cut the fiscal and political links with local people. The Corporation has little incentive to be responsive. Not surprisingly, its record in solid waste management and construction and maintenance of storm water drains is uneven.

In this vacuum, the activities of NGOs and other organized groups, that involve local people, and represent them to the Corporation and other key public agencies, are key. The

[53] Such centralization of power and responsibilities in national government agencies and parastatals took place throughout the developing world in Latin America, Africa, and Asia from 1945 to 1970, with a corresponding decline in the powers and responsibilities of local government.

[54] The income of the Madras Corporation is composed of: property taxes (36.6 percent), other taxes (6 percent), taxes assigned by Government for use by Madras Corporation (39.2 percent), Government grants (4 percent), and miscellaneous sources (14.2 percent). Similarly, for other urban centers in the Madras Metropolitan Area, the property tax is the major source of revenue (ranging between 19 and 45 percent). The entertainment tax (ranging between 2 and 31 percent), and in some cases the professional tax, are also important sources of revenue.

improvement of Madras' urban waterways is a case on point.

Environmental NGOs: the Case of Exnora

Exnora International ("Exnora") started with nine members in Madras in April 1989. It now has 1,300 branches throughout the state of Tamil Nadu and outside, and 200,000 members. At the heart of this dramatic growth is this organization's ability to get people to participate through a chain of self-help groups.

The organization first directed its attention to cleaning up garbage in Madras. Exnora volunteers encourage blocks of households--roughly 100 to 150 families--to form "Civic Exnoras." Households then contribute 10 rupees a month to pay the Rs. 700 wage of a "street beautifier" to pick up their garbage with a three-wheel cart. The street beautifier takes the garbage to a transfer station from where the Madras Corporation's trucks transport the solid waste to one of the two municipal landfills.

This project has proved highly successful in breaking the passivity and reliance on government and demand-making that often paralyze local people, and in involving them to get garbage off the streets. Civic Exnoras now cover one-third of Madras. They have emerged in other areas around Tamil Nadu, and--recently--in other states. Over a 1,000 Civic Exnoras exist.

Although successful in primary garbage collection, this project has depended on local government's uneven performance in secondary collection and disposal. Exnora has started a composting project aimed at reducing this problem.[55]

Exnora has sought to work with and through the government in these projects, rather than confront the government. This strategy and the positive accomplishments of these and other programs have gained Exnora great credibility with both public and private-sector leaders in Madras. Exnora has tapped into the idealism of the elite as well as energized the poor. Many highly qualified and well connected people typically attend Exnora International meetings--university professors, civil engineers from government agencies, retired high-ranking administrators etc.

In turn, Exnora International staff have considerable governmental and administrative experience, although modest technical capacity. People in positions of leadership include a former head of the Madras Metropolitan Development Authority, a civil engineer and organizer, and a local banker.

These garbage pick-up and composting projects share an emphasis on community organization, working with government, and self-help that Exnora has transferred to its efforts

[55] In contrast to Bombay and Delhi, Madras' solid waste is highly (66 percent) organic and, hence, easily composts.

to monitor and clean up of Madras' urban waterways. The Citizen's Waterways Monitoring Program (WAMP) started in December 1991 as a coalition of committed individuals and voluntary organizations with Exnora at its head. Other groups involved in this coalition include the Indian National Trust for Art and Cultural Heritage, the Consumer Action Group, and the Enviro Club.

WAMP works with both governmental and non-governmental polluters that discharge into the river. Because of Exnora leadership, WAMP is able to intercede constructively with government leaders--the heads of Metro Water and the Municipal Corporation. WAMP also works well with the poor. WAMP has organized the youth of slum areas to conduct visual surveys along the Cooum, Adyar River, and the Buckingham Canal to produce detailed maps of pollution sources.

Although the project has a "monitoring program", WAMP still lacks a systematic, scientific means of measuring river water and effluent quality on a regular, on-going basis.

Exnora and WAMP's participatory style has decided pros and cons. A strong positive is that Exnora is able to involve the community. However, with cleaning up the waterways, Exnora and WAMP have taken on an environmental problem requiring a different kind of solution. Unlike primary garbage collection--where many small-scale, community based actions can result in substantial systemic results--households can have little direct affect on urban waterway quality. Even targeting industry promises relatively minor improvement. Only systemic actions by key organizations--particularly Metro Water--can greatly affect pollutant levels.

In short, Exnora is adept at micro, community-based waterway improvements. However, to improve water quality, Exnora must also find levers to influence key organizations--particularly Metro Water--in order to achieve macro improvements as well. As discussed below, a systematic, scientific water monitoring program is one of these levers. Promotion of a clear action plan is another.

Tamil Nadu Public Works Department

While the responsibility for providing and maintaining the storm and sanitary sewers and the sewage treatment facilities lie with Metro Water and the Madras Corporation, the maintenance of the rivers and canals is the responsibility of the irrigation wing of the state Public Works Department (PWD). This further fragmentation of water-related responsibilities tends to hinder progress, especially since the condition of the waterways in Madras is only a small part of the PWD's responsibilities.

The major function of the PWD is irrigation management. The major interest of this organization is water quantity, not necessarily quality. PWD focusses on areas such as flood control, irrigation dams, reservoirs, and navigation.

A secondary concern is the provision of drinking water. For example, PWD is experimenting with check dams upstream of Madras on the Cooum River, to determine if holding back some of the monsoon rains can help recharge groundwater. The central government funds this experiment.

However, PWD is suited to a supporting role in cleaning up waterways. For example, part of a comprehensive waterways clean-up is dredging stretches of Madras' waterways to remove the highly contaminated sludge that has settled to the bottom. Any dredging would be the responsibility of the PWD. In fact, this organization has made such a proposal to the Central Government.

Tamil Nadu Slum Clearance Board and Tamil Nadu Housing Board

As discussed elsewhere in this report, the slums that line Madras' waterways are not the major source of the water pollution problem. They do contribute, however.

Two state agencies are charged with developing housing alternatives that could have a major impact on this part of the problem. The most important agency is the Tamil Nadu Slum Clearance Board (TNSCB).

Established in 1970, the TNSCB has responsibility for clearing and/or improving the slums in flood-prone and other vulnerable areas in the City of Madras. Towards this end, the TNSCB constructs low-income housing, prevents the growth of new slums and encroachments, prevents eviction of slum dwellers on private lands, and extends basic shelter infrastructure such as drinking water, street lights, drainage and sanitation facilities to slums.

The Tamil Nadu Housing Board (TNHB) is an older agency with a broader scope of responsibilities. Established in 1961, this organization develops housing and related facilities for various income groups. About 80 percent of their housing production has targeted lower income groups.

Tamil Nadu Water Supply and Drainage Board

The Tamil Nadu Water Supply and Drainage Board (TWAD) plans and constructs water supply and sewage systems outside the city of Madras. Towns outside Madras City rely on groundwater sources and on the Palar River for their water sources. Current supply is about 25 lpd per person.

Little underground sewerage exists in the metropolitan area outside of the City of Madras. Most people rely on septic tanks and dry latrines. New neighborhoods developed by the TNHB since the 1960s, however, have their own underground sewage systems with local treatment plants.

As urbanization spreads beyond the limits served by Metro Water, and as additional water becomes available through the Krishna Project, coordination between Metro Water and TWAD will become increasingly important. Neither has a plan for sewerage or waterway quality. Both should turn their attention to these tasks.

Tamil Nadu Pollution Control Board

In India, water is a state-government responsibility. State Pollution Control Boards, established under the 1974 Water (Prevention and Control of Pollution) Act has the authority to regulate water pollution.[56] The 1986 Environmental Protection Act Environmental laws further tightened by environmental laws. This Act provides sweeping powers to close down a polluting industry. Officers of a company who violate provisions of the Act can be held criminally liable. Similarly, heads of Governmental agencies can be punished if found guilty.[57]

The Pollution Control Board (PCB) has a wide range of responsibilities for controlling surface water pollution: (1) sets the state standards for sewerage and trade effluent; (2) issues permits (consents) for discharging effluent into streams, wells, sewers or on land; and (3) monitors and enforces discharger compliance with their permit.

The frequency of monitoring depends on the expected level of pollution. Certain small-scale industries (such as automobile repair shops, PCB assembly with electronic components, and the fabrication of many articles like paper conversion, cotton knitwear, and milling) fall outside the purview of the Pollution Control Legislation. Madras has many of these small-scale operations. PCB has innovated in dealing with industrial dischargers. For two groups of small tanneries, PCB has organized common treatment facilities. Because of their small size, these tanneries cannot afford individual treatment and so were not treating their wastewater. Now these industries pipe their waste to a common treatment plant.

The Pollution Control Board is also charged with issuing permits to and monitoring the sewage treatment plants of Metro Water. PCB samples Metro Water's discharges once a month. PCB appears to be doing an adequate job of testing water and effluent for monitoring purposes. PCB staff skills and techniques should improve with technical training, now provided by the Danish International Development Agency (DANIDA). The Pollution Control Board, however, only reluctantly and rarely make the results of these monitoring efforts available to the public.

This failure contributes greatly to the lack of accountability surrounding government's role in sanitation and waterways quality. The Madras public--and NGOs such as Exnora and WAMP--have only scant information on these topics. PCB and Metro Water have monitoring labs and

[56] The Central Pollution Control Board is responsible for setting standards and conducting water quality studies. The states may establish more stringent standards than those set by the Central Board.

[57] According to some, these stiff penalties have resulted in a reluctance to pursue violators.

information, but refuse to make the great bulk of this data publicly available. The information vacuum hobbles public involvement and, hence, undermines enforcement of environmental laws.

This strategy has a double edge for Metro Water and PCB. Greatly restricting information may serve the immediate narrow interests of these bureaucracies--to control debate and decision-making in the short run. However, by failing to involve the public, it undermines the political will necessary for funding the macro investments essential to improve waterways quality and, arguably, the long-term interest of these organizations.

In principle, such monitoring should have an additional purpose--feedback to improve the operation of sewage pumping stations, sewage treatment plants, and other sanitation facilities. To efficiently operate a sewage treatment plant or pumping station, the operator needs to "tinker" with it and continuously adjust the various steps to achieve the best treatment. Data on the amount and content of sewage to be handled -- its constituents and their concentration -- tells the operator what needs to be done, and data on the effluent tells him how successful he was.

These two uses of monitoring data--enforcement and continuous improvement--need not conflict, if the operators and the monitors develop a cooperative relationship. Currently, the monitoring of PCB and Metro Water appears to serve neither of these important purposes.

Hence, establishment of an independent water monitoring program is an essential pre-requisite for waterways improvement. WAMP--which has the goal of monitoring waterways quality--is the logical organizations to house this function, in conjunction with Exnora International.

Madras Metropolitan Development Authority

Established in 1975, the Madras Metropolitan Development Authority (MMDA) is the regional planning authority for this area.[58] Its focus is land use. Land-use controls can have important implications for water quality. For example, this organization can withhold permission to construct until adequate sewage collection and treatment are assured.

In practice, MMDA--as many land-use planning agencies in developing countries--has modest impact on development for three fundamental reasons. First, a large amount of development occurs informally, outside the controls of this agency. Second, other agencies--such as Metro Water--make the key decisions on basic infrastructure (water, sanitation, roads, electricity) that impact development far more than land-use controls. Third, the Development Control Rules framed under the MMDA's Master Plan, however, appear poorly enforced. Various local bodies--rather than MMDA--are supposed to enforce these rules, but do so with

[58] The MMDA has jurisdiction over 1,177 sq. km., which includes the City of Madras, five municipalities, four townships, 27 town panchayats and 10 panchayat unions, having a total population of 6.5 million, according to the 1991 census.

widely varying degrees of efficiency and interest.[59] MMDA's administrative machinery is inadequate to supervise and monitor development. Compounding the problem, the procedures for stopping construction and demolishing unauthorized constructions appears highly cumbersome.

Overall, MMDA has little ability to reduce pollution through the control of land use.

Implications for the Action Plan

- The main motivation for waterways clean-up in Madras has come from Exnora and WAMP, and their involvement of the community. Hence, strongly supporting these NGOs is critical for further progress. However, these NGOs must go beyond the micro improvements at which they have become adept to influence the key organizations controlling macro improvements--particularly Metro Water. A systematic, independent water quality monitoring program can offer an important lever for such influence. Citizen-based monitoring is particularly important given the lack of local elections for twenty years and lack of public accountability. A second lever is the development and promotion of an action plan--such as that proposed in the next section--for waterways improvement.

- Metro Water should also receive support. This organization has the authority to solve many waterways problems and has shown some dynamism. Ultimately, the financial feasibility of the macro improvements essential to improving waterways quality rests on the ability of Metro Water to afford the debt service on financing these projects. Hence, technical assistance to this organization in privatization, personnel management, cost recovery, and other aspects of administration, represents a key to achieving waterways improvement.

- A strong institutional development and program management component must accompany any program of macro investments. Capital investments are likely to be wasted otherwise.

4.5 Action Plan for Urban Waterways Clean-Up In Madras

In sum, assessment of sanitation and waterway quality, urban development, and institutions results in seven key findings crucial for an action plan.

First, an action plan is critical and timely for Madras--India's fourth largest metropolis. One reason is that the conditions of the urban waterways are poor. Average BOD levels of these

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[59] Both the MMDA and the municipal Corporation have jurisdiction within the City of Madras,and various local bodies have jurisdiction outside Madras.

four waterways is remarkably high--200-600 mg/liter--above that typical for raw sewage (200 mg/liter).

Although conditions are bad now, they will worsen if no action is taken because of population growth and the great quantities of water from projects soon to be commissioned--such as the Krishna Water Project. By the year 2011, water supply and, hence, the sewage generated from formal water supply are scheduled to triple. Population in Madras City and the Metro area as a whole will roughly double.

Although plans and investments promise to take care of water supply, no comparable plan exists for treating the sewage that the great increase in water will generate. Current sewage treatment capacity will cover only one-third of the wastewater generated in 2011. This situation deserves to be called a "crisis" as some have labelled it.

Second, the action plan must focus on water quality. Various attempts to improve Madras' waterways failed because they neglected to deal with water quality. Although other factors--such as greenbelts and walkways--have some importance, water quality should have first priority. As wastewater is the main pollutant, expanding and reforming sewage treatment, intercepting wastewater flows into rivers and canals, and extending sewers to new areas are the key macro investments necessary to reduce pollution of the waterways of Madras. Activated sludge--the method currently used in Madras--appears a suitable sewage treatment process for this metropolis, given the area's economic importance and fast-growing, large population. Dredging sludge from the most highly polluted stretches of waterways must complement reduction in discharges.

Third, although all four waterways are inter-connected, hence, the solution to their pollution problems should also reflect this connection, the Cooum River deserves special focus because of its central place in the life of the city.

Fourth, a strong program management and institutional development component must accompany the heavy investments--necessary for improving sanitation and waterways quality.

Fifth, the poor water quality of Madras' waterways and the mismatch between water supply and sewage treatment has developed over decades, and cannot be reversed overnight. Credible solutions for Madras require a long-term commitment and massive investments to commensurate with the city's importance as the fourth largest metropolitan area in India. Because of the size of investments, staggering them in phases may be useful. This section presents the first stage of an action plan with a time horizon of five years.

Sixth, a series of micro investments undertaken by NGOs and involving local people in waterways improvement are just as important as the macro improvements. The main motivation for waterways clean-up in Madras has recently come from NGOs--particularly Exnora and WAMP--and their involvement of the community. Hence, strongly supporting these NGOs is critical for further progress.

However, these NGOs must go beyond the micro improvements, at which they have become adept, to influence the key organizations controlling macro improvements--particularly Metro Water. A systematic, independent water quality monitoring program can offer an important lever for such influence. Citizen-based monitoring is particularly important given the lack of local elections for the last twenty years and lack of public accountability. A second lever is the development and promotion of an action plan--such as that proposed in this section--for waterways improvement.

Seventh, the action plan must also target the technical, institutional, and financial capacity of Metro Water. This state company is generating the dramatic increases in water supply and the sewerage largely responsible for pollution of the waterways. Hence, it is critically important. Metro Water is a relatively dynamic water/sanitation company that has made substantial progress in water provision and is at the forefront of privatization. However, the Board has yet to take seriously waterway quality and the treatment of the sewage that its water projects generate.

In addition, Metro Water still has far to go in its management and financial reforms. Ultimately, the central question for most of the key macro improvements of this action plan is whether Metro Water can afford the debt service for project loans. Many factors contribute to the prospects for financial and economic feasibility, including: (1) cost recovery from household beneficiaries, commerce, and industry; (2) streamlining staff and operational efficiency; and (3) internalizing the positive externalities from sanitation and waterways clean-up in the form of grants from state and central government and marketing the by-products of treatment (treated wastewater, sludge, methane etc.) to industry and agriculture. Analysis of these questions must accompany any proposals for finance of macro improvements.

An eighth finding emerged from public meetings held as part of this consultancy that is important for this action plan. Madras residents hold a wide range of visions for improvement of their waterways. These visions range greatly in their ambitions and costs, from returning these waterways to their condition forty years ago--when residents swam in them--to at least removing their stench.

The most ambitious vision--returning these waterways to their state forty years ago so that residents could safely swim in them--would be extremely expensive and difficult. The rapid urbanization of the last four decades has permanently changed Madras from a town, into a metropolis with immensely greater discharges of many types. In addition, diversion of much of the water of the Cooum and the Adyar upstream of Madras has permanently altered the character of these rivers, which no longer flow continuously throughout the year. The least ambitious vision--removing their stench--is, perhaps, not sufficient to galvanize public support.

Hence, this action plan targets a vision, in between these two, also expressed by Madras residents--water quality sufficient for fishing and boating in the Cooum and Adyar Rivers, and navigation in the Buckingham Canal.

The First Stage

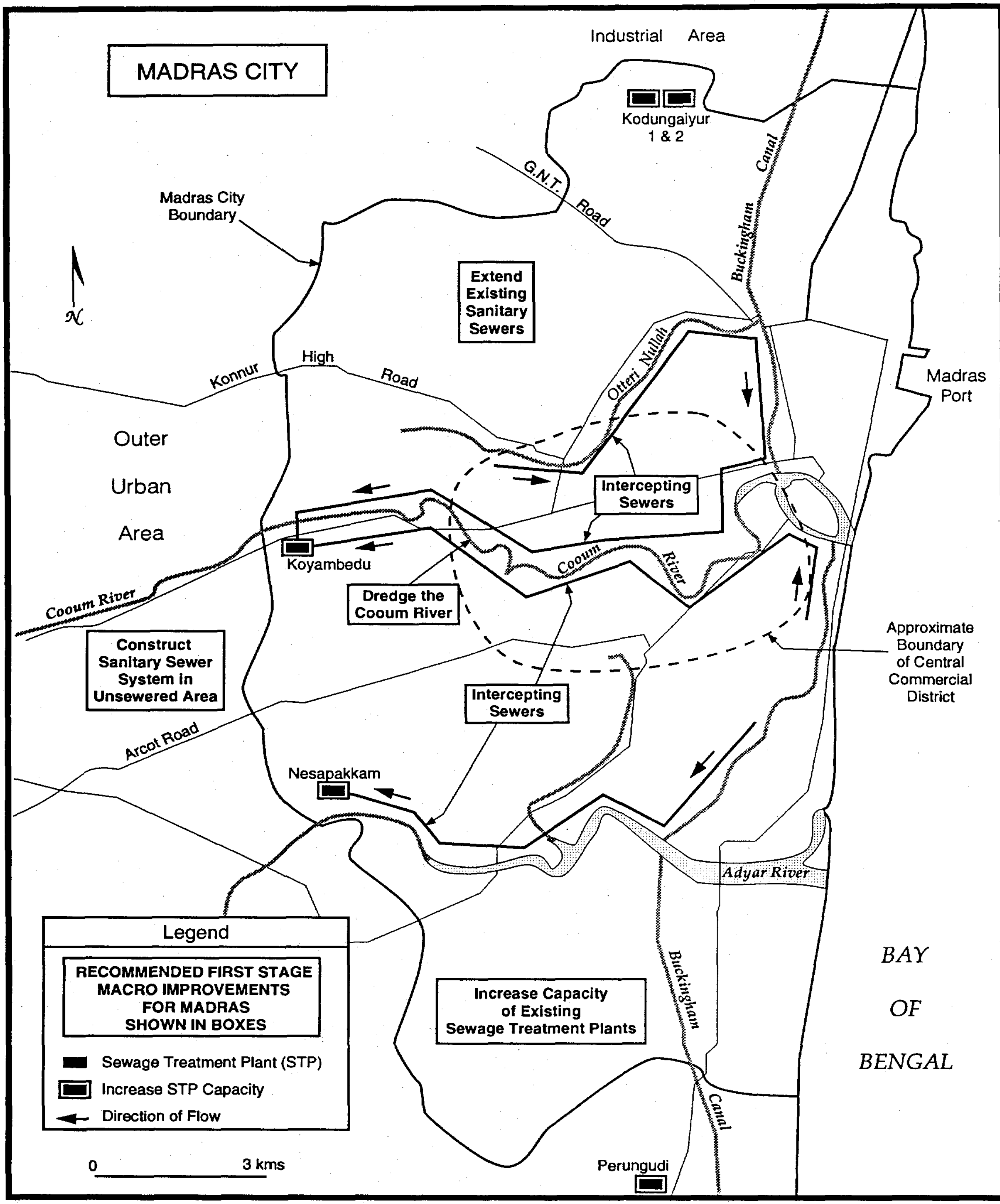
This action plan is mainly a first stage in rehabilitating the waterways of Madras that can start to improve water quality. The time horizon is five years. (Refer to Map of Madras).

It consists of a set of "macro" and "micro" improvements. The macro improvements require heavy investments, and the involvement of a wide range of organizational actors. The micro improvements can be undertaken with the assistance of NGOs and other local groups.

The macro improvements aim at collecting all sanitary sewage from Madras City and the existing population of the outer urban area, and the institutional strengthening of key organizations, particularly Metro Water. They also refurbish and expand the four existing wastewater treatment plants. These improvement efforts not only focus on the Cooum River by constructing intercepting sewers along its banks and dredging this waterway, but also deal with the Adyar, Buckingham Canal, and Otteri Nullah. In addition, this stage includes proper disposal of solid wastes from the banks of the river and the city.

First-Stage Macro Improvements

Table 5 lists these macro improvements and their components. It also breaks down the operation and maintenance, and capital cost. The map illustrates first-stage macro improvements.



MADRAS CITY
Industrial Area
Kodungaiyur
1 & 2
G.N.T. Road
Buckingham Canal
Madras City
Boundary
Extend
Existing
Sanitary
Sewers
Konnur High Road
Otteri Nullah
Madras
Port
Outer
Urban
Area
Intercepting
Sewers
Koyambedu
Cooum River
Dredge the
Cooum River
Construct
Sanitary Sewer
System in
Unsewered Area
Approximate
Boundary
of Central
Commercial
District
Intercepting
Sewers
Arcot Road
Nesapakkam
Adyar River
Legend
RECOMMENDED FIRST STAGE
MACRO IMPROVEMENTS
FOR MADRAS
SHOWN IN BOXES
Sewage Treatment Plant (STP)
Increase STP Capacity
Direction of Flow
Increase Capacity
of Existing
Sewage Treatment Plants
BAY
OF
BENGAL
0
3 kms
Perungudi

Table 5
First-Stage Macro Improvements
(Millions of US Dollars)

	Improvement	Annual O & M Cost	Capital Cost
1.	Rehabilitate existing wastewater treatment plants -all 4 plants -clean out tanks -refurbish structures & replace equipment	0.75	12
2.	Increase capacity of existing wastewater treatment plants		
	-Nesapakkam to 35 MLD	1	10
	-Koyambedu to 51 MLD	1.8	13
	-Perungudi to 68 MLD	2.4	30
	-Kodungaiyur to 240 MLD	4.8	44
	-all secondary treatment -demonstration project for sludge stabilization		
3.	Extend sanitary sewers to unsewered population of Madras City	0.5	19
4.	Construct sanitary sewers for existing populated areas in the Outer Urban Area	2.5	95
5.	Construct intercepting sewers along both of the banks of the Cooum -direct flows to Koyambedu plant -connect all sanitary sewers and storm drains	1.0	37
6.	Dredge Cooum River	--	25
7.	Construct intercepting sewer along the north and south Buckingham Canal. -direct flows to the Cooum and Adyar interceptors -connect sanitary sewers and storm drains	0.25	8

8.	Construct intercepting sewer along portions of the Adyar river -direct flows to the Nesapakkam plant -connect sanitary sewers and storm drains	0.25	9
9.	Construct intercepting sewer along the Otteri Nullah -direct flows to the north Buckingham Canal interceptor -connect sanitary sewers and storm drains	0.25	7
10.	Construct new sanitary landfill for Madras City	0.50	20
11.	Technical assistance -institutional strengthening for sanitation and solid waste -feasibility studies and final designs	--	12
12.	Program management -5 year duration for first stage project -manage and coordinate all technical functions	--	5
	Total Annual Operating and Maintenance Cost	16	
	Total Capital Cost		5

Taking each of the macro investments in turn:

Rehabilitate existing wastewater treatment plant. This component includes the replacement and rehabilitation of structures and equipment in the four existing wastewater treatment plants (STP) over the five-year time horizon--including cleaning out the aeration tanks, settling basins, and digesters.

Increase capacity of existing wastewater treatment plants. The current STP are near or at their effective capacity. Given population growth and increase in water supply from the Krishna project in the next five years, additional capacity of 50 percent is necessary simply to keep pace. A demonstration project for sludge stabilization to replace the current method--sludge digesters--is recommended. This demonstration project may include an alkaline stabilization process, possibly using fly ash.

Extend sanitary sewers to unsewered population of Madras City. One-tenth of the population of Madras City--about 400,000 people--are unsewered. Extending sanitary sewers requires connections to homes, buildings, and pumping stations, as necessary.

Construct sanitary sewers for existing populated areas in the outside urban area. Two million people are unsewered outside Madras City.

Construct intercepting sewers along both of the banks of the Cooum. This measure intercepts sanitary sewage now reaching the Cooum River from homes, buildings, and industries. It will carry the flows west (upstream) to the Koyambedu STP. In the absence of an intercepting sewer, flows go through local sewers and pump stations before reaching treatment plants, which often bypass this raw sewage into the waterways. Currently, substantial time, effort, and energy gets spent lifting these sewage flows repeatedly, at many pump stations with little effect. The proposed intercepting sewers pick up and channel these flows by gravity to the treatment plant, to which they are then lifted by one pump station.

Dredge Cooum River. The Department of Public Works of the state of Tamil Nadu has made a proposal to remove the extensive sludge and silt deposits in the lower part of the Cooum River in Madras City. The figure noted below is their proposed cost.

Construct intercepting sewer along the north and south Buckingham Canal. An intercepting sewer should be constructed on portions of the north and south Buckingham Canal in order to receive flows from sanitary sewers and storms drains. Flows should be directed to the Cooum and Adyar intercepting sewers.

Construct intercepting sewer along portions of the Adyar river
An intercepting sewer should also be constructed along part of the Adyar River in order to receive flows from sanitary sewers and storm drains, and convey them to the Nesapakkam STP

or to the Perungudi STP.

Construct intercepting sewer along portions of the Otteri Nullah. Flows from sanitary sewers and storm drains, will be collected and directed to the north Buckingham Canal intercepting sewer.

Construct new sanitary landfill for Madras City. Providing for the proper and safe disposal of solid waste is high priority in Madras. Currently, two highly unsanitary landfills exist. The new sanitary landfill should have controlled access, daily cover, and leachate control.

Program management. A program management unit should be created to coordinate the technical functions of the first-stage macro improvements, including contracts, quality of work, costs, schedules, designs, and construction.

Cost. The total capital amount--1,034 crore (US $350 million) is a large absolute sum, but modest for sanitation improvements to a major metropolis. It is only US $66 per capita for the current population of the metropolitan area of Madras (5.3 million), and US $36 per capita for the projected 2011 population (roughly 9.6 million). In contrast, major sewage treatment and collection programs in the U.S.--such as those of Chicago and Boston--not uncommonly cost US $1,500-2,000 per person. The cost of a major water supply project for Madras--such as the Krishna project--is in this range.

The annual operation and maintenance cost--48 crore (US $16 million) is, perhaps, a greater challenge to finance. Coming up with this sum each year out of current revenues, the normal procedure, is difficult.

Some of these macro investments can achieve substantial cost recovery and, thus, have the potential for supporting commercial finance of part of their total cost. Hence, they may be good candidates for debt finance under the USAID-Government of India FIRE Program, and other commercial financing vehicles.

Any program that includes debt finance must also make progress at reforming the financial, management, and administrative systems of the borrowing organization to be successful. Without organizational reforms, any capital investments are likely to have little lasting impact--in effect, they will be wasted. Metro Water, in particular, appears an excellent candidate for a joint debt finance/institutional strengthening program.

First-Stage Micro Improvements

Micro improvements are smaller projects essential to complement macro improvements, increase public awareness, and maintain the political will to carry out the overall program. They include establishment of an independent water quality monitoring program, support of Metro Water and other key organizations in institutional strengthening and project implementation, and sanitary upgrading of slums along river banks.

Table 6 lists these micro improvements and their cost.

Taking each of these micro improvements in turn:

Establish an independent wastewater monitoring program. Various entities in Madras have monitoring equipment, including Metro Water, the Pollution Control Board, and private firms. However, a systematic independent monitoring program has a number of important advantages. It can have a broader focus than that for the specific purposes for which existing organizations monitor. Its independence can increase confidence in the results. Finally, its results can be widely disseminated to inform the public and increase transparency.

Systematic monitoring has two key purposes. First it is essential to increase the accountability of the public and private organizations that should be involved in waterways improvement--such as Metro Water, the Municipal Corporation, industries etc. Currently, these entities make little information related to waterways quality publicly available.

Second, monitoring can provide the feedback necessary to improve performance in such tasks as wastewater treatment. Use of monitoring to improve performance receives little attention and interest. Monitoring appears to be viewed as a legal requirement, and not an integral part of the operation and improving performance of entities such as Metro Water.

Independent monitoring would also help make the monitoring entity--such as WAMP or Exnora--an important player in the decisions on the macro investments necessary for substantial waterways quality improvement.

Two alternatives exist for establishing such a monitoring function. An NGO could establish and operate its own laboratory. Or, the NGO could fund private companies with monitoring capacity to conduct and analyze samples.

The Rp. 400,000 figure in Table 6 for this activity represents the cost of conducting and analyzing 500 samples per year for five years.

Table 6
First-Stage Micro Improvements
(US Dollars)

	Improvement	Cost
1.	Establishment of an independent wastewater monitoring program	13,350
2.	Analysis, publication, and information dissemination on waterways quality	15,000
3.	Sanitary upgrading of slums along river banks	100,000
4.	Cattle waste demonstration project	6,670
5.	Assist public agencies in project operation and implementation	16,670
6.	Greenbelt and walkways along banks	16,670
7.	Survey health-care providers, households, and industrial users of water	10,000
8.	Technical assistance	50,000
	Total Cost	$228,360

Analysis, publication, and information dissemination on waterways quality. Once more systematic data becomes available, means must exist to disseminate this information to the public. Various possibilities exist. Public meetings can be held. The results of the public meetings can be the basis for press conferences and published in newspapers. Organizations dedicated to cleaning up the waterways--such as Exnora and WAMP--can expand the scope and circulation of their newsletters.

The total Rp. 450,000 for this activity finances one public meeting per month (Rp. 100,000), publication of the results of the public meeting in a local newspaper once per month (Rp. 250,000), and strengthening of a newsletter (Rp. 100,000).

Sanitary upgrading of slums along river banks. Roughly 150 informal settlements exist along the waterways of Madras, containing roughly 40,000 households. Slum upgrading is ultimately the responsibility of government entities such as the Tamil Nadu Slum and Housing Boards. However, NGOs such as Exnora and WAMP can catalyze small sanitation projects in these places important to water quality, such as the self-help laying of sewers. Since local people provide the labor, the only cost is the materials. Rp. 3,000,000 is the cost of the materials and supervision for laying such lines in 50 of these 150 slums over 5 years.

Demonstration cattle waste program. Various studies have documented the substantial problems that cattle waste currently cause to the sewer system because of its fibrousness and high BOD. A pilot project is important to demonstrate how a cattle yard can be organized properly so as not to challenge the sewer system. Part of this project involves using cattle waste to produce methane for household cooking and lighting. Part would demonstrate how the slurry can be used and/or sold as fertilizer.

Assist public agencies in project operation and implementation. If there is one lesson that can be learned from other countries, for improving the urban environment in Madras, it is that government cannot do everything by itself. NGOs and the private sector must become government's partners.

NGOs in Madras--such as Exnora and WAMP--already assist public entities--such as Metro Water and the Municipal Corporation--in various ways. These means include orienting pump station operators on doing their job to minimize pollution of waterways, getting households connected to the sewers, public education on sanitation, and supporting pubic agencies in neighborhood meetings and the political process when appropriate--for example, when neighborhood opposition threatens to derail the use of a key piece of land for a needed facility, such as a pumping station.

This micro project finances similar assistance of NGOs to public agencies for five years.

Greenbelt and walkways along banks In the context of a larger program to improve water quality, beautification--such as greenbelts and walkways along river banks--is useful.

Survey health-care providers, households, and industrial users of water. Three surveys could gather critical information on waterways pollution and the health effects useful. A survey of health-care providers could collect information on water-borne disease. Similar data could be collected by a household survey. Finally, a survey of industrial users of water collects data on their water needs and the cost of getting water to their plants and treating it. Based on these three surveys, SMF could roughly quantify these costs of water pollution.

Technical assistance. Metro Water--which has the responsibility for sanitation and water supply--and the Madras Corporation--which has the responsibility for solid waste management and storm drainage--require technical assistance to carry out the macro program. This technical assistance should include feasibility studies and final designs for the facilities constructed in the first stage.

Even more important, technical assistance must embrace the financial, management, and administrative systems of these entities. Specifying these reforms lies beyond the scope of this consultancy. Hence, detailed analysis aimed at strengthening these entities and demonstrating the financial feasibility of projects is a pre-requisite for any program of macro investments.

Cost. The cost of these six micro improvements totals US $228,360. This modest amount can make a pivotal contribution to urban waterways improvement in Madras, the fourth largest metropolis of India. The largest component of these components consist of the cost of sanitary upgrading of one-third of the slums along the waterways and technical assistance to entities, in particular, Metro Water.

Conclusion

In sum, the macro and micro improvements of this action plan take a substantial step towards water quality suitable for fishing and boating in the Cooum and Adyar Rivers, and for navigation in the Buckingham Canal--a suitable vision expressed by Madras residents for these waterways.

V. VARANASI

5.1 Description of Urban Waterways

The Ganges River ("Ganga") originates in the Himalayas, flows across three states containing over 700 towns and cities in the northern plains of India, into the Bay of Bengal. The Ganges basin covers more than one-fourth of India's total geographic area--nearly a million square kilometers--and is extensively cultivated and irrigated. Forty-seven percent of the total irrigated area of the country is located in the Ganga basin. The Ganga is the largest river in India, with a mean annual flow of over 400 billion cubic kilometers. (Refer to map of Varanasi)

Although physically large, the Ganges holds a spiritual and cultural meaning even greater than its size. Hindu tradition views this river as sacred. Hindus achieve religious purification and spiritual satisfaction through bathing and sipping its water. The temporal and spiritual importance of the Ganges makes it the "mother of India."

The Ganges at Varanasi holds a particularly important meaning. The city is situated about 1,395 kilometers from the river's source. Varanasi is one of the oldest living cities of the world, with a recorded history of 3,000 years. It is a sacred city for Hindus and Buddhists, and the holy city of the Ganges. No other stretch of the Ganges has so much sacred bathing and such a concentration of temples. 60,000 people per day, on average, bathe in the river. Most concentrate near the "ghats", stone walkways leading down from the many temples that line the sacred area to the river.

Varanasi depends heavily on the Ganges in many respects. Irrigated agriculture and holy pilgrimages support the local economy. The temples are the center of Varanasi's cultural, religious, and economic life. These religious institutions--which typically date from 300-700 years ago--only exist because of the Ganges. The city also draws the great bulk of its water supply from this river.

In the last two decades, however, the urban development of Varanasi has begun to threaten this river's water quality. The pollution load of Ganga at Varanasi has increased steadily and now accounts for about 23 percent of the pollution of the state of Uttar Pradesh into the river. Two other small rivers that feed the Ganges through Varanasi--the Assi and the Varuna--have become virtually sewage and storm water drains. (Refer to map of Varanasi)

The main contributor to the pollution of Ganga at Varanasi is household wastewater; 85 percent of BOD is the figure often given. The central city of Varanasi generates roughly 170 million liters per day (MLD) of sewage, the great bulk of which finds it way into the Ganges. Two growing urban fringe areas--the Trans-Varuna and upstream south of the Assi River (see map of Varanasi)--generate additional amounts. Industrial pollution is still negligible.

Although potentially disastrous if unchecked, the pollution and water quality problems of the Ganges at Varanasi are still localized. The water quality upstream of the urban area and 15 kilometers downstream of the city is very good. Even opposite the ghats in the city center, water quality on the far bank (right side facing downstream) and middle of Ganga is reasonable.

Unfortunately, one of these highly polluted locales is the sacred bathing area.[60] Bacterial counts in this strip are in the tens and hundred of thousands, compared to the Indian standard of no more than 500 mpl/liter for Class-B rivers. High BOD levels are also near the ghats. Typically, they range from 4-15 mg/liter compared to the Class-B river standard of no more than three. Pilgrims who bathe in and sip this water and others who bathe in it run considerable health risk. Protecting the water quality of this bathing area has become the main mission of an environmental NGO--the Sankat Mochan Foundation.

A second highly polluted area is that near the confluence of the Varuna and the Ganges Rivers. The Varuna serves as the main sewage channel for the Trans-Varuna area of Varanasi, and receives considerable untreated discharge from other areas. Visual inspection shows septic conditions at this confluence.

Although municipal sewage contributes most of the pollution load to the Ganga at Varanasi[61], other factors have an impact. These include human and animal carcasses dumped into the river, bathing and washing, and poor municipal services. In addition to bathing, residents use the Ganges to clean clothes and for many other purposes that cause pollution. Although incineration has received increasing acceptance as a means of ritually joining human corpses with the holy waters, cadavers still pollute the Ganges.

A wide range of poor municipal services exacerbate the problems cause by household wastewater. Garbage remains virtually uncollected in large parts of the city. Informal garbage dumps can be found along many streets. When the monsoons arrive, flood conditions wash large amounts of garbage into the sewer system and into the river. Poor roads--often little more than winding, irregularly paved paths--contribute to making garbage collection difficult. Poor electrical service makes sewage pumping unreliable, increases BOD levels throughout the sewage system by allowing effluent to sit. Although an abundant water source exists--the Ganges--and adequate water treatment capacity is coming on line, water, too, is a major problem.

In short, Varanasi largely lacks the basic infrastructure of a twentieth century city, despite its population of over one million.

Varanasi is very poor, consisting mostly of what would be called "slums" in Indian metropoli such as Madras and Delhi. The lack of basic services of all kinds hits this largely poor population with particular force. More than in most cities, the river quality problem of Varanasi

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[60] Up to 40 meters from the bank.

[61] No systematic assessment has broken down the sources of pollution to the Ganga at Varanasi. The rule-of-thumb used elsewhere--that household waste water contributes 80-90 percent of key pollution parameters (BOD, bacterial counts)--gets used here, too.

is one part of a basic infrastructure crisis that threatens the people of this city as well as its waterways.

A centrally funded, high-profile effort--the Ganga Action Plan Phase 1--has recently targeted the pollution of the Ganges along its course in three states. Amidst great fanfare in 1985, the Government of India announced the start of this plan for cleaning up the Ganges. Phase 1 of GAP has channelled US $150 million to various sanitation projects related to water quality in cities over one million in population ("Class-1 cities) along the Ganga.

GAP Phase I projects included the major sanitation treatment and pumping facilities now in use in Varanasi: the Dinapur Sewage Treatment Plant and the Konia Pumping Station. GAP Phase 1, in general, and these Varanasi projects, in particular, have come under great criticism (section 5.4--Waterways Quality and Sanitation Assessment)--examines this topic in greater detail.

The debate over GAP Phase I and its results in Varanasi, is sure to continue. All sides appear to agree, however, that water quality along the ghats remains very poor and that GAP Phase II represents a crucial and, perhaps, final opportunity for the foreseeable future to improve waterways conditions in Varanasi substantially. In this context, the design and implementation of the next round of sanitation investments deserve the most careful attention and scrutiny.

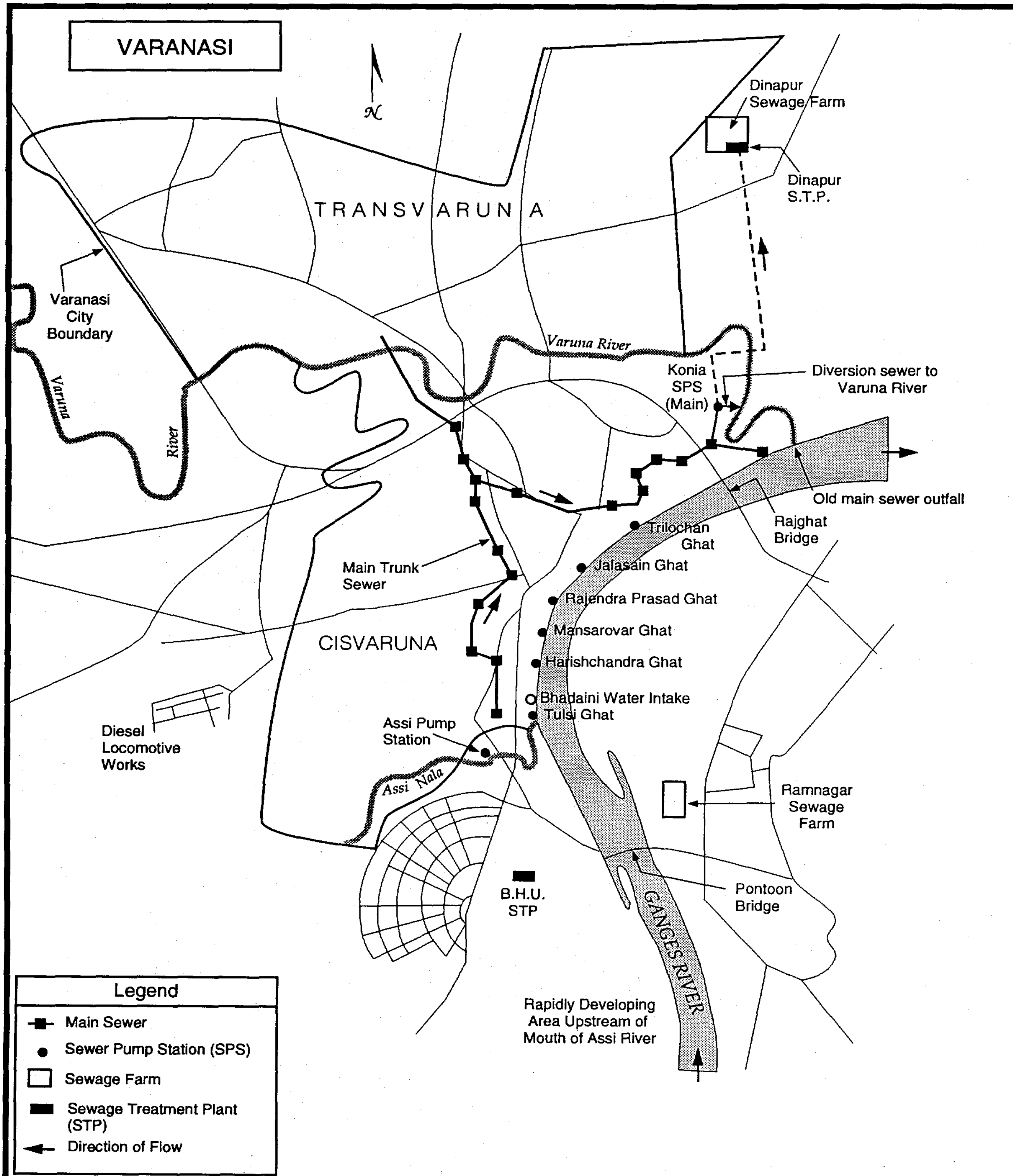
5.2 Urban Development Assessment

Both Varanasi the city and its basic infrastructure have a long history. Public toilets were built for the pilgrims in the 1790s. The first attempt to build drainage on modern scientific lines was undertaken in 1860. The Banaras (the traditional name for the area now known as Varanasi) Municipal Board formed in 1866. A sewer was constructed in 1899, discharging at Rajghat after passing through the old city. Piped water first became available in 1892. The pollution of the Ganges began with the spread of flush toilets and sewerage system in the early twentieth century.

Until recently, Varanasi amounted to little more than a large town. As of 1941, the Varanasi Urban Agglomeration contained a population of 266,000. Since then, population growth has averaged roughly 30 percent per decade, and had increased to 1,052,250 in 1991.[62]

The urbanization of the last four decades has dramatically increased densities and put intense pressure on the city's infrastructure. New people--both permanent and transient--have chosen to reside in the sacred area--the portion of the city in between the Varuna and the Assi Rivers--for religious reasons. Densities in this central area (the "Cis-Varuna" area, or "old city") have doubled since 1960. (Refer to map of Varanasi) While the Varanasi Development Authority considers 300 persons per acre to be the maximum desirable density, some places in the old city

[62] Most of this population growth has occurred in the City itself. With a population of 7.74 lacs in 1981 and 9.96 lacs in 1991, the population growth rate of the City was 28.7 percent. The estimated 1994-95 population of the City is nearly 12 lacs.


VARANASI
N
TRANSVARUNA
Dinapur Sewage Farm
Dinapur S.T.P.
Varanasi City Boundary
Varuna River
Varuna River
Konia SPS (Main)
Diversion sewer to Varuna River
Old main sewer outfall
Rajghat Bridge
Trilochan Ghat
Jalasain Ghat
Rajendra Prasad Ghat
Mansarovar Ghat
Harishchandra Ghat
Bhadaini Water Intake
Tulsi Ghat
Main Trunk Sewer
CISVARUNA
Diesel Locomotive Works
Assi Pump Station
Assi Nala
Ramnagar Sewage Farm
B.H.U. STP
Pontoon Bridge
GANGES RIVER
Rapidly Developing Area Upstream of Mouth of Assi River
Legend
Main Sewer
Sewer Pump Station (SPS)
Sewage Farm
Sewage Treatment Plant (STP)
Direction of Flow

have densities of 1,000 persons per acre.

Infrastructure systems in this central area appear to be crumbling. Many streets are very narrow--sometimes little more than paved paths--and are in poor repair. Although water supply is potentially ample, problems with distribution leave a large portion of the city with low pressure and intermittent service--averaging eight hours per day. Electricity outages constantly occur. Garbage collection appears haphazard to non-existent in many areas, and refuse piles up throughout the city. Although sewerage exists in the Cis-Varuna, not all areas of the city have sewers. Recent investments in sanitation and water appear have produced uneven results and burdened Varanasi with high operation and maintenance costs.

As the old city has filled, pressures on outlying areas to develop have increased. The major focus of development pressure is now upstream of the City near the Assi River, and beyond the Varuna River (the "Trans-Varuna"). Although densities are much lower, these newly developing areas lack sewerage.

The monsoons aggravate these problems in many ways. Most of the infrastructure systems virtually shut down during the heights of the monsoons in July and August for a number of weeks.

Urban Development, Land Use, and the Master Plan

Following its establishment, the Varanasi Development Authority drew up the first master plan for the urban area in 1974. The major goals of the plan are to disperse development away from the old city, improve the transportation network--in part by providing by-passes to keep through traffic out of the city--and to integrate new development with the improvement and extension of basic services in the existing city.

Population levels in 2011, as projected in the master plan, are 500,000-600,000 for the Trans-Varuna area, 500,000 for the area upstream of the Assi, and 800,000 for the central part of the city ("Cis-Varuna").

Development south of the Assi promises to be particularly rapid and threatening to Ganga water quality. The completion of the Ramnagar Mogalsarai By-Pass, which will provide a major new bridge crossing the Ganges, is fueling the growth of this area. The master plan calls for developing a large wholesale market and transportation node along this by-pass. In addition, the plan calls for residential construction at Chitaipur, a nearby site[63], to accommodate 15,000 on about 100 acres of land. The plan calls for hotel and other tourism developments on about 67 hectares of land. In short, the area south of the Assi is likely to become a major growth node. However, the sewage from the great bulk of this new development is likely to remain untreated

[63] Near the Banaras Hindu University (BHU) and the Diesel Locomotive Works (DLW)

and to flow into the Ganges upstream of the ghats.

According to Varanasi's city planner, most of the new housing colonies install sewers but many are not connected to the city's system. In the area of the Assi, many of these localized systems discharge directly into the Assi. Even the housing built by the Development Authority, outside the central part of the city, is sewered but not connected to the sewage treatment plants. In addition, some industrial development is occurring on the far side of the Assi, including metal-working facilities and a pharmaceutical plant. Industrial pollution has been minimal, so far, in Varanasi. However, these new industries threaten to make toxic waste a problem.

Land-use regulations have proved largely ineffective in securing sewage collection and treatment. While the Development Authority decides on building requests, political pressure frequently results in approval of development that fails to conform to the master plan.

Transportation patterns also impact the community's ability to clean up the Ganges. Streets are very narrow and the traffic is extremely heavy in much of the city. These problems hamper digging up the streets to repair existing sewer and water lines or to lay new ones. Currently, a new water main is being laid through the middle of the city, and the trenches are being dug by hand. While cost effective given the low cost of labor and the difficulty in using large machinery in such crowded circumstances, this method makes progress very slow.

Water Supply

Varanasi gets its water mainly from two sources, the Ganges (60 percent) and from groundwater (40 percent).[64] Given the substantial flows of the Ganges, an ample supply should exist. The city currently withdraws 1.6 cubic meters per second for water supply from this river's total flow, which averages about 200 cubic meters per second.

Starting in the early 1970s, a series of World Bank projects sought to expand capacity to meet growing demand. Piped water supply totals 210-230 mld currently. Under a Uttar Pradesh Urban Development project funded by the World Bank, another 150 mld of water from the Ganges are in the works and set to be commissioned in 1996. The total -- 360-380 mld -- would be ample for the entire Varanasi population--at somewhat over a million.

However various problems have arisen in implementation. The distribution system cannot handle the entire additional 150 mld of water. It can handle about 70 mld. Pressure in the distribution system has reportedly dropped from an earlier level of 110 units to 70. Water is available for 8 hours a day as compared to 16 hours per day earlier. A new filtration plant is

[64] Several sources gave this split between river water and tubewells. However, a recent publication by Jal Sansthan (*Estate for Water Supply for Varanasi City Projectedfrom 1996 to 2016*) stated that 110 mld came from the Ganges and 120 mld came from tubewells. This would be a split of 48 percent from the river and 52 percent from the tubewells. In either case, the river Ganges is major source of drinking water for Varanasi and needs to be protected.

working improperly. Frequent power outages make electricity to pump the additional 150 a problem. In addition, groundwater levels have fallen 10 meters in the last decade.

For planning purposes, the Jal Sansthan projects the 2016 population to be 1,203,000 in the Cis Varuna area and 520,000 in the Trans Varuna area. This organization also assumes an average per capita demand for water of 270 liters per day (much higher than that the 150 MPLD figure used for water planning purposes in Madras and India, generally). Based on these figures, the total need for water would be about 465.2 MLD, or about 100 MLD more than available after the completion of the World Bank project. However, Varanasi would have more than ample water supply using the 150 MPLD standard. Additional investments to improve the water distribution system appear as or more critical.

As in Madras, the most important problem for river water quality is the absence of integrated water and wastewater planning. Water supply and distribution investments--although problematic--are planned for, and coming on line. However, no government entity appears in charge of either water resource management or comprehensively dealing with the wastewater produced by increased water supply. The Central Water Commission supposedly has some responsibility for overall water resource management. However, no such planning is underway at this organization. The lack of planning and adequate investments in sanitation threatens increasing amounts of untreated and inadequately treated sewage flowing into the Ganges.

Centralized water resource management disconnected from local needs and waterways improvement aggravates this problem. Large withdrawals of Ganges water for agricultural irrigation occur.[65] These withdrawals have substantially lowered flows and decreased the ability of the river to clean itself, particularly during the dry season. At the height of the dry season--May and June--the Ganges River is at its lowest, with a depth of about 15 meters by the ghats and a mean velocity of about 0.25 meters per second. In contrast, after the monsoons, the Ganga will be 15-20 meters higher than its dry-season trough, and its mean flow will increase to about four meters/second.

The water supply situation is considered to be acute. Overall, water levels in the Ganga are down and the ground water table (level) in Uttar Pradesh is dropping, making protection of the Ganga all the more important.

Sewers and Sanitation

Neither the sewage collection nor the sewage treatment systems in Varanasi can handle the current amount of sewage, let alone meet the increasing demands that population growth and increased water availability will place on the system. Before the Ganga Action Plan Phase 1, virtually all wastewater ended up in the Ganges untreated. Despite the construction of sewage

[65] In addition, the city of Delhi is drawing water from the Ganga. Plans exist to provide Delhi with water from the Indus River basin, but it is not known when the water will be available.

treatment plants and expanded collection systems, much of the wastewater still discharges into Ganga with no or insufficient treatment.

While the first sewage collection system in Varanasi was built in 1917, the system has failed to keep up with the growth of the city. This first system, built of brick and still in use, was designed for a population of 200,000. The city is now about five times that size. The main trunk sewer--which dates from 1917--starts near the Assi and runs parallel to the Ganges, passing under heavily built up areas of the old city. Until the Ganga Action Plan construction, the main trunk sewer discharged effluent into the Ganges, without treatment.

A second sewer, the Orderly Bazaar, was also laid in 1917. It collected sewage in part of the Trans Varuna area and transported it to the Main Sewer. In 1946, part of this sewer was destroyed in a flood. Since then the sewage from the Trans Varuna area has discharged, untreated, into the Varuna River.

Over time, the sanitation system has expanded through additional interceptors (trunk sewer mains) and lateral sewers, all of which discharge into the main trunk sewer or directly into the Ganges, Assi, or Varuna rivers. Together, however, the sewer collection system covers only about 60 percent of the population of the city. Any plan to reduce contamination of the Ganges must include expansion of the sewage collection system to the currently unsewered population, as well as the areas of new growth.

Expansions of the system, however, require additional trunk line capacity. The main sewer cannot handle the current sewage flows. It runs full most of the time, and during peak hours, morning and evening, the sewer runs under surcharge conditions. At various places, the sewage oozes out of the manholes creating health risks.[66]

A relieving trunk sewer would provide a second benefit. The current main trunk sewer is beginning to show significant signs of age. Areas near the main trunk line have subsided and, sometimes, collapsed. A second trunk line would make rehabilitation of the old sewer easier, and would provide minimum service if a true emergency occurred with the old sewer.

Precise data is unavailable on the amount of sewage generated each day. Estimates tend to run around 200 to 260 million liters per day. Varanasi's treatment systems, however, are designed to handle one-third to one-half of this amount.

Three treatment plants exist in Varanasi. The two small ones (each of which handle 7-10 MLD), are located at the Diesel Locomotive Works (DLW) and the Banaras Hindu University (BHU).[67] The DLW treatment works handles both domestic sewage of about 80,000 people and

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[66] This problem becomes much worse during times of heavy rain, when the system is completely incapable of handling the loads.

[67] The BHU plant is also called the Bhagawanpur sewage treatment plant.

industrial wastewater. BHU handles only domestic sewage.

The Ganga Action Plan I built the third plant, Dinapur, which provides most of the sewage treatment available in Varanasi. Built to handle 80 MLD, Dinapur is currently running at about 100 MLD. The treatment processes used at Dinapur are primary sediment, trickling filter, aeration, and secondary sediment. The plant also has sludge digesters to sterilize the sludge and methane tanks, to produce gas for use in generating electricity. A visit of this consultancy to the treatment plant showed it to be in full operation[68], although substantial documentation exists on problems---see section 5.3 for discussion.

Wastewater entering the Dinapur plant first passes through the Konia Pumping Station. (Refer to map of Varanasi) The intent of the system is to send all wastewater from the main sewer to Konia. However, Konia cannot always handle the inflow, especially during times of heavy rains. The excess discharges directly into the Ganges.

However, the Konia can handle a greater flow than the Dinapur Sewage Treatment Plant, so some wastewater discharges into the Varuna River after passing through the screens at Konia but before treatment at Dinapur. Based on our observations, during the height of the dry season, and on reports from Jal Nigam, a minimum of 85 MLD of untreated wastewater discharges to the Ganges and the Varuna.

Much disagreement exists on the degree of treatment that Dinapur provides and the quality of water leaving the plant. Jal Nigam--the state-level water/sanitation company that built this plant--offers data showing that this plant achieves excellent BOD removal--25 mg/l in its outflow. Measurements taken by an environmental NGO equipped with a laboratory--the Sankat Mochan Foundation--show much higher levels of BOD, above 80 mg/l.

Regardless of BOD levels, the Dinapur Sewage Treatment Plant--which is an activated sludge facility--lacks separate disinfection and, hence, does little to reduce bacterial counts. While BOD is a measure of the load on the overall condition of the waterway, bacterial accounts are more closely linked to water-borne illnesses.

In sum, Varanasi, in contrast to Madras, has recently invested substantial sums to increase dramatically its sewage treatment capacity, largely in order to improve waterway quality. Only minimal sewage treatment existed before the Dinapur Sewage Treatment Plant. However, the uneven performance of this plant, and the Konia Pumping Station continues to put Ganga water quality at risk. Moreover the operation and maintenance of the expanded sewerage system costs roughly US $1 million per year. This sum burdens the entities (mainly the state government, at present) involved and, ultimately, may burden the city and local people directly.

Contamination of water by sewage is also a problem. Varanasi has old, brick sewers that

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[68] We were told that the plant was producing enough electricity to meet about two-thirds of their needs. The electricity was generated with a fuel mix of 90 percent methane and 10 percent diesel.

leak and have even collapsed in several places along the branch lines. These sewers often close to water lines and contaminate them, particularly during times of heavy rainfall when the sewers tend to surcharge, especially in low-lying areas. When cross contamination occurs, the municipality must provide these areas with trucked-in drinking water and pump the flood waters long distances. A plan has been developed to help the approximately 300,000 people affected by this problem. It involves providing a separate sewer for this population, with the water to be pumped into the Varuna River. In this way, the water will not burden the current city sewer system.

Solid Waste Collection and Storm Sewers

Two other local services appear to have a substantial impact on water quality in the Ganges: solid waste collection and storm sewers. The Municipal Corporation of Varanasi is responsible for both services. The poor level of both these services contributes to degradation of the waterway.

As in Madras, the storm water and sewer lines effectively form one system.

The garbage collection system involves several steps, with ultimate disposal in the form of dumping the waste in low-lying areas, ponds and wetlands. Currently there are about 2,500 sweepers, who sweep the garbage and rubbish into piles that are then collected by handcarts (about 1,000). The handcarts then transport the solid waste to one of 52 garbage dumps located around the city. From there the solid waste is lifted onto large trucks and carried to disposal sites. No sanitary landfill exists. This process is particularly difficult to manage during wet weather. Overall, garbage collection is extremely poor and chaotic. Mini garbage dumps line many of the streets, some used by the city and some not.

Slums and Informal Settlements

Poverty levels are clearly high in Varanasi. Unlike Madras, however, Varanasi has few informal settlements along the waterways. The Ganges is lined with temples, and the ghats.

Slums do, however, contribute to the poor water quality Varanasi waterways because their wastewater typically remains untreated. The Varanasi Development Authority attempts to bring public services, including drinking water and sewers, to these areas.

Cumulative Effect of Poor Urban Services on Waterways Quality and Quality of Life

The poor quality of various urban services interact to worsen waterways quality and depress the quality of life of Varanasi residents.

Many examples exist:

Small, windy, poorly maintained roads make garbage collection difficult. Garbage, in turn, clogs the sanitation system. Frequent power outages make water and sewage pumping difficult, leading to intermittent water service and increased BOD levels in sewage. The sanitation system backs up and floods many areas, contaminating water supply, and requiring separate delivery of water to some areas of Varanasi by tanker trunk.

Implications for the Action Plan

- The water quality of the Ganges at the ghats has special importance for religious pilgrims, residents of Varanasi, and decision-makers.

- Sewage is a key, but not the only key to improving the Ganges and the ghat area. The poor quality of various urban services--including electricity, roads, and solid waste management--interact to exacerbate the problem. Garbage has particular importance.

- Water supply is outstripping the city's ability to handle the sewage that results. As of next year, Varanasi will be receiving a total of about 350 MLD in water and generating around 250 MLD in sewage. At best, Varanasi treats 100-140 MLD of this sewage. This imbalance will worsen as more water comes on line.

5.4 Technical Assessment of Waterways Quality and Sanitation

The principal waterways of Varanasi are the Ganges River (the Ganga) and two of its local tributaries--the Varuna River and the Assi Nala. These two tributaries and the left bank of Ganga along the bathing ghats are highly contaminated. The sources of pollution include:

- Human settlements, both formal (officially sanctioned by the city) and informal (not sanctioned)
- Untreated overflows and bypasses from the sanitary sewer system
- Disposal of dead animals and human corpses along the river banks
- Municipal solid waste accumulations on river banks and streets
- Cattle wastes
- Residual sludge deposits in waterways

Human settlements contribute to pollution of the waterways in several ways:

- Direct discharges of raw sewage from settlements located on the banks
- Discharges from storm drains which receive raw sewage as well as storm water
- Discharges from ditches and other conduits in currently unsewered areas
- Defecation along river banks and streets

Untreated overflows and bypasses from the sanitary sewer system occur at several points along the waterways, including the ghat area. The largest of these sources is the diversion of raw sewage from the special manhole--a component of the sewer system that is located upstream from the Konia Pumping Station--to the Ganga at Khirkia Ghat nala. This consultancy (during dry weather) noted additional sources along the ghats and at the old main sewer outfall to the Ganga. The Orderly Bazaar sewer from the Trans Varuna area discharges raw sewage into the Varuna River. In addition, regular, daily surcharging of portions of the existing main trunk sewer reportedly occurs.

The disposal of dead animals and human corpses along river banks and in the waterways of Varanasi, municipal solid waste accumulations, cattle wastes and defecation along river banks contribute to pollution of the waterways, particularly during monsoon season. These materials contribute greatly to unhealthy conditions and a lower quality of life.

Sludge deposits from years of sewage bypassing and direct discharge of wastes reside in the Varuna river especially in its lower reaches and at its confluence with the Ganga.

Description and Assessment of Sanitation System

The sanitation system of Varanasi consists of the following components:

- Four wastewater treatment facilities, although one of these--Dinapur--accounts for the great bulk of treatment capacity
- A main sewage pumping station
- A main brick sewer from Assi to Rajghat
- 315 kilometers of sanitary sewers
- A storm drainage system
- Six ghat pumping stations

The four wastewater treatment facilities are the Dinapur Sewage Treatment Plant (STP), the Bhagwanpur BHU STP, the Diesel Locomotive Works (DLW) STP. and the Ramnagar Sewage Farm. The first three facilities discharge to the left bank of the Ganga (facing downstream), and the last to the right bank.

The Ganga Action Plan Phase One constructed two of the principal components of the sanitation system--the Dinapur Sewage Treatment Plant and the Konia Pumping Station. Two distinct versions of the operation of this pumping station and plant exist.

One version is that of the state water/sanitation company that contracted the construction of these facilities and operates them. Very broadly, Jal Nigam's view is that these facilities are performing largely as designed.

The other perspective is that of an environmental/cultural NGO closely linked to one of the main temples along the Ganges, the Sankat Mochan Foundation (SMF). The view of SMF--which has a well-equipped laboratory and three local professors of chemical and civil engineering as key members--is that these facilities are highly flawed in design and construction, and performing poorly.

This consultancy visited and conducted an observational tour of both these facilities accompanied by Jal Nigam staff. We summarize our observations below, and contrast and compare the perspectives of Jal Nigam and the Sankat Mochan Foundation as useful.

This assessment starts with the sewage treatment plants and works back along the path of sewage flow to examine the Konia Pumping Station, the Special Manhole, the main trunk sewer lines, the sewage collection system, and storm drains.

Sewage Treatment Plants. The Dinapur STP is an 80 MLD activated sludge plant constructed under Phase I of the GAP and commissioned along with other works by the end of 1992. One of these is that of This consultancy visited the plant for a two-hour observational tour conducted by plant staff.

The plant was recording an influent flow rate of around 140 MLD at the time of this consultancy's visit at 8:00 AM on June 4, 1995. Plant staff stated that the average daily flow at present is about 100 MLD or 25 percent above design and that the Konia Pumping Station pumps as much as 180 Millions Liters Per Day (MLD) at peak flow periods. Daily plant influent flow records show an average of 85 MLD for the month of April. The plant contains the following process units:

- Hand cleaned screens
- Primary sedimentation basins with circular scrapers and skimming devices
- Roughing trickling filters with rotary distributors
- Aeration basins with mechanical surface aerators
- Secondary or final sedimentation basins (clarifiers)
- Sludge pumping for primary, waste activated and return sludge
- Sludge digesters
- Dual fuel electrical generators
- Open sludge drying beds for digested sludge

These units appeared to be functioning during the visit of the team. Incoming sewage appeared fresh, i.e. not septic. However, bubbling in the primary sedimentation basins indicated undesirable anaerobic conditions in the sludge lying on the bottom. Similarly, septic conditions appeared to exist in the secondary clarifiers, which adversely affects effluent quality. No floating or rising sludge was noted in the final clarifiers. However, staff noted that sewage remains in these final clarifiers for 3.95 hour. This detention time is far too long for activated sludge, especially in Varanasi's hot climate, and contributes to raising BOD levels. The stated operating parameters for the aeration basins were within normal ranges.

Plant staff normally operate one and one-half units of the four 400-kilowatt generators each day. According to staff, the plant digesters generate sufficient methane gas each day to operate one generator for 24 hours.[69] On a normal day, plant staff stated that this facility generates about two-thirds of its power requirement.

Of the total annual dried sludge production of 25,000 m3 about 18,000 m3 is sold, mostly to farmers, for a total of Rs. 150,000 (US $5,000). Income from the sale of undisinfected effluent is Rs. 25,000 (US $833) per year.[70] Thus, income from plant by-products is minuscule.

Wastewater must be pumped three times (including twice at Konia) in order to remove it from the Dinapur STP into a disposal channel. The sewage flowing out of Dinapur STP exhibited considerable foam in the open discharge channel, which leads via the Nagwa Nala to the Ganga. Effluent quality recorded by Jal Nigam for the plant ran between 12 and 30 mg/l BOD5 for the month of April (except for April 11 which had a concentration of 48 mg/l) with an overall removal efficiency of 85.5 percent.[71] This removal rate--if correct--would be satisfactory.

However, this level of BOD seems too high because of the constant overloading of the plant and the septic condition of the secondary clarifiers. On April 13, 1995--during the same month in which plant staff state that effluent quality ranged from 12 to 30 mg/l BOD5--the Swatcha Ganga Laboratory of the Sankat Mochan Foundation recorded a BOD5 concentration of 69 mg/l in the effluent. The difference between the measurements of the plant staff and those of the Sankat Mochan Foundation may be due to differences in sampling technique, refrigeration of samples, or other causes.

The Bhagwanpur BHU STP has a total capacity of 9.8 MLD and was not visited by this consultancy. This plant consists of an 8 MLD Upflow Anaerobic Sludge Blanket plant and an old 1.8 MLD trickling filter plant. In April 1995 the recorded average daily influent flow was 16.6 MLD. Despite this drastically overloaded condition, treatment reportedly removed 91.5 of BOD5, with the quality of effluent ranging between 8 and 12 mg/l. These results, too, are dubious. The plant site is flooded during monsoon rains. Hence, little or no treatment during this period occurs.

The Diesel Locomotive Works STP is also a UASB plant with a capacity of 12 MLD. It, too, is reported to be operating satisfactorily. Raw sewage enters this plant quite diluted, with

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[69] For a power demand above 210 kilowatts a fuel mixture of 90 percent gas to 10 percent diesel is used. Below 210 kilowatts all diesel is used.

[70] Tests are being performed by a fertilizer manufacturer regarding the possible use of sludge.

[71] Influent strength was between 110 and 260 mg/l during the same period.

a BOD5 concentration of 70 to 80 mg/l.[72] This description has not been confirmed.

Konia Pumping Station, Special Manhole, and Ghat Pumps. This consultancy visited the main sewage pumping station at Konia at 7:30 a.m. on a weekday morning during the height of the dry season (early June). This station was constructed under Ganga Action Plan (GAP) Phase-I and is located in the village of Konia in Cis-Varuna near Rajghat. In April 1995 records show an average total daily flow of 143.9 MLD of which 85.15 was pumped to Dinapur.

At the time of our visit, the flow meter registered 190 MLD. The Dinapur Sewage Treatment Plant--to which the Konia Pumping Stage pumps sewage--can only handle 100 to 150 MLD of this flow. Hence, a minimum of about 50 MLD of raw sewage was being diverted from Konia PS to the Varuna River at the time.

A special manhole diverts most of the flow in the 2438 mm (96 in) diameter main trunk sewer (which carries the bulk of city sewage) to the Konia pumping station. However Konia--as Dinapur--cannot handle all the flow of this main trunk sewer.[73] Hence, excess flows are bypassed from the manhole directly to the Ganga at Khirkia Ghat Nala.

The Konia pumping station has two stages of pumping. First-stage pumping is through three screw pumps each with a capacity of 100 MLD.[74] Two screw pumps were operating during the team's visit. One was on standby. Space exists for a fourth screw pump. After the screw pumps, flow passes through manually cleaned bar screens and grit chambers, which protect downstream equipment and processes.

Screened and degritted sewage then enters the sump of the second-stage pumping station. This second stage has three 65-MLD and three 35-MLD pumps.[75] These pumps send sewage through two force mains[76] 2.7 kilometers to the Dinapur STP. For normal operation one pump of each size is operated. During peak periods two of each type are operated. During the team's visit this station appeared to be operating as intended. However, excessive flows (reportedly 140 MLD at the time of the visit) were being sent to the Dinapur STP. The power requirement of the Konia pumping station is around 1600 Kilovolt Amperes (KVA).

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[72] Three MLD is diverted to the Ramnagar Sewage Farm on the right bank of the Ganga, however this sewage goes to the river directly when it is not required for irrigation of the sewage farm.

[73] In addition, the connecting sewer between the special manhole and Konia pumping station is flat which could, especially during low flow periods each day cause grit, debris and sludge to build up in the system.

[74] Of Dutch manufacture with 8.51 meter head.

[75] All at 18 meter head.

[76] One of 900 mm, the other of 1200 mm diameter.

The special manhole and the Konia pumping station are connected by a 2286 mm (90 in) diameter sewer laid to an essentially flat grade. The manhole has two gates to control flow diversion.

The Konia Pumping Station serves to pump sewage from the main trunk line to Dinapur Sewage Treatment Plant. In addition, six other pumps exist, which are located at the ghats. World Bank funding helped build these six ghat pumping stations and associated rising mains (force mains) in the 1970s. They seek to stop sewage flows carried in a variety of local drains from entering the ghat area of the Ganges, by pumping this wastewater up to the main trunk sewer. In April 1995, these stations were reported by Jal Nigam to be pumping the following average daily sewage flows:

- Tulsi Ghat — 6.08 MLD
- Harishchandra Ghat — 2.67 MLD
- Mansarovar Ghat — 3.21 MLD
- Rajendra Prasad Ghat — 14.14 MLD
- Jalasain Ghat — 1.66 MLD
- Trilochan Ghat — 3.11 MLD

Despite the existence of these pumping stations some dry weather discharges to Ganga in the ghat area were observed during a boat trip of this consultancy.

Main Trunk Sewers. The main trunk sewer--which feeds Konia--serving the Cis-Varuna area (the old city) was constructed in 1917 from Assi to Rajghat. Its size varies from 76 to 244 cm (30 to 96 in) diameter. It is made of brick. Several branch sewers designed to carry only domestic wastewater were connected to the main trunk sewer after its initial construction. Underground and surface drains for stormwater were also connected.

In 1987, the road near the trunk sewer caved in at several places. This subsidence raised concern about the life and strength of this sewer, as well as the other main trunk line--the Orderly Bazaar Trunk Sewer from the Trans-Varuna area. A team supported by technical assistance of Thames Water International and funded by Overseas Development Agency of the UK conducted a sewer assessment. This assessment included television inspection and a trial relining project of a 100-meter section of the Orderly Bazaar sewer.

Jal Nigam advocates Ferrocement relining of the main trunk sewer based on this trial project. In addition, however, the main trunk sewer lacks adequate capacity to handle peak flows. Thus, additional lines must relieve or replace this trunk sewer in order to provide adequate capacity for increased future flows.[77] Rehabilitation and relining of the main trunk sewer should be pursued in order to preserve it as a major asset.

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[77] Indian practice is to design such a sewer to flow half full at present peak flows which are taken to be two times the average daily dry weather flow rate.

Sewage Collection and Storm Drain Systems. The sewage collection system covers only about 60 percent of the population of the Cis-Varuna (the old city). Almost no sanitary sewer coverage exists in Trans Varuna. Much standing wastewater in residential areas and pollution of inland nulas, the Varuna river, and Ganga results. Sewers must be extended to these areas along with effective storm drainage to prevent these problems. As part of this work, the reconnection of the Orderly Bazaar sewer trunk line to the sewer system--rather than to the Varuna River--is essential.

Storm drainage compounds the sewer problems. Many built up areas have no proper stormwater drainage systems. The result is an acute waterlogging problem. Sanitary sewage and other wastes mix with the storm water because of system inadequacies. Considerable interconnection exists between the sanitary sewer system and the storm drains in the city.

As in Madras, the sewers and storm drains function largely as one system. Efforts should be made to rationalize this combined system rather than trying to separate sewers from storm drains--which has proved a futile, costly exercise elsewhere. Therefore, we suggest that existing storm drains connect to the relieved or replaced main trunk sewer in order to pick up all dry weather flows of sanitary sewage. Excessive storm flows could then be diverted to the waterways.

In sum, the sanitation system of Varanasi is problematic, and, as a result, largely causes ghat pollution problems.

The major difficulties are the following:

Uneven performance of Dinapur and Konia, insufficient protection for water quality along the ghats, and insufficient coverage. Considerable divergence exists on the performance of the existing sewage system, particularly Konia and Dinapur.

Viewed most hopefully, the shakedown of these facilities in the first two and a half years of their operation has proved problematic, particularly because Jal Nigam had no previous operating experience with similar facilities. For example, septic conditions appear to exist in its clarifiers, partly because of improper operation. The operation of a large activated sludge plant is a difficult task requiring high skill levels, particularly in a hot tropical climate such as that of Varanasi.

However, the evidence also indicates that serious flaws exist in the design of this system that better operation and maintenance, alone, would be unable to overcome. Raw sewage discharges from Konia, in particular, but also from Dinapur at other points in this system because of overloads.

Konia Pumping Station design flaws make this facility inefficient. Double pumping of all entering wastewater occurs at Konia, while sewage is pumped still one more time at Dinapur. This triple pumping escalates energy and operational costs of the system. Reportedly, the Konia screw pumps fail to pump efficiently and contribute to back-ups of the sewage system because of a wide range of design flaws.

All parties agree, however, that water quality along the ghats is poor, mainly because of pollution from wastewater. In addition, the sewer collection system covers only about 60 percent of the current population of the city and treats perhaps half of the amount of wastewater collected. These coverage problems will worsen as population and water supply expands.

High cost. GAP Phase I has sunk large sums into the Dinapur STP and the Konia Pumping Station.[78] Because this money has come in the form of grants, neither Jal Nigam nor the locality need repay it. However, the operational uneven performance of these facilities represent make the opportunity cost of this investment high. GAP Phase I was one of only perhaps two opportunities that Varanasi has to improve waterway quality in the foreseeable future. GAP Phase II--currently under consideration at the current level--is the other.

However, the operation and maintenance cost of these facilities is a burden for a relatively poor, modest-sized city such as Varanasi. The total annual O and M cost for the sanitation system is 3-4 crore (US $1-1.3 million). Roughly two-thirds of this total comes from Dinapur and Konia. Triple pumping and the high skill and operational requirements of activated sludge secondary treatment are the major causes.

Ganges River water backs up into the sewage system during monsoons. When the river stage is above an elevation of 64 meters (mean sea level datum) the river begins to back up into the sewage system--as far as 2 kilometers by some estimates--causing surcharging especially in low-lying areas. River stages exceed this 68 meter elevation roughly 10 percent of the year and can reach 74 meters.

Old and failing main trunk sewer. The main trunk sewer is known to be structurally questionable. Its collapse could create a disaster. The capacity of the existing main trunk sewer is known to be inadequate for current daily peak flows

Effect on Waterways Quality

The Swatcha Ganga Research Laboratory in Varanasi has conducted an ongoing series of analysis of water quality in the Ganga since 1992. This state-of-the-art laboratory is considered to be the best laboratory in the Varanasi area. It possesses a sterilized room for bacteriological tests, not available in any other laboratory in the region. Its dedicated, competent technicians appear to make proper use of the facility.

All information on water quality of the waterways in Varanasi relates to Ganga. To the

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[78] Dinapur and Konia account for the great bulk of the roughly US $50 million spent under GAP Phase I in Varanasi.

best of our knowledge no such information exists for the Varuna River or Assi Nala. Nevertheless, observation of septic conditions in these waterways indicates that their water quality is comparable to that of raw sewage. In fact, raw sewage discharges make up most, if not all, of the flow of both the Varuna and Assi Rivers during dry weather periods.

In contrast, ample data exists on water quality of the Ganges River, largely because of the Sankat Mochan Foundation laboratory (the Swatcha Ganga Lab). During 1994, the Swatcha Ganga Lab took more than 114 fecal coliform counts along the left bank of the Ganga (facing downstream)--that is, the side of the ghats. Results always indicated unsuitable water quality in the Ganga with counts generally ranging from 10,000 to 100 million per 100 ml. The Indian government has yet to set a standard for fecal coliform bacteria. However, pollution-control authorities elsewhere commonly consider fecal coliform counts above 1000 per 100 ml to indicate water quality unsuitable for bathing.

BOD5 concentrations ranged from an acceptable 1.3 mg/l at the pontoon bridge upstream from Varanasi to an average of 55 mg/l at Bhagwanpur, 70 mg/l at Nagwa nala. Most readings at the other ghats were at or above acceptable levels. In comparison, the standard fixed by the Government of India for BOD5 in a Class B waterway such as the Ganga is 3.0 mg/l or less.

Some points show extremely high levels of pollution. On April 13, 1995 samples taken in the vicinity of the Varuna's confluence with the Ganga showed the following:

- BOD5 — 22 to 36 mg/l
- Fecal Coliform count — 2.1 to 2.62 million per 100 ml

These BOD and bacteria count measures clearly show that wastewater of human origin is reaching the Ganga in great quantities and great strength. The Ganga is one of the great rivers of the world with a tremendous flow and still it is showing signs of deterioration at Varanasi.

Implications for an Action Program

Proposals by both the Swatcha Ganga campaign and Jal Nigam suggest considerable common ground for action toward improvement of the waterways in Varanasi:

- The actions taken under the Ganga Action Plan Phase I have failed to solve the key problem of water pollution at the ghats and in the Ganga at Varanasi. The investments in sanitation under the Ganga Action Plan Phase I have proved high in cost, problematic, and largely ineffective in reducing critical pollutant levels--particularly bacteria--in Ganga. Realistically, Varanasi cannot hope to treat fully and effectively more than a modest portion of this sewage in the near to medium-term, with conventional secondary treatment methods such as activated sludge.

- Despite the controversy and confrontation that has surrounded the Ganga Action Plan Phase I, broad agreement exists between Jal Nigam and the Sankat Mochan Foundation on the next steps for improving waterways quality and sanitation. Both organizations advocate expanding treatment and pumping capacity, rehabilitating and preserving the use of the existing main trunk sewer, a new relief trunk sewer or interceptor, sewering uncovered areas of the city, and extending sewage treatment to rapidly urbanizing areas outside the city.

- Formal organized training of wastewater treatment plant, pumping station, and collection system personnel should be conducted on a permanent basis.

5.4 Institutional Assessment

Many agencies and departments (at the central, state, and local level) affect the quality of water in the Ganges River at Varanasi. Their responsibilities often overlap and are in flux. Hence, waterways improvement in Varanasi presents a particularly complex institutional picture.

A brief overview of the many commissions, departments, and other entities serves as an essential preface for entering into more details. We discuss the central, state, and local bodies involved.

Phase One of the Ganga Action Plan has provided (directly and indirectly) the great bulk of funding used to upgrade the Varanasi sewage system. The Ganga Project Directorate--headquartered in New Delhi--administers these monies. Under GAP Phase I, GPD has selected various types of partners at the state and local level to work with, and channeled funding to these entities for capital projects.

A second central government entity exercises less influence. In principle, the Central Water Commission manages the quantity and quality of river water throughout India, including that of the Ganges. In practice, this organization does little more than measure the flow of the Ganges at Varanasi.

Two state organizations (Jal Nigam and Jal Sansthan) and the municipal corporation (Nagar Nigam Varanasi) are directly responsible for drinking water and sanitation.[79] In many cities (as discussed in section 2.1), the state water/sanitation Board (a "Jal Nigam") builds major projects, such as sewage treatment plants, typically through contracting them out. A local water/sanitation company (a Jal Sansthan) operates and maintains water and sanitation systems, including the sewage treatment plants.

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[79] Both Jal Nigam and Jal Sansthan are part of the Utter Pradesh (U.P.) Ministry of Urban Development.

In Varanasi, however, Jal Nigam has contracted out the construction of the Dinapur sewage treatment plant, but continues to operate it, and has yet to devolve O & M of Dinapur to Jal Sansthan. Varanasi's Jal Sansthan has also gone much further than the typical local water/sanitation company in construction of other major capital projects. The Jal Sansthan has had major responsibility for the capital improvements for upgrading the water treatment system. Jal Sansthan has also acquired sewage system maintenance equipment under the Ganga Action Project. Thus, Jal Nigam and Jal Sansthan compete for capital projects in Varanasi, and a certain rivalry exists between these organizations.

A local body--the municipal corporation of Varanasi--has most of the responsibility for operating and maintaining sanitary sewer lines. The Municipal Corporation also collects solid waste. Until local elections occur (currently scheduled for July but expected in October) as mandated by the Nagarpalika Act, an Administrator (from the Indian Administrative Service) appointed by the state runs the city. After the election, the Administrator is supposed to share power with the Corporators and the Mayor. Until the Mayor is elected, the Administrator also serves as the chairman of the Jal Sansthan.[80]

Regardless of the ostensible level of government, state government appointees or employees are in charge of virtually all non-central government entities in Varanasi, most of which are state agencies with local jurisdiction. Autonomous local government hardly exists in Varanasi. Its absence distances government from local people and decreases public accountability and responsiveness on issues, such as waterways quality.

The District Commissioner, a state government appointee from the Indian Administrative Service, holds the most power and has responsibility for coordinating state programs at the local level. In many ways, the Commissioner acts as a mayor does in many other countries. The Commissioner directly oversees five District Magistrates in the Varanasi area, one of whom has the responsibility for the city itself.

Other local decision-makers report to the Commissioner, including Jal Nigam, Jal Sansthan, and the Varanasi Development Authority, the District Magistrate, and the Local Government. State government appoints, employs, and/or pays all of these key people. Jal Nigam, Jal Sansthan, the Varanasi Development Authority are state government entities with local jurisdiction.

Election of mayors and corporators under the Nagarpalika Act is supposed to devolve power from state and central appointees to local authorities. However, these decision-makers and key local people in Varanasi--such as members of Sankat Mochan Foundation--have only a murky idea of this Act and expect no real change to occur. Broadening awareness of this Act's mandates in both Varanasi and at the state level of Uttar Pradesh (in Luchnow) is essential to increase its impact and the responsiveness of these public entities to local needs, such as

[80] The Mayor will serve as the chairman after elections.

improving waterways quality.

Jal Nigam

Headquartered in Luchnow, the Jal Nigam has several representatives in Varanasi, including the Superintending Engineer of the VII Circle, and the General Manager of the Ganga Pollution Control Unit. The primary responsibility of Jal Nigam is the planning and execution of drinking water and sanitation capital projects, such as the Dinapur sewage treatment plant (STP). They provide technical know-how to and execute projects for the Jal Sansthan.

Jal Nigam played several roles in the construction of the Dinapur STP. While the Ganga Project Directorate chose the contractor to build the facility, Jal Nigam advised the GPD on the tenders, oversaw the final contract and negotiated the price. Jal Nigam has operated the Dinapur since the plant's commissioning, in 1991. Previously, Jal Nigam had not operated an activated sludge plant. Some of the problems of Dinapur have arisen from this lack of experience.

Jal Nigam intends to continue to operate Dinapur until 1996. The plan is to have trained Jal Sansthan staff and to hand the operations over to Jal Sansthan at this point. However, the considerable operation and maintenance cost of this and other key facilities that must accompany it is a problem for the transition (see below).

The bulk of the funding that supports Jal Nigam comes from the Ganga Project Directorate. GAP funds currently pay for the operation and maintenance and administrative costs of the Dinapur treatment plant. In addition to receiving direct government funding, Jal Nigam charges fees on its projects to local governments: four percent of estimated costs for engineering and planning services, and fifteen percent for supervision of construction. However, as GAP Phase I winds down, so does Jal Nigam's main source of funding. This decline in GAP funding joined with the decentralization of authority from state to local governments intended by the Nagarpalika Act is likely to force Jal Nigam into a more entrepreneurial mode if the organization is to survive.

Indeed, Jal Nigam has embarked on efforts to expand and market its skills elsewhere. This organization has created a Construction and Design Services Unit to go outside of the state of Uttar Pradesh to supply services. Jal Nigam has also secured contracts with other departments within the Uttar Pradesh state government, including a project for the Tourist Department. At the moment, U.P. local governments must use the Jal Nigam for water and sanitation improvements since the bulk of funding comes from the state or central government via the state. However, U.P. local governments may have more choice in the future. For various reasons, the Jal Nigam of Uttar Pradesh--as other Jal Nigams in India--must increasingly compete to survive.

GAP Phase I has made Jal Nigam the major player in sanitation in Varanasi until now. However, the spinning off of key facilities to Jal Sansthan and decentralization under the Nagarpalika Act tend to make this local water/sanitation company the major player in the future.

Jal Sansthan

World Bank influence resulted in conversion of the Local Self Government Engineering Department of the state of Uttar Pradesh into two autonomous bodies--a state water/sanitation company (Jal Nigam) and eight local water/sanitation companies (Jal Sansthan) in the 1970s.[81] In principle, the Jal Nigam designs and contracts out the construction of capital works, and then delivers them for operation and maintenance to the Jal Sansthan.

However, the Jal Sansthan of Varanasi has increasingly taken over the function of the Jal Nigam. Jal Sansthan now designs and contracts out a major portion of new water and sanitation projects, as well as operates and maintains the drinking water system.

In practice, Jal Sansthan and Jal Nigam's responsibilities currently show considerable overlap. Both are involved in capital construction, and in operation and maintenance. A certain competition exists between these organizations. Water investments under a World Bank Uttar Pradesh Urban Development project are an example. Jal Sansthan was given major design and construction responsibilities under this project, including the construction of a new water tower, new pumps in the new water tower, a wet sump in the older tower, a new mechanical filter, a new reservoir for storing drinking water, a new pump house, and remodeling an existing settling tank. The project gave Jal Nigam the responsibility for constructing tubewells, overhead tanks, new drinking water mains, and modernizing pumping units. The two organizations share responsibility for setting up hand pumps.

With decentralization under the Nagarpalika Act, Jal Sansthan is likely to become more important and the major actor in water and sanitation and, hence, waterway quality in Varanasi. The transition to Jal Sansthan and greater local government control offers opportunities for going beyond the impasse that has characterized the current debate on sanitation and waterway quality. The cost of operating and maintaining the major investments in the sewage system is a key issue in the transition.

At present, Jal Nigam continues to operate and maintain the major components of the sewage treatment system. The cost of operation and maintenance is substantial, running roughly Rs. 3-4 crore per year (US $1 to $1.3 million); the O and M cost of Dinapur, Konia, and the rising main between them represents roughly two-thirds of this total. Jal Sansthan is being asked to take over this burden. Without this deficit, Jal Sansthan's finances show an operating surplus. Water charges, which have recently been raised substantially, and other fees more than cover the

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[81] The Varanasi Jal Sansthan is an independent and autonomous body, under the U.P. Ministry of Urban Development. There are five urban Jal Sansthan (one in each of the five Utter Pradesh cities with populations greater than 10 lacs), and three regional Jal Sansthan serving rural areas.

local water company's current costs (including O and M[82], interest charges, and a depreciation factor). However, fully taking over operation and maintenance costs of the sanitation system would throw this local water/sanitation company into a considerable operating deficit.

Hence, Jal Sansthan has an incentive to re-think the sanitation system. This organization is free from commitment to and responsibility for past practice and past technologies, such as secondary treatment of all effluent through activated sludge. Its management seems open to considering reform.

Varanasi District Commissioner and the District Magistrate

The Varanasi District Commissioner (VDC) oversees five districts (Varanasi, Vhadohi, Mirzapur, Sonebhadi, and Ghajipur). He has his office in Varanasi, along with the Varanasi District Magistrate. The Commissioner is the local representative of the state and the chief coordinating officer for state functions. He is expected to solve problems, coordinate programs, and oversee expenditures of state funds allocated to local governments, including central funding which goes through the state.

Both state and central government resources fall under the jurisdiction of the District Commissioner and Magistrate. The state allocates a certain portion of the state budget for local programs. The Magistrate, in turn, allocates these funds among departments. The District Commissioner is responsible for the local aspects of several central government funded programs, such as Integrated Rural Development, Employment and Antipoverty , and Health Programs.

While the Jal Sansthan and Jal Nigam do not report formally to the District Commissioner, the Commissioner is concerned with the administration of the water charges.[83] In addition, he has final approval on all policy decisions, such as water tariffs and staffing. Such requests are initially made by the Jal Sansthan Board and sent to the State Secretary. Upon approval at the state level, requests come to the Commissioner for final approval. As a result, the Commissioner has considerable influence on Jal Sansthan and Jal Nigam in practice.

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[82] Although Jal Sansthan reportedly does fully not pay its electrical bill, which saves considerable sums.

[83] In terms of the most pressing problems facing Varanasi, the District Commissioner listed the water supply deficit, sewage, and the problem of cattle waste. One problem with the water supply is the shortage of electricity. Two water wells are not functioning because the community cannot afford to connect them and pay the electricity charges.

When asked about the expected impact of changes under the Nagarpalika Act, the District Commissioner said that he did not expect to see many in terms of his role. While some of the functions of the municipal Administrator would be replaced by the elected Mayor, the Commissioner anticipated that both local bodies and local representatives of state bodies would continue to come to him for help in solving problems.

Varanasi Development Authority

The Varanasi Development Authority is another state-established agency with a local mandate. It was created in 1974, under the Urban Planning and Development Act. At that time a master plan was developed. The Development Authority has both regulatory and development responsibilities.

VDA has mainly developed housing. Since the old city is densely populated and its infrastructure overloaded, the master plan calls for decentralizing the population. The Development Authority has developed about 5,000 housing units in 3-4 major housing colonies and several smaller ones, the bulk of which lie outside the central city. This organization has also developed a number of commercial complexes. Using loans from such institutions as the World Bank and HUDCO, the Development Authority builds the infrastructure for these colonies, and sells both lots and housing.

VDA has taken little account of sewage treatment in both its development and regulatory functions. VDA lays and connects sewers to the municipal system in the city. However, the organization provides no sewage treatment to the outlying colonies that it develops. Plans exist, however, to build an independent sewage treatment plant for one of the larger colonies. The Development Authority, however, has no plans for handling the large amounts of sewage that will be generated by the development expected to occur up-stream from Varanasi south of the Assi River.

On the regulatory side, the Development Authority has the power to sanction building plans. In this way, VDA should be able to prevent inappropriate and illegal construction and control sewage. The organization's ultimate recourse is demolition, although this option is very rarely used. The major problem with enforcement seems to be notification. Illegal construction takes place "at night and on weekends" when no one will notice until "it is too late to stop the construction." In general, the ability of the Development Authority to control waterways pollution through the control of land use seems very weak.

Uttar Pradesh Pollution Control Board

The state Pollution Control Board (UPPCB) has a lab in Varanasi. Reportedly, however, this organization is not sampling for water quality on a regular basis. Apparently, the UPPCB lab depends heavily on Ganga Action Plan money, which is currently unavailable.

UPPCB has brought no serious lawsuits under the Water Pollution Control Act or other environmental legislation. Part of the problem is that "society has not accepted this act, and enforcement is considered to be harassment." Another part is the reluctance of one government agency to take enforcement action against another.

Varanasi Municipal Corporation (Nagar Nigam Varanasi)

The head of Nagar Nigam, the Municipal Administrator, is appointed by the state. The current appointee appears to be an able administrator and an excellent spokesman for his city. Elections under the Nagarpalika Act mandates elections of a mayor and city council ("corporators"), which the Administrator expects will occur by October of this year.

The Municipal Corporation of Varanasi is already intimately involved in sewage services. Nagar Nigam has responsibility for maintaining sewer and storm water collection lines throughout the city. In addition, Nagar Nigam has responsible for a wide range of other services, many of which are in the nature of public works: construction and maintenance of roads, solid waste collection and disposal, streetlighting, the electric crematorium, community toilets, slum upgrading, public health, parks and gardens, and the ghats.

Many of these responsibilities impact water quality. Perhaps foremost is solid waste. The Municipal Administrator considers solid waste one of Varanasi's biggest problems. As noted, garbage collection and disposal is extremely poor and chaotic. Another major concern is the cross contamination between the sewer and the water lines. Cattle are a third major problem in Nagar Nigam Varanasi. Not only does cattle waste end up in the sewer system, but people open up the manholes and deposit dead animal carcasses, as well as other garbage, in the sewers.[84]

While the Municipal Corporation has several sources of revenue[85], by far the major one is state government. Out of an annual budget of Rs. 16-17 crore, about 80 percent (Rs. 13.2 crore) comes from the state government.[86] The major local source of revenue is the property tax. Varanasi levies about Rs. three crore a year in property taxes and collects about 75 percent of that amount. A bigger problem than collection rate is assessed values. While property is supposed to be reassessed every five years, new assessments have not occurred in Varanasi in 20 years. Attempts to reassess were met with such wide-spread opposition that they were abandoned.

Thus, the Municipal Corporation is a key entity for reducing the vicious circle, caused by the interaction of many poor urban services that contributes to worsening waterways quality. Strengthening the Municipal Corporation requires a variety of reforms: increasing cost recovery through fiscal and administrative improvements, broadening awareness of the Nagarpalika Act to promote local autonomy and responsiveness of government to the electorate, and technical assistance and capital investments in specific services (municipal solid waste, drainage, managing

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[84] Improper use of municipally-provided services, and failure to act in a responsible manner, was a common theme in these discussions. For example, the street sweepers work early in the morning, presumably to be finished before the traffic gets heavy. When shopkeepers open up later in the morning, they sweep out their shops, just leaving the sweeping on the street. When asked to pick up the sweepings, their response is that they pay taxes to have the streets swept and so it is not their responsibility to pick up their sweepings.

[85] In addition to the property tax, sources of local income include rents on buildings owned by the municipality, license fees, and an advertisement tax.

[86] Of this, Rs. 1.2 crore are dedicated to road construction and repair.

cow manure and cattle yards).

Ganga Project Directorate

The Ganga Project Directorate (GPD) has controlled the expenditure of funds under the Ganga Action Plan I. GPD is part of an elaborate structure established ten years ago to clean up the Ganges River.

In 1985, the Government of India announced the creation of the Ganga Authority, headed by the Prime Minister. The eight-member authority includes the central government's planning and environmental ministers and the chief ministers of the three states through which the Ganges flows. As a first step in the process, the Central Pollution Control Board produced an *Action Plan for the Prevention of Pollution of the Ganga*, which was to serve as a guide for steps in the clean up. In addition to the Ganga Authority, the government established an inter-departmental steering committee to formulate detailed components of the Plan and to administer and monitor implementation of the Plan. The Ganga Project Directorate was set up in the Department of Environment to review and approve projects prepared by field-level agencies, release funds, and coordinate long-term activities under the Action Plan.

The Ganga Action Plan has been the source of most of the funding for recent sewage system improvements in Varanasi, including the construction of the Konia pumping station and the Dinapur Treatment Plant, laying of new and renovation of old sewers, and capping of nallahs/drains. According to Jal Nigam, GAP has resulted in 34 projects in Varanasi involving Rs. 46.26 crore (US $46 million).[87]

The Plan has come under severe criticism, both in Varanasi and in the courts, for failure to accomplish its objectives. In response to a lawsuit brought by Mr. M.C. Mehta, the Supreme Court has taken over control of Ganga Action Plan Phase II, and will directly approve all expenditures made under Phase II. The Court also ordered Mr. Mehta to work with the GPD to develop an approach to be used in Phase II.

Central Water Commission

The Central Water Commission (CWC) is another state agency with a local presence. The local office of the CWC is responsible for collecting hydrological and water quality data on the Ganga. Extensive water quality sampling is performed two to three times a year, covering 42 parameters, including metals, BOD, and fecal coliform. These data are compiled every year in

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[87] *Ganga Action Plan Phase I (A Review Note)*, Syed Hammad, General Manager, Ganga Pollution Prevention Unit, U.P. Jal Nigam, Varanasi, January 25, 1994.

the form of a Water Quality Yearbook for each river and major tributary. Unfortunately, the data on the Ganga is considered "classified" because of border disputes with Bangladesh.[88] Some hydrological data are collected at fixed points daily.

The local CWC office is also responsible for surface water resource planning. The local office does not do such planning, which is supposed to occur in Delhi. Thus, CWC ostensibly makes critical decisions affecting the flow of the Ganga and its self-cleaning capacity, such as the amount of withdrawal for irrigation. However, no local authorities or people interviewed for this study are aware of water resource management planning or that--if it occurs--waterways quality enters into decisions.

The River Management Division of CWC has been asked to look at the question of using an island downstream of Varanasi as a site for oxidation ponds. In particular, the question has been raised as to what flood protection might be needed and what would it cost. They are studying this and have yet to release their findings.

Non-Governmental Organizations (NGOs)

Several NGOs are concerned about the Ganga River. However, the only one focused on water quality is the Sankat Mochan Foundation (SMF). SMF started in 1982 as a catalytic organization to educate people about environmental problems and solutions.[89] It maintains close links to one of the main temples in Varanasi, the Sankat Mochan, and to Tulsi Ghat. The head of Sankat Mochan Foundation is also the spiritual leader of this 500-year old religious institution. He and the two other main participants in the organization are also engineering professors at Banaras Hindu University. The background of these participants in SMF has given the organization a strong technical grounding.

SMF's main focus has shifted towards analyzing sanitation options for Varanasi and advocating these options to various levels of government.

In January 1992, the Sankat Mochan Foundation held an international seminar on the pollution of Ganga waters. Swedish participants funded and helped set up a laboratory for monitoring Ganga water quality housed in SMF. As a result, SMF has a state-of-the-art laboratory and regularly monitors Ganges river water at various points along the ghat and at the mouths of the Assi and the Varuna rivers.

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[88] It may be possible to get this information directly from the Central Water Commission in Delhi: Central Director, Central Water Commission, Building Ceva Bhawani, R.K. Puram, Sector 2, New Delhi 110066.

[89] The name "Sankat Mochan" means liberation from troubles and hardships. The four objectives of the Sankat Mochan Foundation are to: 1) restore and preserve the Ganga by alleviating its fast deteriorating condition, 2) promote education and health care programs for the less privileged members of society, 3) to maintain and encourage the age-old cultural and religious traditions of Varanasi, and 4) popularize the literature of Goswami Tulsi Das.

In addition to regularly monitoring water quality, SMF has mounted a campaign criticizing the Ganga Action Plan I, in general, and Jal Nigam, in particular. SMF has developed alternative sewage collection and treatment proposals which they feel will be more successful in cleaning-up the Ganges.

Three other NGOs in Varanasi are concerned with the Ganges. One is the Ganga Improvement Society. It has a relatively limited scope of concern: keeping the bathing areas clean. Another NGO is called the Pilgrimage of Priests Association. This organization is interested in making the area pleasant for pilgrims by trying to keep people from washing clothes or defecating in the river. The newest group is called the Ganga Service Association. While it is similar to SMF, this organization has more interest in rituals.

Only the Sankat Mochan Foundation has the prestige and broad focus necessary to lead a campaign for waterways improvement. SMF and its members are a remarkable, sui generis group that has already made a critical contribution to saving the Ganges. The organization's experience has reverberated throughout India, and could serve, in some respects, as a model for other waterway improvement efforts. However, SMF's modus operandi has decided pros and cons, and the organization may have reached an impasse--at least temporarily--in making progress towards its goals.

Successful environmental improvement efforts typically have both a strong technical component and a strong educational/grassroots component (see Section 2.2 for greater details). The technical component focuses on the major sanitation investments--the "macro" projects--affecting waterways quality. The educational/grassroots component focuses on micro projects that complement the macro investments, but--more importantly--involve the community and, thus, generate the political will necessary for sustained reform.

Because of the background and interests of its key members--three engineering Professors--SMF has a very strong technical component. This forte has allowed SMF to become a player in decisions on the Ganga Action Plan Phase II.

However, SMF--as it operates currently--largely lacks an educational/grassroots component. The organization has no projects that involve large numbers of local people comparable to those of Exnora International in Madras, for example. The organization also has no staff and lacks members experienced in community organization and in working with government--the political side to environmental-reform equation.

The strong technical focus and weak educational/grassroots connections have contributed to creating a confrontation between SMF and some governmental agencies, notably Jal Nigam. SMF must move beyond this impasse to succeed at its main goal: cleaning the Ganges and improving water quality opposite the ghats.

Four strategies can help SMF re-orient its actions to move beyond the current impasse. First, the organization should undertake some micro projects, preferably that involve the community--the action program detailed in Section 5.5 describes a number of such projects.

Second, the organization must hire staff as part of undertaking these micro projects that has experience working with government and organizing the community.

Third, SMF must start developing working relationships with government entities and key public managers--such as the Municipal Corporation and its Administrator, the District Commissioner, and Jal Sansthan. The best way to nurture such relationships is through the operation of micro programs that help these public organizations and managers in some way. As noted, Jal Nigam--the focus of much of SMF's attention in the form of criticism--is likely to lose power and funding for projects in Varanasi, while some of these other organizations are likely to gain them. SMF should actively pursue good working relationships with these other organizations. SMF could learn from other NGOs such as Exnora International about how to establish relationships with government that go beyond demand-making.

Fourth and, perhaps, most important, in the long run, SMF should form alliances with other NGOs and help stimulate other organizations to participate in Ganges clean-up efforts and undertake related micro projects. In particular, SMF must seek to involve the other major religious organizations--the other ghats and temples--in cleaning up the Ganges. Varanasi and the temples--which are the core of the city's economic, cultural, and spiritual life--exist mainly because of the Ganges. The fouling of the ghats and the Ganges threatens both. Alone, SMF can, most likely, have only modest impact on the macro decisions that will determine waterways quality. However, a coalition consisting of the main religious organizations of Varanasi and other NGOs would have the power to play a major if not decisive role in these choices. SMF should seek to form such a coalition.

In addition, other NGOs may be more suited and have greater interest in taking on important micro projects than SMF. Community based primary garbage collection similar to that of Exnora International in Madras is an example. Varanasi badly needs such a program, both for waterways quality and improving living conditions. However, SMF appears to have little interest in starting one. Yet the prestige and technical capacity of SMF could be helpful to another NGO that undertook such a project. A coalition could coordinate the activities of SMF and other NGOs.

Implications for the Action Plan

- An NGO--the Sankat Mochan Foundation--has largely motivated Ganges and ghat clean-up. This organization has impressive technical capacity and a sophisticated water monitoring laboratory, which have allowed SMF to have some influence on macro investments. However, SMF largely lacks a public awareness and grassroots component necessary to generate the political will for continued waterways improvement. SMF should undertake micro improvements and hire a staff with experience in working with government to this end. SMF should also take the lead in forming an umbrella organization to involve other environmental NGOs and the many religious organizations of Varanasi in its mission.

- Jal Nigam has been the main player in sanitation in the recent past. However, decentralization under the Nagarpalika Act and the decrease of GAP funding promise to shift funding, power, and responsibility to local entities, including Jal Sansthan and the Municipal Corporation. The shift opens opportunities for reform and better performance in sanitation and other urban services affecting waterways quality. The Municipal Corporation is a key entity for reducing the vicious circle caused by the interaction of many poor urban services that contributes to polluting the Ganges.

5.5 Action Program for Waterways Improvement in Varanasi

Thus, five key findings emerge from this analysis with critical importance for improving waterways quality in Varanasi:

First, the water quality of the Ganges at the Ghats has special importance. Cleaning and improving this sacred bathing area has been an important goal of much planning and action in Varanasi, and of many of the improvements of Phase 1 of the Ganga Action Plan. However, these efforts have failed to solve the problem. The bacterial counts in the sacred bathing area remain very high, in the tens and hundred of thousands. Reducing them should be a first priority.

Second, sewage and sanitation is a key, but not the only key to improving the Ganges and the ghat area. In many respects, Varanasi faces difficult and critical challenges in sanitation. One key problem is that water supply is far outstripping the city's ability to handle the sewage that results. As of next year, Varanasi will be receiving a total of about 350 MLD in water and generating around 250 MLD in sewage. A second is that the investments in sanitation under the Ganga Action Plan Phase I have proved high cost, problematic, and largely ineffective in reducing critical pollutant levels--particularly bacteria--in Ganga.

Realistically, Varanasi cannot hope to treat fully and effectively more than a modest portion of this sewage in the near to medium-term future with conventional secondary treatment methods such as activated sludge. The main reason is the high capital and operation and maintenance costs of conventional biological systems and of sewering newly developing areas upstream near the Assi and in the Trans-Varuna area. A relatively poor city, Varanasi managed to afford the large sums necessary for construction of the current sewerage facilities--Dinapur Sewage Treatment Plant and the Konia Pumping Station--only because they came in grant form from the Ganga Action Plan Phase II. Even the operation and maintenance cost of these existing facilities is out of reach without outside help.

GAP Phase II represents the last opportunity for improving the ghats and Ganges River water quality for the foreseeable future. Rather than attempt to achieve secondary treatment through conventional means of another fraction of sewage at high, unsustainable cost, other approaches are necessary.

Third, in Varanasi as in most places, river water quality and urban environmental quality depend a great deal on public awareness. In some respects, the public in Varanasi is aware of environmental problem and to protect the Ganges from pollution. In other respects, much of the public believes that the problem is someone else's and does not act responsibly.

Many examples exist. Carcasses from slaughterhouses, cow dung from cattle yards, and other inappropriate materials are routinely disposed of in the sewer system. Garbage lies strewn throughout the city. People wash their clothes and textile businesses their newly-made saris and other items in the ghat area. The expectation exists that government will do everything.

Sankat Mochan Foundation and, if necessary, other NGOs must undertake micro projects that involve the public, too, in solving these problems. The Sankat Mochan Foundation has largely motivated Ganges and ghat clean-up. This organization has impressive technical capacity and a sophisticated water monitoring laboratory, which have allowed SMF to have some influence on macro investments. However, SMF largely lacks the public awareness and grassroots component necessary to generate the political will for continued waterways improvement. SMF should undertake micro improvements and hire a staff with experience in working with government to this end. SMF should also take the lead in forming an umbrella organization to involve other environmental NGOs and the many religious organizations of Varanasi in its mission.

Fourth, Jal Nigam has been the main player in sanitation in the recent past. However, decentralization under the Nagarpalika Act and the decrease of GAP funding promise to shift funding, power, and responsibility to local entities, including Jal Sansthan and the Municipal Corporation. The shift opens opportunities for reform and better performance in sanitation and other urban services affecting waterways quality. The Municipal Corporation is a key entity for reducing the vicious circle caused by the interaction of many poor urban services that contributes to polluting the Ganges.

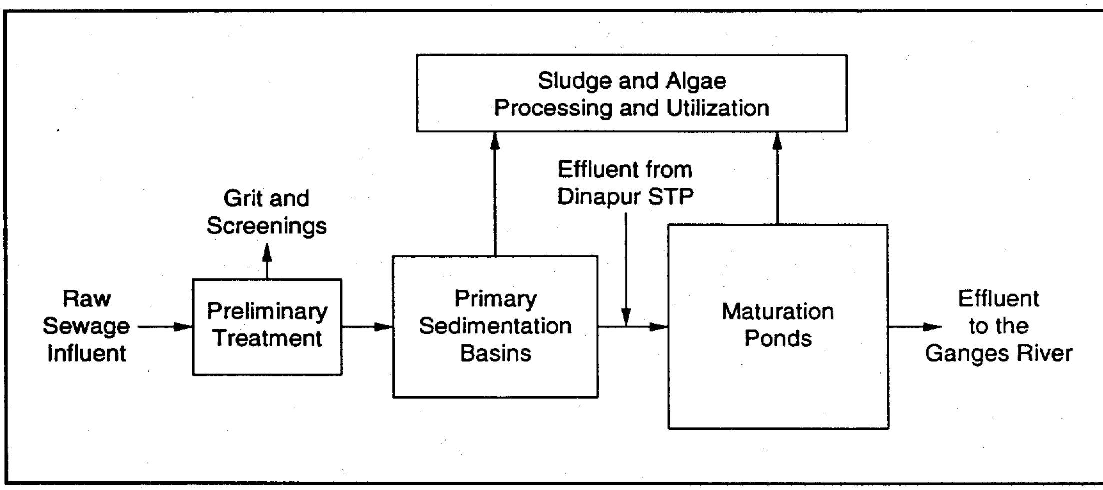
Fifth, despite the controversy and confrontation that has surrounded the Ganga Action Plan Phase I, broad agreement exists between Jal Nigam and the Sankat Mochan Foundation on the next steps for improving waterways quality and sanitation. Both organizations advocate expanding treatment and pumping capacity, rehabilitating and preserving the use of the existing main trunk sewer, a new relief trunk sewer or interceptor, sewering uncovered areas of the city, and extending sewage treatment to rapidly urbanizing areas outside the city.

As in any major city, commitment to a long-term vision, and heavy investments to correct these problems are necessary in Varanasi. The high cost of these investments may require staggering them over a number of stages. Hence, this action program proposes mainly a first stage in rehabilitating the Ganga consisting of macro and micro improvements. (Refer to Figure 5)

Macro Improvements

Table 7 presents the heavy investments for a first-stage action program for waterways improvement in Varanasi. The attached map illustrates the first-stage macro improvements.

Figure 5. Recommended process flow diagram for Varanasi sewage treatment



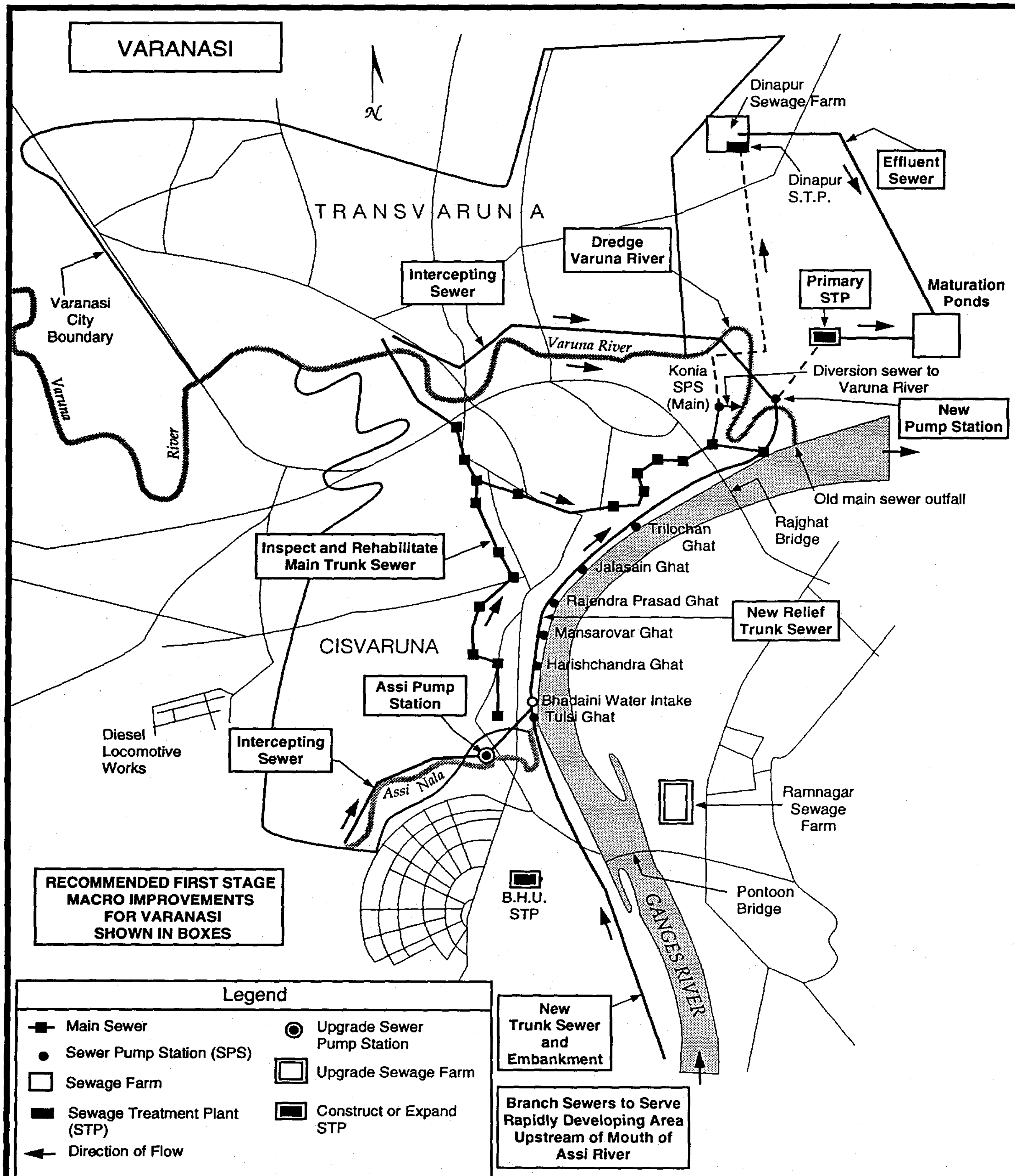

VARANASI
N
TRANSVARUNA
CISVARUNA
Dinapur Sewage Farm
Dinapur S.T.P.
Effluent Sewer
Dredge Varuna River
Intercepting Sewer
Primary STP
Maturation Ponds
Varanasi City Boundary
Varuna River
Varuna River
Konia SPS (Main)
Diversion sewer to Varuna River
New Pump Station
Old main sewer outfall
Rajghat Bridge
Trilochan Ghat
Jalasain Ghat
Rajendra Prasad Ghat
New Relief Trunk Sewer
Mansarovar Ghat
Inspect and Rehabilitate Main Trunk Sewer
Harishchandra Ghat
Bhadaini Water Intake
Tulsi Ghat
Assi Pump Station
Diesel Locomotive Works
Intercepting Sewer
Assi Nala
Ramnagar Sewage Farm
Pontoon Bridge
B.H.U. STP
GANGES RIVER
RECOMMENDED FIRST STAGE MACRO IMPROVEMENTS FOR VARANASI SHOWN IN BOXES
New Trunk Sewer and Embankment
Branch Sewers to Serve Rapidly Developing Area Upstream of Mouth of Assi River
Legend
Main Sewer
Sewer Pump Station (SPS)
Sewage Farm
Sewage Treatment Plant (STP)
Direction of Flow
Upgrade Sewer Pump Station
Upgrade Sewage Farm
Construct or Expand STP

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Table 7
First-Stage Macro Improvements for Varanasi
(Millions of US Dollars)

Improvement		Annual O and M Cost	Capital Cost
1.	Construct primary treatment plant for 100 mld • Located at Dinapur or the Sota • Receive flow from new relief trunk sewer	1	20
2.	Construct maturation ponds for 200 mld • Simple oxidation ponds for disinfection • To receive flows from Dinapur STP and new primary STP • Land area required less than one square kilometer	0.25	5
3.	Inspect and rehabilitate existing main trunk sewer • Television inspection • Relining techniques	--	5
4.	Construct new relief trunk sewer ("interceptor") • 800 to 2,000 mm diameter • Length of 10 kilometers • Preferably located under ghats • Diversion structures required for storm flow	0.25	26
5.	Construct new pumping station • Near Mohana Village, Konia PS, or the Sota • Pump in parallel to existing Konia PS • Pump to new primary STP	0.5	4
6.	Construct force main to the new primary STP • Approximately one 750 mm diameter main • Four miles long	--	3
7.	Upgrade the BHU Assi pumping station	0.125	1

8.	Clean and repair branch sewers in Cis-Varuna • 100 kilometers	--	1
9.	Construct branch sewers in Cis-Varuna • 100 kilometers	0.125	20
10.	Construct trunk sewer, branch sewers, and embankment to serve areas south (upstream) of the Assi area • Interceptor 7 kilometers • Branch sewers 30 kilometers • Embankment 7 kilometers	0.25	 3 9 1
11.	Construct intercepting sewers • Along Varuna River, 5 kilometers • Along Assi Nullah, 3 kilometers	0.25	 13 3
12.	Dredge Lower Varuna River • At confluence with Ganga • Dispose of sludge	--	3
13.	Other minor technical improvements • Construct new STP with capacity of 3 mld at Ramnagar with disinfection • Expand BHU STP with disinfection • Expand DLW STP with disinfection • Construct electric crematorium at Rajghat • Animal carcass incineration facility	0.25	3
14.	Technical assistance for design, construction, O & M, and cost recovery • Institutional strengthening • Diagnostic studies • Feasibility studies and designs	--	5
15.	Program management unit • Monitor and control	--	5

- Costs, technology, quality control, scheduling, contracts

Total Annual Operation and Maintenance in Millions US	3	
Total Capital Cost in Millions US		130

Taking each of these macro improvements in turn:

Construct primary treatment plant for 100 mld. This primary treatment plant receives flow from a new relief trunk sewer (of "interceptor")--see below. The capital and operation and maintenance cost of primary treatment is roughly one half of that of secondary treatment of the same flow.

Construct maturation ponds for 200 mld. Currently, the lack of separate disinfection of the Dinapur STP contributes importantly to high bacterial counts in parts of the Ganges along Varanasi. These maturation ponds remedy this problem, by disinfecting sewage already processed by Dinapur STP. The maturation ponds also disinfect sewage from the new primary STP. Simple oxidation ponds rather than Advanced Integrated Pond System are recommended, largely because they require much less land, well complement the primary treatment facility, and are suitable for further processing the effluent from Dinapur.

Inspect and rehabilitate existing main trunk sewer. Television inspection should diagnose the condition of the old trunk sewer line in order to determine the parts to reline.

Construct new relief trunk sewer. A new relief trunk sewer must supplement the existing one in order to: (1) provide additional flow capacity for increased sewage loads; (2) allow rehabilitation of the existing trunk sewer; (3) provide redundancy for trunk sewage flows, i.e. the new and old trunk sewers can back each other up; and (4) intercept flows that currently pollute the ghats and carry them ten kilometers downstream of the ghats for treatment before disposal. The new interceptor should preferably lie under the ghats.

Construct new pumping station. Greater sewage flows and more sewage treatment requires more pumping capacity. A new pumping station is necessary to lift sewage to the new primary treatment plant. It best pumps in parallel to the existing Konia Pumping Station.

Construct force main to the new primary sewage treatment plant. This force mainly connects the new pumping station with the new sewer plant.

Upgrade the Banaras Hindu University Assi pumping station. The new development occurring south of the Assi River requires much more sewage pumping capacity, along with more treatment (see below).

Clean and repair branch sewers in Cis-Varuna. The sewers of the old city date from decades to hundreds of years ago. Cleaning and repair of selected parts (100 kilometers) of this system can greatly increase its capacity and efficiency.

Construct trunk sewer, branch sewers, and embankment to serve areas south (upstream) of the Assi area. In addition to more sewage treatment, this fast growing area requires considerable expansion of trunk and branch sewers to stop direct discharge of raw sewage into the Ganges directly upstream of the ghats. The embankment serves to house the interceptor as well as prevent flooding.

Construct intercepting sewers along Varuna River and Assi Nullah. Currently, much direct discharge of raw sewage into these waterways make them, essentially, part of the sanitation system. This raw sewage flows directly into the Ganges. Septic conditions exist at the confluence of these waterways with this larger river. Interceptors along the most polluting stretches of these waterways can start to rehabilitate them.

Dredge lower Varuna River. Past pollution has left a thick layer of sludge on the bottom of the Varuna--particularly near its confluence with the Ganges--that would continue to cause pollution even when current discharges decline. Hence, dredging should remove the worst of this build up.

Other minor technical improvements. Other, more minor improvements include: (1) constructing a new STP with capacity of 3 MLD at Ramnagar to help serve this fast developing area; (2) expanding the Banaras Hindu University STP from 9.8 MLD to 15 MLD; (3) expanding the Diesel Locomotive Works from 12 MLD to 18 MLD; (4) constructing an electric crematorium at Rajghat to cut down on pollution of the ghat area by ritual cadaver disposal; and (5) constructing an animal caracas incineration facility, to reduce the common practice of disposal in the Ganges.

Technical assistance for design, construction, O and M, and cost recovery. The track record of sanitation improvements in Varanasi is not good. Dinapur and Konia, in particular, have serious design and implementation flaws. In addition, cost recovery is still minuscule in Varanasi. Technical assistance in a wide range of areas must orient these heavy investments in order to avoid wasting large sums of money.

Program management unit. These units houses much of the technical assistance and manages costs, technology, quality of construction and O and M, construction scheduling, and contracting.

Total Cost. The total cost, US $130 million, represents about $130 per person for the population of Varanasi. In contrast, major US cities often spend $1,500-2,000 per capita for major sewerage improvements. Although low in relative terms, this amount is high in absolute terms for a low-income city such as Varanasi. The substantial grants under the Ganga Action Plan Phase I indicate that ghat area and the Ganges, generally, represents a public good for India. Hence, Ganga Action Plan Phase 2 may well provide the bulk of this funding.

The operation and maintenance cost of US $3 million is just as crucial and may be more difficult to raise. Most likely, Varanasi will end with at least part of the responsibility for this sum. When finances are tight, O and M customarily gets cut. However, maintaining these facilities in good working order is just as important to water quality as their initial construction.

Micro Improvements

The macro improvements are the key technical solutions to turning around the sewage and sanitation problem and, thus, impacting river water quality. However, by themselves, they are insufficient, mainly because they do not involve local people and, thus, do not generate the financial support and political will necessary for success.

The micro improvements serve this crucial role. They also have the advantage of immediately and, sometimes, dramatically benefitting the living conditions of local people. NGOs--such as the Sankat Mochan Foundation--are key entities in undertaking and assisting government in these micro improvements.

Demonstration garbage collection project. Before the garbage collection program of Exnora International, Madras bore some similarities to Varanasi now. Garbage was strewn throughout the city. Now, largely because of this program, Madras is one of the cleaner cities in India.

An environmental NGO in Varanasi--either Sankat Mochan Foundation or another--could operate this program, much as Exnora International does in Madras.[90]

Exnora International notes that the key to success is as much the self-reliant philosophy of this program as the mechanics. The community must act for itself, without any government assistance.

Exnora International has ample experience setting up this program outside Madras in other areas of Tamil Nadu and India, and could be contacted to assist the set-up of such a program in Varanasi.

The cost of starting this program in Varanasi is Rp. 200,00 for the first year, and Rs. 35,000 each of the four years thereafter--for a total cost of Rs. 340,000 (US $11,350) for five years.

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[90] The environmental NGO organizes block of 80 to 100 households into local clubs. Each household pays 15 to 20 rupees per month to hire what they call one "street beautifier", who receive about 700-1,000 rupees per month total. The NGO approaches local businesses, religious institutions, and better-off individuals to pay to equip these street beautifiers with a three-wheeled bicycle cart. The street beautifier picks up garbage from the households with a three-wheeled bicycle to deposits this garbage in at a pick-up point from which the municipality removes the garbage to a dump site outside the city.

Table 8
First-Stage Micro Improvements for Varanasi
(US Dollars)

1.	Demonstration garbage collection project	11,350
2.	Demonstration cattle waste and animal carcass project	10,000
3.	Ghat environmental education program	11,700
4.	Industrial pollution monitoring and education project	25,000
5.	Form an environmental NGO umbrella organization	8,350
6.	Assist government agencies in key aspects of project implementation when appropriate	8,350
7.	Survey health-care providers, households, and industrial users of water	10,000
Total Five-Year Cost in U.S. Dollars		$84,750

Demonstration cattle waste and animal carcass project. Varanasi--as many Indian cities--has a cattle problem. Cattle waste has very high BOD--one cow produces the BOD of 12 to 15 humans--and it is highly fibrous. These characteristics strain the efficiency of sewer systems and, hence, contribute to river pollution.

Slaughterhouses in Varanasi also often dispose of animal carcasses in the sewer.

A pilot project could demonstrate how a cattle yard can be organized properly so as not to challenge the sewer system. Part of this project involves using cattle waste to produce methane for household cooking and lighting. Part would demonstrate how the slurry can be used and/or sold as fertilizer.

This project might also have a component that included the cremation of animal carcasses and other alternatives to their disposal in the sewer system. The five-year cost of such a project is estimated at Rs. 300,000 (US $10,000).

Ghat Environmental Education Program. Sixty thousand people bathe daily, on average, along the ghats, including many pilgrims. NGOs could undertake a program to orient new arrivals, as well as teaching existing residents on non-polluting use of the ghats and river area. Soon, many of the boats that are on the river are likely to have motors, causing noise pollution as well as discharge oil and gas. However, these motors allow the boat owners to increase their income substantially. Banning them is not possible. However, a code of conduct and official norms should be established for use of the banks and river near the ghat area. Enforcement of such rules represents a challenge. Here, NGOs may be in a particularly good position to influence ghat users. But river guards and penalties also have a role to play.

This project involves exhibitions, audio-visual presentations, and distribution of literature. Its cost is estimated at Rs. 350,000 (US $11,700) for five years, consisting of Rs. 150,000 for the first year, and Rs. 50,000 thereafter.

Industrial pollution monitoring and education project. Currently, industries contribute relatively little to the pollution of the river and ghat area at Varanasi. As the city grows, however, industries---particularly small ones such as auto repair--are likely to grow rapidly. Toxic waste is very costly to clean up. The best strategy is prevention--which means starting now.

Sankat Mochan Foundation with its laboratory is in an excellent position to monitor industrial effluent and educate small industries about alternatives to simply dumping by-products into sewers and waterways. This project involves the acquisition of some new pollution monitoring equipment, a computer, and working with industrial polluters. Its cost for five years is estimated at Rs. 750,000 (US 25,000), consisting of Rs. 400,000 for start-up and equipment, and Rs. 87,500 for each subsequent year of operation.

Form an environmental NGO umbrella organization. These micro projects are too numerous for any one NGO or organization to conduct. A number of environmental NGOs, however, already exist in Varanasi. In addition, Sankat Mochan Foundation should approach the other religious organizations in Varanasi to participate under this umbrella NGO in the ghat and Ganges clean-up activities. Formation of an umbrella organization that speaks for these NGOs as a whole and helps coordinate their activities could greatly increase their influence on government at all levels and play a decisive role in decisions for Varanasi under Phase II of the Ganga Action Plan Phase.

Assist government agencies in key aspects of project implementation when appropriate. In other areas, NGOs have played a key role in assisting government agencies in projects related to the urban environment and river quality. One critical area is using key pieces of land. Sanitation and solid waste facilities have the reputation of being dirty and neighborhoods strongly resist these facilities. The Not-in-My-Back-Yard syndrome, as it is called in the US, is a key problem for siting pumping stations and other critical facilities. NGOs can intercede with local people when such facilities are necessary to support government and make a big difference.

This principle extends in Varanasi to the key infrastructure improvements necessary to protect the ghats--the interceptor and maturation pond proposed here. The interceptor is certain to cause substantial disruption to city life. Acquiring the land for a maturation pond is one of the major problem of implementing such a facility. NGOs--such as the Sankat Mochan Foundation--can play a critical role in assisting government in these tasks. Indeed, the government may find these tasks difficult to almost impossible without strong NGO and popular support.

Survey health-care providers, households, and industrial users of water. Three surveys could gather critical information on waterways pollution and the health effects useful. A survey of health-care providers could collect information on water-borne disease. Sankat Mochan has already started this activity in conjunction with a monthly clinic held in villages along the Dinapur effluent channel. This initial work shows a large share of patients suffering from water-borne disease. This initial effort should be expanded to include the number of days of illness and other information. Similar data could be collected by a household survey. Finally, a survey of industrial users of water collects data on their water needs and the cost of getting water to their plants and treating it. Based on these three surveys, SMF could roughly quantify the costs of water pollution.

Total Cost of Micro Projects. The total cost of the micro improvements for a five-year period is $84,750. Relative to that of the macro improvements (US $130 million), this expense is minuscule. However, these micro improvements are no less important in the process of waterways improvement, because they can generate the public involvement, political will, and leadership necessary for positive change. Thus, these micro improvements represent a highly cost-effective means for cleaning Varanasi's waterways.

Conclusion

Decision-makers, religious pilgrims, and the residents of Varanasi agree that the ghat area of the Ganges River, in particular, should be clean. This vision drives waterways improvement in this city. The action program that achieves this vision cost effectively--through building a new primary plant rather than an activated secondary treatment plant, intercepting sewage before it enters the ghat area and selected stretches of the Varuna and Assi Rivers, and conveying this sewage downstream for further treatment in maturation ponds before disposal. A series of micro improvements complement these macro improvements and can help motivate the long-term commitment necessary for clean up.

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