Provision of Municipal Infrastructure through Demand Management

Guidebook and Case Studies

1999

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Cette publication est aussi disponible en français sous le titre : *Rapport d'une infrastructure municipale par un guide et des études de cas sur la régulation de la demande,* PF0353

Canadian Cataloging in Publication Data

Main entry under title:

Provision of municipal infrastructure through demand management: guidebook and case studies

Issued also in French under title: Rapport d'une infrastructure municipale par un guide et des études de cas sur la régulation de la demande.

ISBN 0-660-17918-0
Cat. no. NH15-335/1999E

1. Municipal services – Canada
2. Water-supply – Canada
3. Sewage disposal – Canada
4. Demand (Economic theory)
I. CH2M Gore & Storrie Limited
II. Canada Mortgage and Housing Corporation

HD4465.C3P76 1999 339.4'836361'0971 C99-980416-2

Printed in Canada
Produced by CMHC

PREFACE

An adequate, efficient and well-maintained municipal infrastructure is one of the key components of a viable, prosperous economy, and a significant determinant of quality of life. As competition for scarce resources at all levels of government increases, infrastructure upgrades and expansion are becoming increasingly difficult to finance.

This paper is the second in a series of three Canada Mortgage and Housing Corporation (CMHC) studies looking at infrastructure finance. The first paper in this series looks at infrastructure finance more generally, the challenges confronting municipalities and different financing methods. The third paper explores the potential for public-private partnerships to fund the provision, operation and maintenance of municipal infrastructure. This paper looks at the ability of demand management (DM) measures to contribute to meeting future water and wastewater infrastructure demands.

Paper #1	Alternative Methods of Financing Municipal Infrastructure
Paper #2	Provision of Municipal Infrastructure Through Demand Management: Guidebook and Case Studies
Paper #3	Public-Private Partnerships in Municipal Infrastructure

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PART I

GUIDEBOOK

1 INTRODUCTION

Demand management (DM) deviates from traditional water and wastewater system planning by focussing on what causes the demand for water and wastewater services. DM looks at why peaks occur and how to reduce them. The approach focusses on shaping demand, as a precursor to meeting demand.

Part I of this report (the Guidebook) introduces DM, describes DM techniques and identifies how to tailor DM programs to the needs and goals of specific communities. It introduces tools that can be used by planners, engineers and administrators to reduce water use and wastewater flow, including the reduction of systems losses due to leaks and the reduction of wastewater flow due to inflow and infiltration. The Guidebook then discusses the engineering considerations of water and wastewater conveyance and treatment systems which assist in ensuring that public health and the environment are protected. The goal is to provide a balanced perspective of DM considering risks, effectiveness and costs. While DM is not identified as a panacea, it has a role and this role is identified.

Part II of the report (the Case Studies) profiles DM initiatives in the following communities:

- City of Barrie, Ontario;
- City of Edmonton, Alberta;
- Greater Vancouver Regional District, British Columbia;
- Communauté Urbaine de l'Outaouais, Quebec;
- Regional Municipality of Ottawa-Carleton, Ontario;
- Town of Port Elgin, Ontario;
- City of Regina, Saskatchewan;
- Regional Municipality of Waterloo, Ontario; and
- City of Windsor, Ontario.

It is hoped that the Guidebook and Case Studies will encourage readers to further explore DM opportunities for their communities. Resources and references are identified throughout to assist those interested in pursuing this topic.

2 THE STATE OF WATER AND WASTEWATER SERVICES IN CANADA: WHERE WE'VE BEEN AND WHERE WE'RE GOING

Approval standards for treatment plants and conveyance systems moved from being almost non-existent in the 1930s and 1940s to departments of health setting modest standards in the 1950s and 1960s. The 1970s saw the imposition of elaborate design guidelines by provincial ministries of environment (or other agencies of the Crown) that prescribed minimal acceptable standards to all municipalities. Recently, some provinces have started putting the responsibility for developing area-specific standards and guaranteeing that these standards are met back on the design engineer and municipality. This provides some opportunity to customize the approach to the community to account for variables including:

- raw water quality—river, lake, groundwater;
- wastewater composition—strong, weak;
- distribution system, topography;
- sewage collection system—combined, separated, mixture;
- seasonal variations in water demand and wastewater flow;
- leakage from water mains, unaccounted-for losses;
- infiltration/inflow into the sewer system;
- receiving stream requirements, nitrification, phosphorus limits; and
- age of the system (Powell and Goodings, 1990).

Not only have approval requirements changed, but construction materials and practices have as well. The original and universally used pipe for water mains before the 1950s was cast iron with leaded joints. While these pipes offered good reliability, asbestos cement (AC) pipe and ductile iron pipe later replaced cast iron as the materials of choice in some communities, depending on ease of use, availability and cost. Joints were made of a variety of materials, ranging from mechanical joints and rubber gaskets to bell and spigot with O-ring gaskets. Corrosion was a problem in the post-cast iron systems, and leakage from the water mains was severe in places. The verdict on today's use of plastic for water mains and sewers is not in yet, but early indications are that plastic will provide a high degree of reliability.

In the 1950s, large-diameter sewers were made from concrete, with poorly fitting joints, and small pipes were made from vitrified clay, with hemp and mortar joints. In some communities, sewers were all combined (i.e., collecting both sanitary and stormwater flows). Some communities made footing drain connection to the sewer system mandatory, helping to flush the sewers and keep them clean. Ensuring dry basements and preventing basement flooding was a priority. When the wastewater was simply discharged untreated into a lake or river, the volume collected was of little relevance. The natural recuperation ability of rivers and lakes was relied on to assimilate the effluent.

Many municipalities constructed their first water treatment plants between 1930 and 1960, with most of the early wastewater treatment plants being constructed after 1950. However, as urbanization increased and treatment technology advanced, the number of treatment plants increased significantly. The early plants also needed upgrading to improve their performance to meet new standards.

The water and wastewater systems of the past served their purpose, but were designed for another day. Today, tough environmental and health standards, site inspections, tight sewers and water mains, use of corrosion-resistant materials, application of advanced treatment technology, leakage control and elimination of overflows and plant bypassing are considered essential. Some municipalities have worked hard to keep pace with these changes, while others need to catch up.

Bringing pipes and plants to today's standards will require considerable and ongoing effort, particularly in the older cities of Canada. On the other hand, growth areas need to provide additional capacity, and in these areas, the issue is how to capitalize new infrastructure most effectively (NRTEE, 1996). Some communities, such as Winnipeg, Vancouver and cities in the Maritimes that have managed with only the most basic water treatment facilities are now facing the need for major investments. Cities that developed without wastewater treatment facilities (e.g., Halifax, St. John's and Victoria) are now planning new facilities.

The need to improve our water and wastewater systems has serious financial implications. According to the National Round Table on the Environment and Economy, estimates of unmet water and wastewater infrastructure needs in Canada range from $38 billion to $49 billion (NRTEE, 1996). This is the cost of ensuring that existing capital stock and services are maintained. New capital demands for water and wastewater infrastructure will exceed $41 billion by the year 2015 (Peat Marwick, 1994). Over the next 20 years, the total capital requirements for environmental infrastructure in Canada are reported to be in the range of $79 billion to $90 billion (NRTEE, 1996).

While the financial burden associated with improving and expanding treatment capacity appears to be staggering, in reality water rates (in many parts of Canada) cover all water costs and largely cover sewage costs. User rates are the source of funds for improved system maintenance and better-performing systems. Generally, in municipalities where higher water rates are charged, systems are meeting today's high standards; where rates are low, system improvements are less feasible.

Many of us are only paying in the range of $200 per year for water and sewage services. Relative to other costs (for example cable television, telephone, electricity, car insurance and property taxes), water and sewer charges are extremely modest. Even with full cost recovery, these essential services provide health and environmental protection at a very reasonable cost.

Water and wastewater servicing in each community has been shaped by many different factors, and it is critical to understand these factors before determining how any given community's needs can best be met.

3 WHAT IS DEMAND MANAGEMENT?

While many "state of the infrastructure" reports paint a picture of overwhelming need to invest in infrastructure renewal, there is some expectation that recognition and management of water as an irreplaceable, valuable resource will help meet this need.

Demand management (DM)—the notion of shaping demand, rather than focussing solely on expanding supplies—may consist of reducing overall water consumption, minimizing peaking of water demand and sewage flow, reducing the loss or waste of water, and increasing the recycling of water so supply is conserved or made partially available for future or alternate uses. The ultimate goal of demand management is to reduce water demand or wastewater flow in terms of both average yearly and peak rates.

In many areas of North America, DM plans are not stand-alone efforts or left to individual development proposals, but are part of comprehensive water system plans. These plans involve consideration of supply and demand-side options. Financing of water systems and water rate analyses plays an important role in comprehensive water plans. This leads to considering conservation measures as legitimate sources of supply and allows direct comparison of the cost of conservation versus new supply. This is the essence of integrated resources planning.

Demand management can impact all areas of water use—residential, commercial, industrial, institutional and system use. Since the industrial/commercial/institutional (ICI) sectors often consume half the total water supplied by municipalities, there are some good opportunities for savings. While the focus of this report is on the residential sector, opportunities in the ICI sectors are also considered.

Overview of Demand Management Practices

A common theme throughout this report is the essential need to consider the unique circumstances and goals of individual communities. The DM measures described below offer options that may or may not be applicable depending on these local circumstances.

The following DM practices provide the greatest municipal (or utility manager) control and are referred to as utility-based DM measures:

- system efficiency programs such as water metering, leak detection and repair, and pressure reduction;
- regulation through by-laws and the plumbing code;
- and use planning mechanisms; and
- water/sewage pricing.

Other DM practices are referred to as consumer-based DM measures and depend on the cooperation of the public to a greater extent. These include:

- audits;
- plumbing retrofits;
- landscaping measures; and
- educational programs.

Table 3-1 provides a listing of the selected DM practices discussed below, reported ranges in water reduction achieved and cost information.

Utility-Based DM Measures

These measures are usually implemented on a system-wide basis by the water provider, typically the municipality. Strong political will is required to implement these initiatives, and public support

Table 3-1:
Select Demand Management Practices

Conservation Measure	Target Sector	Reported Ranges in Water Reduction	Cost Range (approx. 1993 dollars)	Comments
Home conservation kits	Residential	15% total supply[6] 10-17% per home[7] 10-40% per home[8] 5.5% per home[9] 5.3-13% per home[10] 22% per home[11] 18% per home[12]	$40-$50 per home[13] $15 per home[10] $125 per home[11] $25 per home[9]	Does not include low- or ultra-low-volume toilets
Home conservation retrofit	Residential High-density residential	33% per home[6] 25-30% per home[13] 30-50% per home[14] 35% per home[4] 30-40% per building[4]	$150-$400 per home[13] $150-$400 per home[13]	Includes low- or ultra-low-volume toilets Includes low- or ultra-low-volume toilets
Increased meter reading	Residential	ND	ND	Increased frequency of reading
Water recycling	Residential	30% per home[17]	ND	Impractical in most homes
Water reuse	Commercial	ND	ND	Golf courses Car washes Laundries
Municipal by-laws	Residential Residential	Impacts future demand potential Impacts future demand potential	No direct cost No direct cost	No load development agreements with developers Require the development of a conservation strategy as a prerequisite to building permit issue
Public education	System-wide Residential Industrial	2-5% during non-crisis period[22] 5-15%[14] 4-5%[1, 28] 5-10%[9] 9-16% L/CPD[18] ND	$1/person/year for large utility with aggressive program[22] ND ND	Very dependent on the type of program Generally used to support other initiatives
School programs	Institutional	ND	ND; generally low cost since materials are already available	

Table 3-1: *(Cont'd)*
Select Demand Management Practices

Conservation Measure	Target Sector	Reported Ranges in Water Reduction	Cost Range (approx. 1993 dollars)	Comments
Conservation rate structure	Residential	27%[4] 10%[4] 13%[4] 3-7%[19] 15-20%[10]	No direct cost	Data from Tampa, FL. Data from Tucson, AZ. Reduction represents % drop with a 10% increase in price Peak pricing strategy (70% increase) can involve various price strategies
Pressure reduction	Low-density residential High-density residential	1%[9] 3-6% per home[1] 12%[9]	ND $75 per home (1) ND	Results estimated for new developments From Edmonton, Canada study
Water audits	Residential Industrial (large) Ind./Comm./Inst.	180 L/d per home[20] 15-70% per facility[6] 10-51% per facility[20] 15-80% per facility[10]	$65 per home (20) $5,750 per facility (20) ND	From Everett, U.S. study Laundry facilities Car washes From Regional Municipality of Waterloo
Inventory of unmetered water usage	System-wide	ND	ND	Will allow for better estimation of effort required for leak detection and repair
Fixture meters/ timers	Residential	ND	$1 to $20	Meter/timer can be fixed to shower or other fixture to encourage user awareness
Fixture leakage repair	Residential and institutional	91 L/d per repaired toilet[30] 20% of homes have plumbing leaks[8], [30] The average toilet after six years of use, leaks between 27 and 455 L/day[8]	ND	
I/I control	Extraneous flow		ND	

Notes:
Bracketed numbers refer to reference number of source documents. ND refers to no data available at the time of review

1 Environment Canada, 1991.
2 Metro Toronto, 1991.
3 CH2M HILL Inc., 1992a.
4 Rocky Mountain Inst., 1991.
5 Gore and Storrie Ltd., 1993b.
6 Town of Cochrane, 1993.
7 World Watch Institute, 1993.
8 Environment Canada, 1991b.
9 City of Edmonton, 1991.
10 Regional Municipality of Waterloo, 1992a
11 City of Winnipeg, 1992.
12 California Department of Water Res., 1990.
13 REIC Ltd., 1993.
14 Regional Municipality of Waterloo, 1992b.
15 Regional Municipality of Waterloo, 1992c.
16 City of Vancouver, 1993.
17 Health and Welfare Canada, 1991.
18 CH2M HILL Inc., 1984.
19 CH2M HILL Inc., 1992b.
20 CH2M HILL, 1993a.
21 CH2M HILL Inc., 1993b.
22 AWWA, 1993.
23 CANVIRO Consultants, 1988.
24 Ministry of Environment et al., 1990.
25 Gore and Storrie, 1993c.
26 State of California, 1990.
27 CH2M HILL Engineering Ltd., 1994.
28 Maddaus, W.O., 1987a.
29 Braun Consulting Engineers, 1996.
30 Maddaus, W.O., 1987b.
31 Adapted from CH2M HILL Engineering Ltd., 1994.

is vital. Rate structures and metering provide incentives to reduce water demand and may provide the impetus to adopt more customer-based programs.

System efficiency programs

Water metering and water rates based on volume: Many customers are charged a flat rate for water. With flat-rate billing, everyone pays the same amount, regardless of consumption. Flat rates provide no financial incentive to conserve, whereas rates based on metered consumption provide consumers with pricing signals that encourage conservation, particularly when discretionary water use, such as irrigation, is concerned (see section on financial measures below). Sub-metering of apartments, condominiums and trailer homes can be used to bill tenants for the water they use rather than for a percentage of total water use for the complex. The Canadian Water and Wastewater Association has produced a guide to assist in analyzing the costs and benefits of installing meters titled Meters Made Easy (James F. Hickling Management Consultants, 1990).

Metering also helps quantify how much of total water demand is unaccounted for (i.e., not billable). As discussed in the section on leak detection and control, unaccounted-for water includes leakage of potable water from the system.

Pressure regulation: In some areas, pressure reduction is a feasible means of reducing the amount of water consumed and wastewater generated on an ongoing basis. Water pressure can be lowered by installing a pressure-reducing valve on the water mains leading to subdivisions. Some new developments may be designed to operate with 50 psi (345 kPa) instead of the more conventional 80 psi (550 kPa) to experience savings (Maddaus, 1987). In Quebec's Communauté Urbaine de l'Outaouais, average water demand is reported to have been reduced by 15 per cent through pressure reduction alone (see case study).

The feasibility of this measure must be assessed on a case-by-case basis, depending on topography, firefighting requirements, and the type and layout of buildings or facilities. It is particularly important to ensure that a decrease in water pressure does not create a potential health hazard, which could occur if pressure is reduced to the point where contaminants are drawn into the system through leaking water main joints and cross connections.

Leak detection and control in water systems: Leaks in water mains and laterals result in the loss of pumped and treated potable water. The problem occurs as pipes corrode with age. The extent of leakage depends on water and soil chemistry, original pipe quality and quality of construction. As pipes settle, they may crack or separate at the joints. Leakage reduction programs begin with inspections and leak detection to assess the need for, and cost of, repair. If justified, a system maintenance and rehabilitation program is initiated.

Leaks can be found by using sonic leak detection and by dividing the system into district meter areas to measure flow in discrete parts of the system. Areas of high leakage can be identified. This is followed by a series of step tests (Howard, 1997). Water pipes in poor condition are then relined or replaced, if they pass a cost–benefit analysis.

Based on a survey by the Ontario Sewer and Watermain Contractors Association, Ontario's water mains experience 25 breaks per 100 kilometres per year, costing $40 million in repairs and losing 40 per cent of purified water (CMHC, 1992). The American Water Works Association (AWWA) estimates that breaks in water mains occur at annual rates of up to one for about every six-kilometre length of pipe (Rutledge, 1989).

Some leakage in municipal water supply is inevitable. Leakage is a component of "unaccounted-for water," which includes authorized uses such as fire hydrant use, water main flushing and other system uses, as well as unauthorized uses such as illegal connections.

Unaccounted-for water also encompasses inaccurate water metering, which may translate into lost revenue to a utility. Physical losses (i.e., leakage) can account for approximately 70 per cent of a typical system's total unaccounted-for water (Howard, 1997).

While a typical figure for unaccounted-for water in newer systems is 10 per cent of total water production, older systems often have 20 per cent unaccounted-for water (AWWA, 1993). Generally, the level of water loss at which it becomes cost effective to detect and repair leaks is in the range of 10 to 15 per cent (CH2M HILL Engineering Ltd., 1994).

Inflow/infiltration control in sewer systems: Wastewater collection systems convey a certain amount of extraneous water that originates as stormwater (inflow) and groundwater (infiltration). Not only does this flow use up valuable wastewater treatment capacity, but it can cause surcharging of the sewers and overflows at the treatment plant which may impact receiving waters. Providing sufficient capacity to accommodate peak periods of inflow and infiltration can be a major factor in the sizing and operating efficiencies of collection systems and treatment plants.

Groundwater may enter the sewer system though defective pipes, open or cracked joints, and deteriorated inspection hole walls. Stormwater can enter through connected downspouts, inspection hole covers, area or yard drains, and catch basins (Stephl and Maciariello, 1993). Reduction in inflow and infiltration may be accomplished through sliplining, replacement, chemical grouting and point repairs, and inspection hole rehabilitation.

In Ontario, it is reported that typically 20 per cent of wastewater treatment capacity is required to treat inflow and infiltration water alone (Ministry of Natural Resources, 1992). Normally, infiltration is more difficult and expensive to control than inflow, as the pipeline defects can be below the groundwater table and the leakage is constant and more uniformly distributed.

Inflow and infiltration control can free up treatment plant and sewer capacity for growth and redevelopment, while delaying the need to construct costly treatment plants and collection systems. Many municipalities have by-laws to control downspout connections, road drainage and footing drain connections. The first two are the main sources of inflow and the latter is one of the main sources of infiltration. While disconnecting downspouts and road drainage from the sanitary sewer system is frequently undertaken through inspection programs, public cooperation and sewer separation projects, eliminating footing drain connections is more difficult. Some municipalities provide subsidies to homeowners with chronic basement flooding problems to assist them in disconnecting their footing drains. The subsidy covers the disconnection of footing drains and installation of a sump pump to redirect the groundwater to the ground surface or to storm sewers.

To appreciate the severity of leakage, it is helpful to know the age of water distribution and wastewater collection systems and the materials used. Systems that were not designed to be completely tight will need significant upgrading to reduce unaccounted-for water and inflow/infiltration. A commitment to doing it right the first time usually pays. Using high-quality materials, providing proper pipe bedding, minimizing drainage connections and maintaining a high standard of quality when new water mains and sewers are being installed will reduce the need for repairs or upgrades later on. Construction inspection and performance guarantees over time are essential to ensure that commitments made by developers or construction companies are adhered to.

Regulation

Regulatory measures to reduce the demand for water include:

- municipal by-laws;
- conditions on new development; and
- plumbing codes.

Municipal by-laws may be passed to restrict water consumption for lawn watering or car washing, prohibit once-through use of water for process equipment (including cooling water) in the ICI sectors, and other measures required to meet a community's objectives. Niagara Falls (Ontario), for example, passed a by-law requiring the installation of water-efficient fixtures in all developments requiring an inspection. While local plumbing codes improve water efficiency in new developments, with the Canadian housing stock growing only at a rate of about two per cent per year, it will take many decades before the existing stock is converted. Moreover, plumbing codes typically only regulate what plumbers install, not what is sold. As a result, there is no guarantee that "do-it-yourself" conversions will adhere to the higher standards. There is some consensus, however, that higher-flow fixtures will eventually disappear from the market due to diminished demand (Gore and Storrie, 1993a).

Some communities require new developments to be planned with water efficiency in mind. In some drought-prone areas in the United States, there are limits on the amount of turf area in new developments and guidelines on soil preparation to achieve effective water retention. The City of Toronto requires a water efficiency and conservation plan for all development proposals. The City of Barrie (Ontario) also requires all draft plans of subdivisions to incorporate water-efficiency measures. Municipalities may also ask that building permit applications be accompanied by water conservation plans and may make meter installation mandatory. Under certain circumstances, they can also limit new developments to those that conform to a no-load (no net increase in water demand) policy.

Land-use planning

Growth management plans, official plan policies and zoning by-laws help to identify the type, density and location of new housing developments. By extension, these planning tools can also be used to control the capital, operating and maintenance costs of water and wastewater infrastructure.

Table 3-2 provides a comparison of water and wastewater costs for different housing types. While the information is derived from an older study, it illustrates that servicing costs for single-family dwellings are significantly higher than for higher-density developments. These capital costs are normally built into the cost of housing, but the operating costs must be covered by user fees and property taxes.

Numerous other studies attest to the higher costs of sprawling, low-density developments. Intensification, or in-fill development is frequently promoted as a way of reducing these costs. If infrastructure components such as water mains or sewers have excess capacity, people can be added in existing urban areas at little or no extra cost. A prerequisite to intensification, however, is ensuring that buildings already connected to the systems are not negatively impacted (e.g., reduced water pressure, increased basement flooding, etc.).

In addition to reducing capital costs, it is generally recognized that the more compact and vertically dense the housing, the lower the water consumed at both the household and aggregate levels. This is primarily due to the fact that irrigation requirements for compact or multi-residential housing are substantially lower than for large-lot, single-family residences.
This is confirmed by a recent study of King County (Washington), which compared three categories of housing according to their mean water use during the summer period.

- Older homes of small urban grid lots averaging 611 m^2 (6,580 sq. ft.) were found to use 916 L/day of water per household, of which 242 L/day were for outdoor water use. (Neo-traditional developments, which are attracting a lot of attention in Canada, conform with this small urban grid style of housing).
- Suburban homes with lots about 1,515 m^2 (16,308 sq. ft.) used 1,268 L/day, of which 594 L/day were for outdoor use.

Table 3-2:
The Cost of Providing Water and Wastewater Services by Property Type and Density, 1973

	Single-Family Homes (1,000 Units)				Multi-Family Homes (1,000 units)				
					Townhouses	Walk-Up Apartments		High-Rise Apartments	
Units per acre	1	2	3	5	10	15	30	30	60
Annual Capital Costs ($)									
Water supply	707,794	360,372	240,939	163,500	109,336	80,455	45,619	53,278	31,469
Sanitary sewerage	243,017	130,075	91,926	66,699	48,710	35,953	29,084	28,295	22,510
Subtotal	950,811	490,447	332,865	230,199	158,046	116,408	74,703	81,573	55,979
Annual Operating Costs ($)									
Water supply	31,821	31,821	31,821	31,821	30,103	30,103	30,103	25,538	25,538
Sanitary sewerage	41,289	34,401	32,133	30,604	28,022	27,250	26,679	22,825	22,476
Subtotal	73,110	66,222	63,954	62,425	58,125	57,353	56,782	48,363	48,014
TOTAL (OP+CAP)	1,022,921	556,669	396,819	292,624	216,171	173,761	131,485	129,936	101,993
Annual cost per dwelling unit	1,023	557	397	293	216	174	132	130	102

Note:
Costs are in 1973 dollars.

Source:
See Downing and Gustely (1977) for more information.

- Estate housing, consisting of newer homes with lots averaging more than 0.6 ha (1.5 acres), had a mean water use of 2,661 L/day, of which fully 1,987 L/day were used for outdoor purposes (Sakrison, 1996).[1]

In this study, the number of people per household and average indoor water use (674 L/day) did not vary significantly by housing type. The difference in water demand was therefore attributed to the size of the irrigated area. The study concluded that increasing residential density lowers water consumption, particularly in the peak summer season. In the Seattle area, increasing the number of multi-family housing units and reducing single-family residences in new developments was projected to reduce total average projected water demand by as much as 35 per cent (Sakrison, 1996).

Across Canada, about 56 per cent of the housing stock is single detached. While studies show that this remains the preferred housing option—with 80 per cent of those surveyed in Montréal, Toronto and Vancouver preferring to live in detached houses (CMHC, 1993)—this may change in coming years as baby boomers age and their housing needs change.

Financial measures

Demand for water and wastewater flow can be reduced through water and sewer rates, surcharges and other market-based incentives. If rates are low, then the financial incentive to implement DM may not exist due to longer payback periods. Higher water rates reduce payback periods, in turn increasing the incentive for DM measures.

Part of the role of DM is to increase customer appreciation of the value of water by making its full costs known. The availability of full-cost data also helps the water provider compare cost avoidance (due to DM) to increasing the supply, and helps identify the conservation measures that are cost effective.

Water rates

When consumers pay less for water than it costs to supply, they are being sent an incorrect pricing signal which encourages higher consumption and increases the pressure to invest in additional supplies.

Communities charging the full costs of water generally have the money to invest in upgrades and expansions, while those that under-price water cannot make the investments required to maintain and improve their systems.

In many cases, municipalities with abundant water supplies subsidize water rates in order to attract industry and increase the tax base. Local circumstances must therefore be considered when evaluating the applicability of DM options and rate structures in particular. Rates may be influenced by how dependable the water supply is, whether total volume or peak use needs to be reduced, how much reduction is needed, what the current rate structure is and the impOrtance of revenue stability.

Rate structures

The primary objectives addressed in rate setting are:

- rate payer equity;
- financial stability;
- conservation pricing signals;
- resource management compatibility;
- affordability;
- customer understanding and acceptance;
- administrative simplicity; and
- overall reasonableness (Farnkopf, 1996).

These objectives must be weighed against one another since they sometimes conflict (i.e., financial stability versus the conservation pricing signal).

The most common rates used in Canada are flat rate, decreasing block rate, constant rate and increasing block rate. A recent rate survey in Ontario showed that 66 per cent of municipalities used a single rate (flat or constant), 25 per cent used decreasing block rate and nine per cent used increasing block rate (OWWA, 1997). The use of flat rates is definitely decreasing, as communities move toward full metering. Declining rates are also being replaced with more progressive rates. Seasonal rates or peak season surcharges are rare, but are occasionally used in municipalities unable to meet peak water demand. Through seasonal charges, municipalities discourage use when water supplies are low and the cost of meeting peak demand is high. Table 3-3 lists different water rate options.

Both Windsor, Ontario and Seattle, Washington, adopted summer rates to signal the higher cost of water provision during peak periods. In 1987, Windsor had two dry periods that caused spiking of water demand beyond the rate at which the reservoirs could be replenished. Watering bans had to be imposed. To avoid similar bans in the future, the utility implemented a summer levy and an educational program, which proved to be very effective. In 1991, when the area's worst drought in 20 years hit, the maximum day water use spike was low enough to avoid having to impose any water restrictions (Miller, 1997).

Water providers wishing to give a pricing signal, but not by using summer rates, can institute increasing block rates as an alternative. They can also impose a rate surcharge during drought periods. These surcharges are over and above a summer water rate or block rate structure, with an extreme rate hike imposed in the driest periods. A study of the effectiveness of conservation programs and the interactions with summer rates and rate surcharges found that all are effective in reducing demand. Moreover, while extreme measures imposed during droughts may only be temporary, there is evidence of a lasting effect. After Seattle used temporary drought-related surcharges, for example, system demands never returned to pre-drought levels (Sakrison, 1997). Similar persistent demand reductions have been reported in the eastern United States (Featherstone, 1998).

Table 3-3:
Water Rate Options

Fixed Charges (independent of flow)
Regularly billed charges
Flat charges for unmetered customers
Service charges based on meter size or capacity of service
Minimum charges (service charges including a flow allotment)
Standby or availability fees
Special device charges
Low-income/senior citizen discounts
One-time charges
Annexation fees
Development charges
Administrative fee
Office and field services
Variable Charges (dependent on flow)
Volume charges
Uniform (constant unit cost)
Multiple block
Decreasing (unit cost decreases as consumption increases)
Increasing (unit price increases with usage)
Humpbacked (increasing followed by decreasing)
Seasonal
Uniform (constant unit cost)
Increasing (base rate with summer surcharge)
Rate surcharges and discounts
"Feebates" (fee for use exceeds allotment/rebate for consumption below allotment)
Peak-demand charges
Excess use/penalty charges
Elevation or distance charges
Lifeline discounts
Sources: Farnkopf, 1996; Collinge, 1996.

Price elasticity

A statistical analysis of common water rate structures was completed to determine their influence on residential consumption. While conventional wisdom suggests that increasing block rate structures yields the greatest conservation, data from 85 communities in Massachusetts do not support this. Seventy-eight communities were analyzed, 20 with increasing block rates, 17 with decreasing block rates and 41 with flat rate structures. The study found that the type of rate structure had little impact on residential water demand, but the price charged for water had a great deal to do with how much water was consumed. The study concluded that utility managers should focus less on rate structures and more on pricing levels (Stevens et al., 1992).

The price charged for water can be determined based on price elasticity. Price elasticity is the ratio of the relative change in commodity use to the relative change in price. If water demand changes very little in response to price change, then the demand is considered to be inelastic. Many studies have confirmed the elasticity of water. Residential elasticities have been reported in a number of Ontario and U.S. locations. Peak demand has been reduced by 3.8 per cent to 7.3 per cent using appropriate price increases (Millard, 1984).

Pricing methods that encourage demand reduction generally require the use of meters. Informing users with a monthly bill that shows water consumption and costs for the current month and previous months, as well as projected consumption and costs if usage remains constant, provides the consumer with the information required to make informed decisions (Rubin, 1986).

Water revenues

While pricing water is an effective conservation strategy, its impact is difficult to predict. Some studies show that a 10 per cent increase in price results in a one to three per cent decrease in residential indoor water use and a two to four per cent decrease in outdoor use. Over time, savings decline as the effect of the price increase wears off (AWWA, 1993).

Revenue stability is a concern for municipalities and utilities considering volume-based rate structures as historical consumption patterns may no longer be reliable. As a result, better pricing signals can actually threaten a utility's ability to recover costs. Some coping mechanisms, such as contingency funds, revenue stabilization funds, the inclusion of a risk margin in the calculation of revenue requirements or rate adjustment mechanisms may be used, depending on the political and legal ramifications (Chestnutt et al., 1996). The AWWA (among others) has produced a manual and software to assist in evaluating the impacts of different rate structures entitled Alternative Water Rates and A Financial Planning Model for Utilities, respectively.

Two-tiered versus one-tiered water systems

In the two-tiered system of government that exists in some parts of Canada, water is sometimes sold wholesale by the upper-tier (regional) municipality to the lower-tier (local/area) municipalities. Under this system, the region is responsible for providing water and wastewater treatment, while the area municipalities usually have responsibility for metering, maintaining the local water distribution system and wastewater collection system, and billing customers. Most of the costs associated with the area municipalities are fixed costs that are not consumption dependent. When demand is reduced through water conservation, local municipalities may not be able to cover their fixed costs. From this perspective, there is little incentive for the lower-tier municipalities to support DM, unless the region and area municipalities develop an arrangement to counter this disincentive. In one-tiered systems, the incentive for municipalities to implement DM is considerably greater, as they exert full control over water pricing and cost recovery.

Plant optimization

While not a DM technique per se, treatment plant optimization can help municipalities face tough environmental standards, growing populations and reduced infrastructure subsidies. A process audit is completed to measure actual treatment capacity and identify optimization opportunities. The first objective of a process audit is not to avoid necessary and costly plant expansions, but only to avoid unnecessary ones. At the same time, opportunities to save energy, maximize the use of existing facilities and improve effluent quality can be identified.

Audits of several Ontario wastewater treatment plants (WWTPs) have demonstrated the effectiveness of optimization. For example, the evaluation of Windsor's Little River WWTP found that an optimized plant could achieve newly imposed nitrification requirements and more stringent effluent discharge limits without changing its original rated capacity. An audit and stress test of the City of Waterloo's WWTP also demonstrated that the plant could nitrify and remove phosphorus to meet effluent requirements without an expansion. While additional secondary clarification capacity would be required in Waterloo, the need for tertiary treatment was unnecessary at the time of the study (CH2M Gore & Storrie, 1997).

The Ontario Ministry of the Environment, together with Environment Canada, commissioned the development of the *Guidance Manual For Sewage Treatment Plant Liquid Train Process Audits* (1996). This manual describes the tools needed to audit and optimize WWTPs and is a companion document to the handbook *The Ontario Composite Correction Program Manual for Optimisation of Sewage Treatment Plants*. Similar manuals are available for water treatment plant optimization.

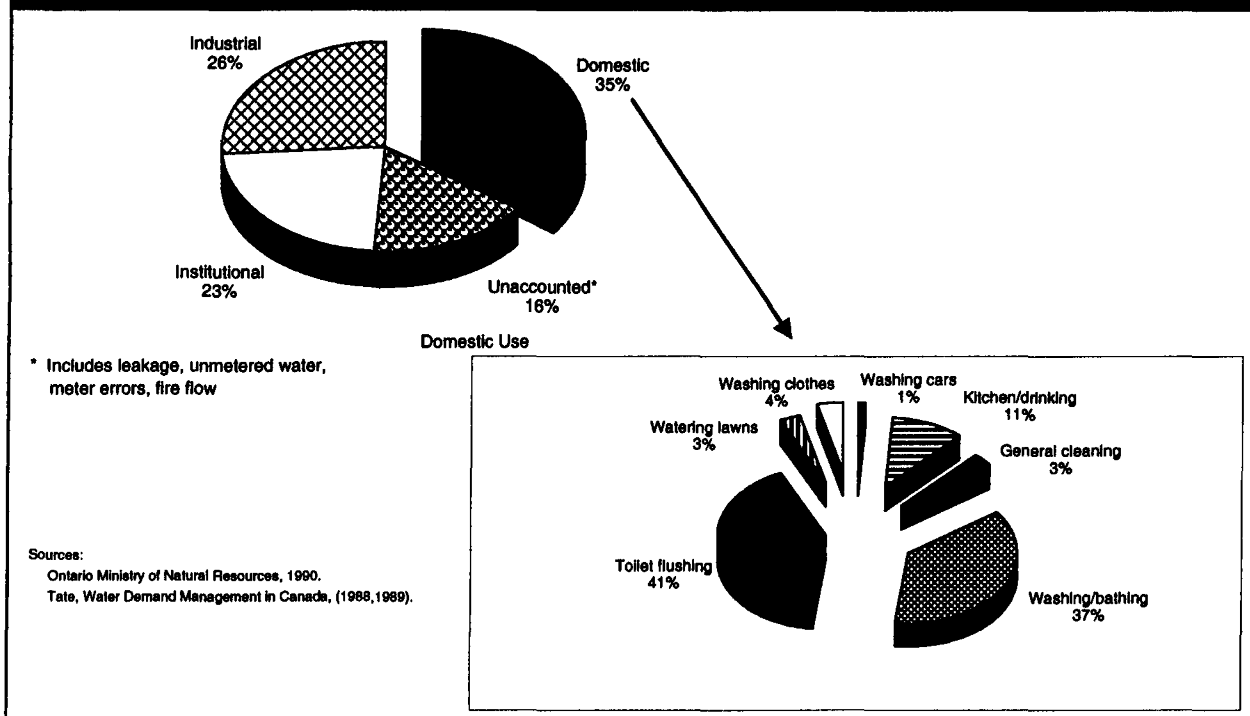
Customer-Based Efficiency Measures

There are various customer-based DM options, including:

- audits;
- plumbing retrofits;
- landscaping measures; and
- educational programs.

Figure 3-1 provides a breakdown of water use by sector, and a breakdown of residential water use by end use. By combining this information with performance data on water-efficient fixtures, average water savings can be estimated. The pie charts illustrate average conditions. However, because the water and wastewater infrastructure is designed to accommodate peaks, completing a similar breakdown during peak periods is advised.

Figure 3.1:
Average Annual Municipal Water Use



On the water side, irrigation demand in the summer can double total water demand. Similarly on the wastewater side, inflow/infiltration following wet weather events can spike flows to the WWTP. Therefore, if the goal is to reduce future capacity requirements, focussing on peak reductions will be most effective. The measures that reduce average daily water demand or wastewater flow will help the systems function better on an ongoing basis, but will not have the greatest impact on facility sizing.

Fixture retrofit and replacement programs

Indoor residential retrofit programs generally include measures to accelerate the installation of water-saving fixtures such as low-flush toilets or toilet tank displacement devices, water-efficient shower heads and faucet aerators. These fixtures reduce average water demand and average wastewater flow. Retrofits can be initiated by the homeowner, promoted by community groups or school programs, or implemented by utilities or the municipality. Table 3-1 reviews many of the DM options available including water audits, retrofit kits and fixture replacement.

Water audits are carried out to determine the nature of water use and the water-saving options that may reduce the amount of water used at any particular facility or residence. Frequently, water audits are performed on high-water-use facilities with great potential for water savings. However, they can also be done on individual households. Normally, household audits are comprehensive in nature, including:

- an interview with homeowners about patterns of water use;
- leak identification and repair;
- installation of low-flow shower heads;
- installation of toilet tank displacement devices or new low-flow toilets;
- evaluation of lawn irrigation practices and recommendation of an irrigation schedule; and
- distribution of publications and promotional items.

Home conservation kits can consist of water-saving plumbing fixtures to replace existing fixtures and other items such as dye tablets for toilet leak detection. Older homes and multiples are usually targeted for these programs because of the savings that can be realized. Kit distribution varies from unsolicited delivery door-to-door, to consumer pickup at specified locations, to rebate programs where kits are purchased from local retailers. They may be distributed through school programs, community projects or utility-driven programs.Some form of assistance with installation usually helps to increase participation rates. Retrofit kits have been provided in Edmonton, Vernon, Winnipeg, the Regional Municipality of Ottawa-Carleton and Owen Sound, to name just a few examples.

Home retrofits can be effective; however, savings are difficult to predict because participation rates vary and low-flow fixtures may be removed over time. Some communities, such as Barrie (Ontario) and the Regional Municipality of Waterloo (Ontario) are supporting toilet replacement programs, where old toilets (22 L/flush to 12 L/flush) are replaced with low-volume toilets (6 L/flush). These kinds of programs are expected to achieve long-term savings.

Other water-saving appliances, such as dishwashers and washing machines, are now on the market. Because these appliances use a lot of water, most of which is heated, they generally provide for quick consumer paybacks.

Overall, the simplest retrofit programs are the most successful. Programs need to be hassle-free and accessible (Mitroff et al., 1996).

Landscaping measures

Although domestic water use for irrigation does not appear to be a large component of total water consumption (Figure 3-1 lists it as three per cent, but it can rise to 15 per cent and more in some communities), in the summer peak, it can double per capita water demand, in turn driving the need for additional water treatment capacity. It is, therefore, a prime target for DM programs for fresh water conservation, but has no effect on wastewater flow since irrigation water does not enter the sanitary sewer system.

A number of DM options can be used to reduce water demand for irrigation, including:

- reduced turf area;
- drought-resistant plants;
- irrigation timers;
- drip systems;
- improved soil structure (increased water retention);
- watering during non-peak times of the day;
- use of water gauges; and
- water restrictions (discussed above under Regulation).

Of these measures, xeriscaping (or water-efficient landscaping) and regulation provide reliable, ongoing water savings. Market incentives, such as reduced development charges may be offered by municipalities to encourage water-efficient landscapes in new developments (e.g., reduced turf area, drought-resistant plants, underground sprinkler systems, etc.).

Educational programs

The goal of public education is to raise consumer awareness of water and wastewater issues in order to encourage conservation. Specific programs must be targeted to specific audiences. Education techniques include:

- billing notices and flyers;
- door hangers;
- city council briefings;
- exhibits;
- press releases;
- open houses;
- video showings;
- workshops; and
- school programs.

School programs are vital components of water conservation programs. The AWWA has developed a school program entitled *The Story of Water* that can be adapted to any community and includes teachers' guides, lesson plans and reproducible student pages. Port Elgin, Ontario, estimates that about 80 per cent of its water customers have adopted conservation measures as a result of the town's education program.

ICI sector programs

ICI sectors can reduce water demand significantly by adopting new technologies, maximizing re-use and recirculation, and using improved maintenance practices. Based on an audit of 18 facilities located primarily in Ontario, potential savings of 15 to 50 per cent were identified, with 15 to 35 per cent being typical. Payback periods were found to be between one and five years, and normally less than 2.5 years (Blease, 1993). Municipalities or utilities wishing to encourage water conservation in the ICI sectors can provide assistance through:

- workshops;
- audits;
- financial incentives such as direct rebates;
- loan assistance;
- recognition programs; and
- mandatory requirements (e.g., by-laws prohibiting once-through cooling water).

4 HOW TO DEVELOP A DM STRATEGY

Because every community is unique, many DM measures are not transferable. The following section provides guidelines for developing DM strategies that are tailored to meet the needs of particular communities. Appendix A provides a step-by-step guide to developing customized strategies. Additional details can be obtained from the *Water Conservation Guidebook For Small and Medium-Sized Utilities* (AWWA, 1993).

Understanding Your Community

Step 1 in developing a DM strategy is the collection of background information (see Appendix A). Understanding your community is essential. In Canada, total per capita water demand (for all uses) averages approximately 500 litres per capita per day (Lpcd), within a range of 400 to 700. In Europe, the rate is approximately 250 Lpcd (Blease, 1993). Canadian consumption is relatively high for a number of reasons, including climate, culture, habit and the perception of abundance.

A breakdown by sector is essential in analyzing the appropriateness of DM options for any community. Estimates of unaccounted-for water and irrigation water must be factored into the sectoral analysis, otherwise the impact of DM on total water demand will be exaggerated. Awareness of peak conditions is also essential and, on the wastewater side, inflow and infiltration must be estimated before DM measures can be evaluated.

For example, inflow and infiltration comprise almost 50 per cent of the total flow in the community of 45,000 people in Figure 4-1. If the residential and ICI flows split the remaining 50 per cent, then the impact of a residential retrofit program (for example) would be seriously blunted by the 75 per cent of wastewater from inflow/infiltration and ICI sources. This community would be better off attacking its inflow/infiltration problem, at least initially.

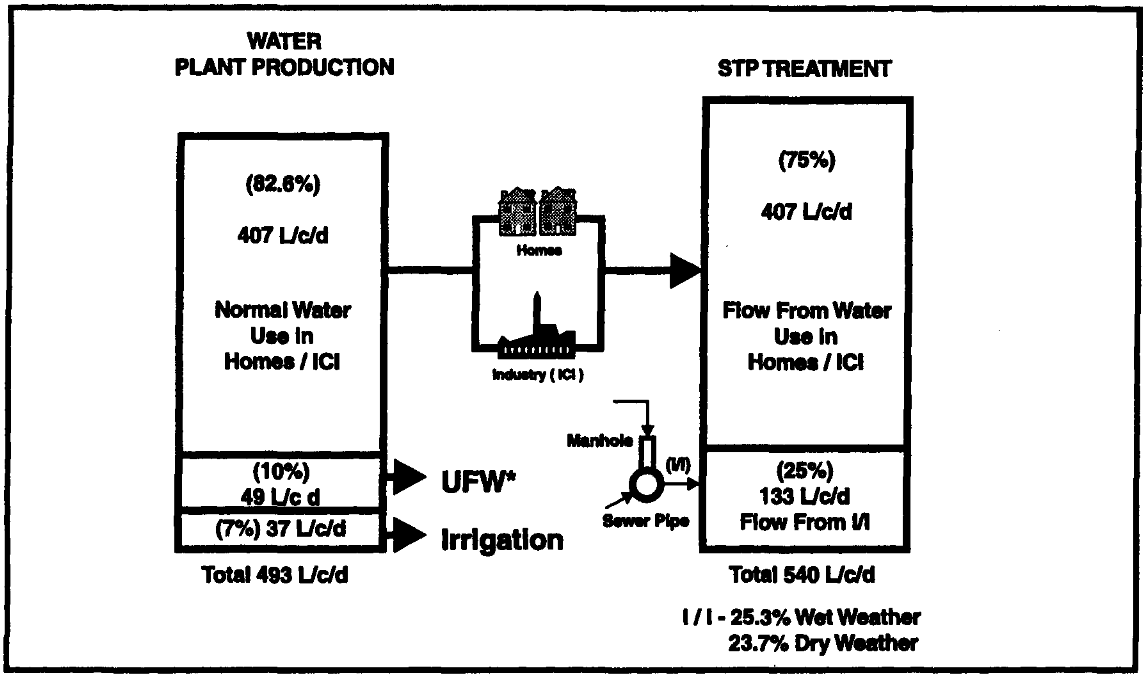
The two community profiles in Figure 4-1 help to illustrate how inflow/infiltration can be estimated. Water demand on normal (i.e., non-irrigation) days, excluding unaccounted-for water, generally shows up as wastewater requiring treatment. Water demand on peak days includes water used for irrigation, which does not impact wastewater systems. On the wastewater side, two streams require consideration—flow from users of the system and inflow/infiltration. If the amount generated by the users is subtracted from total wastewater flow, an estimate of inflow/infiltration can be made. This simple methodology is elaborated in a recent article entitled "How much treated water ends up in the sewer?" (Geerts et al., 1997).

This type of analysis helps municipalities identify their servicing priorities and set community goals (Step 2 in Appendix A). It also serves to educate the public (Step 3) about how servicing priorities were set and how public funds were allocated.

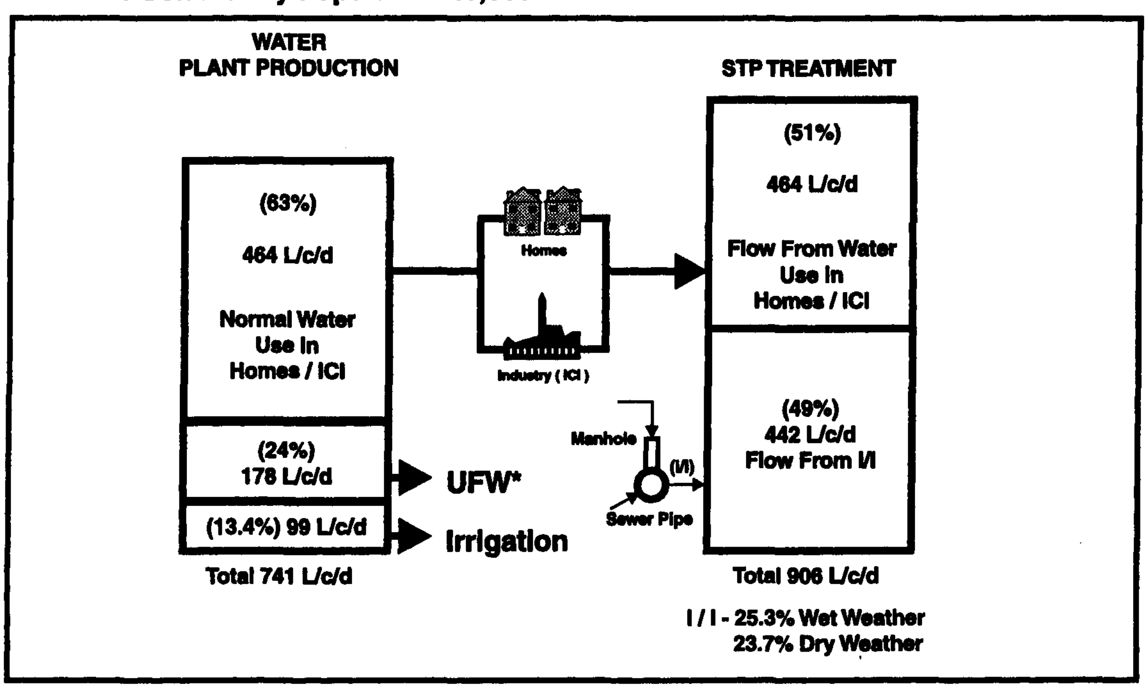
Every community will have different goals or problems driving the examination of DM options. For example, if protection of water quality in receiving streams is an objective, inflow must be reduced to minimize WWTP overflows. On the other hand, water conservation initiatives that reduce daily flows will help the WWTP do its job more effectively on a day-to-day basis. Table 4-1 provides some examples of DM measures that satisfy different community goals. All the information municipalities require to analyze these options is within their own data bases, notebooks and spreadsheets and cannot be deduced from external studies, trends or literature. What worked in one community may not work in another. Analyzing daily, monthly and yearly water and wastewater data, along with specific information on customers large and small, will be more useful than extrapolating from experiences elsewhere. In Canada, there are no standardized reporting requirements for water data, so each municipality must develop its own comprehensive tracking method.

Figure 4.1:
Example of Water/Wastewater Profiles in Two Ontario Communities

Profile of Community Population 71,000



Profile of Community Population 45,000



*If unaccounted for water (UFW) included unmetered services (and not just leakage), some would end up at the STP .This would result in a small reduction in the amount of flow assumed to come from inflow/infiltration (I / I)

Table 4-1:
Matching DM Programs to Municipal Goals

Problem to be Addressed /Goals	Priority DM Measures to Evaluate
Water System	
Financial sustainability	Metering, financial measures to ensure full cost recovery
Rapid growth	Land-use planning, regulation
Older residential community	Retrofit/fixture replacement program; leak detection and repair
Inability to meet peak water demand in summer	Seasonal water rates, lawn watering restrictions, landscaping measures
Long-term water supply shortage	All DM measures
Severe temporary drought or other short-term supply problem	Emergency rate structure, regulations
Extend life of treatment plant (i.e., capacity expansion deferral)	Reduce peaks through measures directed at outdoor water use
High unaccounted for flow	Leak detection and repair
Wastewater System	
Financial sustainability	Financial measures
Reduce peak flows to WWTP to eliminate/reduce overflows into receiving waters	I/I control
Extend life of treatment plant (i.e., expansion deferral)	Reduce average flows through I/I control, measures addressing indoor water use (e.g., ICI programs, retrofits)

Setting a DM Target

A DM target is the reduction in water and wastewater flows a community intends to achieve. Basic approaches to setting DM targets include:

- capacity objectives—basing the target on the reduction required to extend the capacity of a facility (e.g., a treatment plant) for "x" number of years;
- cost–benefit analysis—setting the target based on cost effectiveness;
- benchmarking; and
- identifying how much reduction is required to keep pace with probable future water supplies.

The first approach (capacity objectives) is discussed in Chapter 6, while cost–benefit analysis and benchmarking are described below.

Implementation and success

The DM measures described in Chapter 3 may be implemented in a variety of ways, including:

- regulation;
- device give-aways;
- direct installation;
- financial incentives;
- grants and loans;
- education and promotion;
- competitive bidding (third parties submit proposals to meet community targets); and
- performance contracting (Rocky Mountain Institute, 1991).

In general, comprehensive DM strategies, in which a series of compatible measures are combined, are more successful than implementing DM measures in isolation. Critical success factors for DM measures vary, but the principal components include:

- public acceptance;
- technical feasibility;
- penetration of the market; and
- long-term maintenance.

Some DM measures, such as public education, promote more than one of these success factors, including public acceptance, market penetration and long-term maintenance.

Cost–benefit analysis

A DM measure is cost effective if the present value of the benefits exceeds the present value of the costs (Pekelney et al., 1996). To understand the equity of DM to different parties and anticipate the community response to new programs, it is helpful to consider costs and benefits from the perspectives of the utility, the municipality and the customer.

Costs are all the negative consequences of implementing DM measures. They can include capital expenditures for conservation devices, operating expenses to implement the program, costs to the public, impacts on aesthetics (e.g., from reduced lawn watering) and increased risk in projecting demand.

Benefits are all the positive consequences of a DM program, such as avoiding capital and operating costs for water and wastewater services, lower costs for customers, the ability to accommodate new growth, environmental protection (streams, wetlands), enhanced reliability of the water supply, improved aesthetics and revenue stability.

To initiate a cost–benefit analysis, background information, such as demographic and historical water data, is analyzed and future water needs are forecast. Potential DM measures are then described including information on the sector targeted, the objective to be achieved, and how the measure will be implemented. The long list of measures is then evaluated on both economic and non-economic factors. One approach is to screen DM measures according to non-economic measures initially to assist in accounting for socio-political factors, and to obtain a smaller set of alternative measures for more detailed economic analyses. Figure 4-2 identifies a methodology for completing the economic cost–benefit analysis.

Using cost–benefit analysis to identify reduction targets is a least-cost approach to servicing. In other words, DM is considered on an equal basis with the alternatives: increasing water supplies and/or wastewater treatment capacity. This is only valid, however, if the risks associated with DM are built into the cost–benefit analysis (see discussion on risk in Chapter 5).

Benchmarking

Although all communities are unique, and comparisons can be very complicated and misleading, water usage in communities with similar soils, weather conditions and consumption patterns, enables some general benchmarking to take place.

Figure 4-3, extracted from *the Survey of Municipal Water Rates & Operations Benchmarking in Ontario* (OWWA, 1997), illustrates that communities with large ICI sectors consume more water per capita than those that are primarily residential in nature. The "lower limit of experience" may be used to benchmark, or target, depending on the circumstances and water use characteristics of the community. While the "lower limit" line is strictly conceptual (based on survey data), it shows generally where values could be. If a community's per capita consumption deviates significantly from this line, water providers will either have an explanation, or will want to find out why.

According to one source, between 300 and 400 Lpcd are required to satisfy all needs in industrial countries. The portion required to satisfy personal requirements is 150 to 200 Lpcd. This is far higher than the basic human need of 50 to 100 Lpcd, which is the typical range of average consumption in developing countries (Kuylenstierna et al., 1997).

Figure 4.2:
Cost-Benefit Analysis Methodology

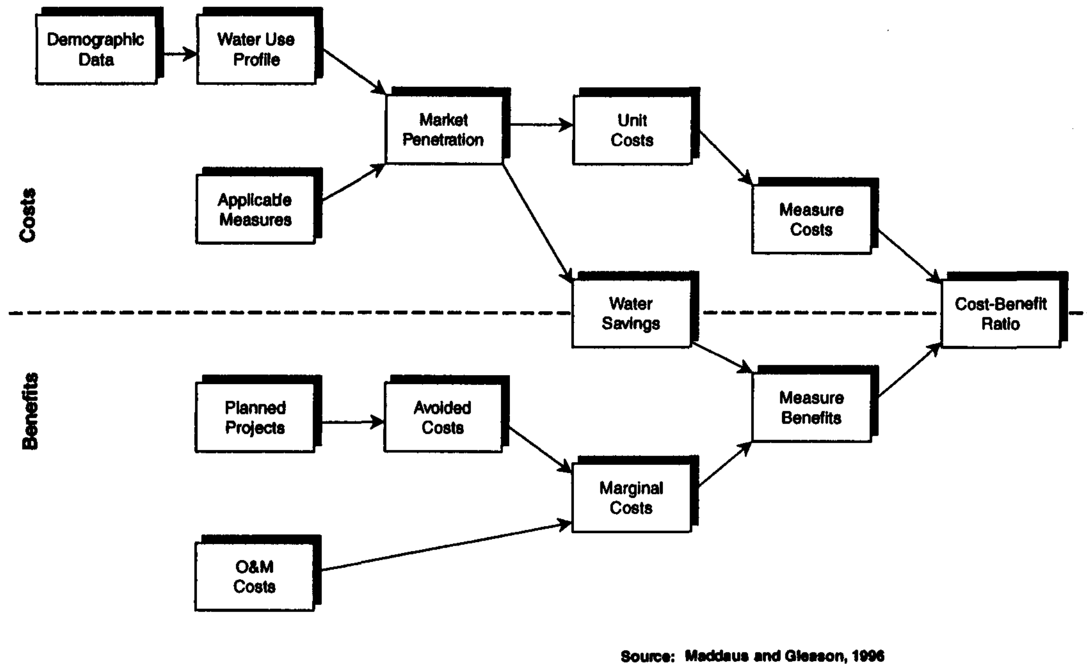
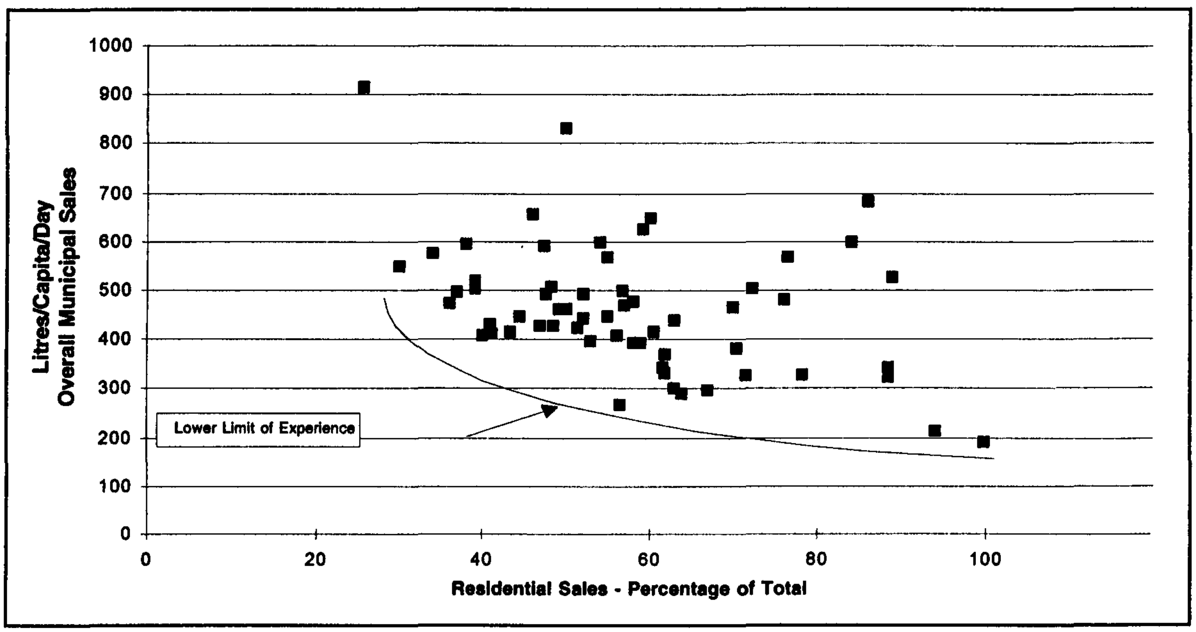


Figure 4-3:
Relationship of Overall Water Use to Percentage of Annual Residential Water Sales



Source: OWWA, 1997.

5 MUNICIPAL INFRASTRUCTURE REQUIREMENTS AND DEMAND MANAGEMENT

The Impact of DM on Water and Wastewater Infrastructure

To identify the potential impact of DM on water and wastewater infrastructure, it is essential to understand the function if each system component, its particular design requirements, and staging or sizing considerations. These engineering considerations are summarized below and in tables 5-1 and 5-2. Appendix B provides additional information.

The first priorities with respect to water supply and wastewater treatment are the protection of human health and the environment, via:

- the provision of clean water; and
- the protection of water quality in receiving waters.

Other municipal priorities include:

- facilitating economic development with quality services; and
- preventing property damage (e.g., from fire flows or basement flooding).

Design standards have been developed to ensure that these priorities can be met.Water supply and wastewater treatment can be provided to small rural residential populations by communal systems or private wells and septic systems. Larger urban communities with a mixture of residential and ICI uses also need to allow for storage and pressure requirements in their water systems and make allowances for inflow/infiltration in wastewater systems. ICI-sector water customers, in particular, must be guaranteed a continuous supply, as well as the ability to meet major fire flow requirements and sufficient pressures for their sprinkler systems. Local water mains and elevated or ground storage reservoirs and pumping stations are often sized to meet these special needs. If they are not, industries may create their own fire storage.

Treatment plants, reservoirs and pumping stations for large service areas can be designed in increments to match demand. This is not always practical for small communities. Because land use, growth rate and other needs can change over time, conservative design factors are used in planning facilities for both large and small communities.

The overall sizing of water and wastewater systems is based on a number of factors. For example, peak flow influences the sizing of feeder mains, local sewers and pumping capacity. Water treatment plants are sized on maximum daily demand, while the size of wastewater treatment plants is based on average day flow because daily wastewater fluctuations are taken care of through storage ponds.

Impact on capital costs

Due to fluctuating peak demands and land-use changes over time, water and wastewater systems have unused capacity under normal conditions, and there is a risk associated with reducing this capacity buffer (factored into original design calculations).

An effective DM program can help to extend the life of facilities by dropping peak and average demands. If the savings resulting from DM are permanent, facilities can either be downsized or communities can continue to grow at no extra capital cost.

The analysis of water conservation impacts on Hamilton's Woodward Avenue Water Pollution Control Plant indicated that a 10 per cent reduction in average sanitary wastewater flows would result in a 14-year delay in any required capital expansions. A 20 per cent reduction in flows would result in a 30-year delay in capital expansions, and a 30 per cent reduction would achieve a 55-year delay in capital expansions (Hydromantis Inc., 1993). While the capital costs of treatment plants and possibly trunk mains and

Table 5-1: Components of the Water System

Component of System	Design Requirements	Staging or Sizing Considerations	Implications for DM
Water supply source[1]	Intake or well capacity normally designed based on maximum day demand	Intakes normally designed to accommodate ultimate populations/service areas, but can be expanded in stages if necessary Groundwater systems can be expanded by drilling more wells, if sufficient resource is available	Typically, surface water supplies are large enough to provide water on an unconstrained basis; generally, the need for conservation is greater in communities reliant on limited groundwater supplies
Water treatment plants	Demand forecasts are completed to determine the appropriate plant size considering population growth, ICI requirements and municipal needs Generally designed to meet maximum day water demand	Frequently designed to meet the need over a 20-year period Can be constructed in stages or modules	Conservation can help to defer plant expansions
Pumping stations[2]	Depending on the amount of storage in the system, pumping facilities are designed on the basis of maximum day, maximum hour and fire protection	Typically sized to meet 20-year needs (life of pumps) Can be staged	DM generally does not influence the timing or size of pumps
Feeder mains	Designed on the basis of maximum hour demand, future growth	Usually designed and installed to meet long-term requirements, but can be duplicated or replaced as growth occurs; duplication can also be beneficial to allow for maintenance	Water conservation can help to extend the life of existing water mains (e.g., Regina) but may not be able to influence the sizing of new local supply mains since they are designed conservatively to meet potential long-term needs
Storage[3]	Storage is sized according to the anticipated need on an area basis Size is very much based on the character of the particular community	Usually designed to meet projected 20-year need Storage can be added or expanded, as required	Since DM can help to reduce peak demand, it can influence the sizing of new storage facilities and extend the life of existing storage
Local distribution system mains[4]	Designed to meet peak demand, future growth and fire protection	Sized for the ultimate anticipated development of an area, but can be staged	DM may not be able to influence the sizing or timing of local supply mains

Notes:

1 74 per cent of Canadians obtain their water from lakes and rivers. The remaining 26 per cent rely on groundwater for domestic use.
2 Pumping may be required to transmit water from the source to the treatment plant, or to distribute the water to topographically high areas.
3 Treated water is usually stored at one or more points along the distribution system using either reservoirs or elevated tanks. Storage helps to even out the flow during the day, and provide a reserve for firefighting or system operating problems.
4 These are generally paid for by the developer of an area.

Source: Adapted from CWWA et al., 1994.

Table 5-2:
Components of the Wastewater System

Component of System	Design Requirements	Staging or Sizing Considerations	Implications for DM
Wastewater treatment plants	Demand forecasts are completed to determine the appropriate plant size, considering population growth, ICI requirements, inflow, infiltration Generally designed based on average annual flow with a peaking factor to account for extraneous flows Some components are based on sewage strength	Frequently designed to meet the need over a 20-year period Can be constructed in stages or modules	Flow reduction (i.e., indoor water conservation and inflow/infiltration control) can help to defer plant expansions and reduce plant or process bypassing
Effluent outfall[1]	Designed to meet maximum day flow	Generally sized for ultimate requirement	Flow reduction can help to extend the life of existing outfalls but may not be able to influence the sizing of new outfalls since they are designed conservatively to meet potential long-term needs
Trunk sewers	Sizing based on peaking factor between maximum day and peak flow	Designed to meet ultimate flow from a catchment area, but can be duplicated if necessary (e.g., if service area increases); duplication may also be beneficial to allow for maintenance, etc.	Flow reduction can help to extend the life of existing trunk sewers, but may not be able to influence the sizing of new sewer mains since they are designed conservatively to meet ultimate needs
Pumping stations	Designed to handle maximum anticipated flow from a tributary area Maximum flow consists of average annual flow multiplied by peaking factor, somewhere between maximum hour and maximum day	Pumps typically sized to meet 20-year needs (life of pumps) Pumps can be added, as required	DM generally does not influence the timing or size of pumps
Sludge management systems	Typically designed to meet the 20-year need, based on flow, strength and the degree of treatment provided	Sludge treatment, storage and utilization facilities can be staged	DM does not influence the amount of sludge generated
Local sewers	Design based on maximum hour flow	Sized for the ultimate requirement of the area when fully developed	DM may not be able to influence the sizing or timing of local sewers

Note:
1 Most WWTPs discharge treated effluent to a water course, but some may use land application.

Source:
CWWA et al., 1994.

sewers can be impacted by DM, rarely can the sizing of pipes in the local distribution system or local sewer system be reduced.

An important factor in evaluating whether new facilities or facility expansions can be influenced by DM is the rate of growth in the community. If the growth rate is flat, the number of years over which the delay of capital expenditures can be extended may be very significant. If the growth rate is high, delaying plant expansions may not be possible. Chapter 6 describes how to estimate the impact of DM on the timing of plant expansions.

Impact on operating costs and operations

Operating costs for water and wastewater systems include:

- energy;
- chemicals;
- labour;
- maintenance;
- management;
- taxes; and
- insurance.

DM may have a nominal impact on energy requirements for pumping operations and the use of chemicals. Operating costs related to labour and maintenance are often a function of minimum staffing requirements and maintenance schedules. Generally, labour, maintenance, management, taxes and insurance are not affected by DM.

Some concern has been expressed over reductions in baseline dry weather sanitary flows in sewers designed for larger flow volumes. Reduced flows can cause longer retention times in sewers and pumping station wet wells, increasing damming of solids by debris and grease, and lowering dissolved oxygen. This could result in hydrogen sulphide buildup in the sewers, causing odour and corrosion problems (Marshall and Batis, 1993). DM could conceivably increase the effort required to maintain these sewers, particularly if wet weather inflow is no longer flushing solids from the sewers.

Impact on water and wastewater quality

Reductions in wastewater flow are believed to have a positive impact on the treatment efficiency of WWTPs. Simulation studies conducted on conventional WWTP performance show that water conservation can lower biological oxygen demand (BOD) concentrations and reduce effluent suspended solids concentrations (Langschwager et al., 1991). Other studies support this finding. Hydraulic load reductions have been found to improve effluent water quality, particularly by reducing total mass loadings of BOD and suspended solids in final effluent (Gall et al., 1993; Patry and Takacs, 1990; DeZeller and Maier, 1980).

Analysis of treatment efficiencies at the Hamilton Woodward Water Pollution Control Plant indicated that a 10 per cent reduction in wastewater flow could result in an 11.9 per cent reduction in total suspended solids and a 5.8 per cent reduction in BOD concentration in the final effluent. A reduction of 30 per cent in flow could result in a 25.6 per cent reduction in total suspended solids and a 10.5 per cent reduction in BOD concentration (Hydromantis Inc., 1993).

Drinking water quality is not directly impacted by DM. However, as noted above, a reduction in wastewater flows through DM enhances the ability of WWTPs to better treat normal sewage flows. By reducing sewage flows, DM also increases the capacity of WWTPs to accommodate increased wet weather flows. During wet weather events, this increase in surplus treatment capacity can reduce the volume of untreated or partially treated wastewater that would otherwise bypass the plant. This reduces the contaminant loading to receiving waters, which in turn improves the quality of the water supply of downstream users.

Understanding the Risks Associated with DM

There are two basic risks associated with traditional supply-side water system planning.

- Actual growth in the community may significantly outpace planning projections, in which case there will be a shortfall in supply.

- Conversely, actual growth may fall significantly short of planning projections, in which case there will be a costly excess of system capacity.

Since utility managers are generally more concerned with undersupply than oversupply, supply-side planners tend to project optimistic growth rates, building in excess capacity to satisfy projected demands. The actual risk associated with not meeting demands over a normal 20-year planning horizon is usually quite small.

The supply-side approach of overbuilding water and wastewater systems is often a poor allocation of scarce resources and fails to recognize the environmental impacts of unmitigated resource use. Demand-side management enables utility managers to look at both supply- and demand-side options, but it is not without risk.

The most obvious risk from the perspective of utility managers is the possibility that anticipated or projected demand reductions from DM measures will not be met or will not be permanent. The more significant the estimated savings, the more significant the risk.

The primary economic risks of DM include the uncertainty over the cost of maintaining a long-term conservation program and the risk of revenue shortfalls where savings actually exceed expected reductions.

For these reasons, DM is best viewed as complementary to traditional supply-side planning. Recently, utility managers have been integrating water demand management into integrated resource planning for water utilities (Call, 1996; Hoffman, 1996; Ruzicka and Hartman, 1996; Hasson, 1993). Demand management from an integrated resource planning perspective allows the utility manager to look at a wide range of options for meeting water demands, includes all stakeholders in the process and allows for a more cost-effective analysis of options.

6 ESTIMATING THE IMPACT OF DM ON CAPITAL DEFERRALS

For many communities, the most compelling motivation to implement a DM program is to defer capital expenditures. In long-range planning, the potential capital savings associated with water and wastewater deferrals must be quantified and weighed against other costs and benefits in order to paint a full economic picture for investment planning.

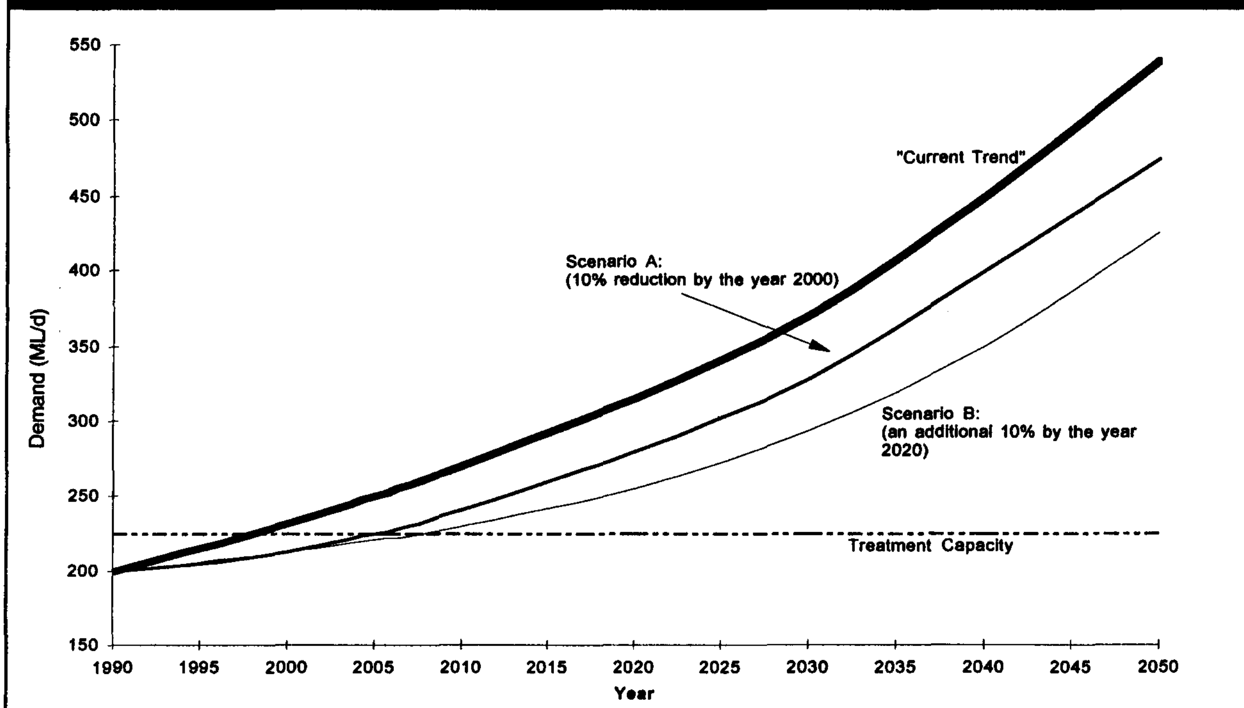
The following steps (based on Lutes, 1996) are a guide for analyzing the economics of DM for water treatment deferral. The same steps can be modified to analyze wastewater treatment deferral.

Step 1: Project maximum-day demand based on historical data
Referred to as the "current trend" demand set, projections into the future of maximum-day demand are made with a 95 per cent confidence limit (see Figure 6-1).

Step 2: Determine conservation goals for maximum-day water use reduction
Goals for reducing demand are then identified. For example, a 10 per cent peak-demand reduction could be set to be attained in 10 years (the year 2000 in Scenario A in Figure 6-1). An additional 10 per cent peak-day demand reduction could be targeted to occur in another 20 years (2020 in Scenario B in Figure 6-1).

Step 3: Using the current trends base projection and the demand reduction goals, chart the curves for scenarios A and B
Continuing with the example, the Scenario A curve (Figure 6-1) for maximum-day demand (the middle curve) is 10 per cent less than the current trends scenario (top curve) at the year 2000 and beyond. If, for example, the peak current trend demand in the year 2000 is 230 ML/d, Scenario A would bring that demand to 207 ML/d. The Scenario B curve (the bottom curve) represents the additional 10 per cent reduction by 2020.

Figure 6.1:
Estimating the Timing of Plant (Capacity) Expansions Based on DM Scenario



Step 4: Determine the timing for treatment plant expansions under the various demand scenarios

By adding water treatment plant capacity information to Figure 6-1, the timing for expansions can be predicted. A line representing the existing treatment capacity is plotted and extended out through the years until it contacts all the demand curves. The intersection points identify the timing of required capacity expansions. The number of deferral years can be identified by comparing the timing of expansions in scenarios A and B with the current trend.

Step 5: Perform a net present value economic analysis

Once the timing for capacity projects is determined, a net present value analysis of the deferrals can be done to estimate the amount of savings with each deferral beyond the current trend. Capital outlays, as well as the cost of borrowing or the interest earned on reserve funds, are considered. The costs of implementing a DM program can then be compared to the savings achievable through capital deferral. The savings potential from capital deferrals is frequently large. When costs, such as loss of revenue, operations and maintenance costs, and externalities are taken into account, investing in aggressive DM programs is often found to be cost effective. This assumes that the risks associated with deferred expansion, as discussed in Chapter 5, are acceptable.

In applying this methodology to wastewater treatment systems, average wastewater flow figures would be used in place of peak water demand. Analysts must acknowledge that a 10 per cent savings in water demand does not necessarily translate to 10 per cent less wastewater requiring treatment. If the DM program, designed to achieve the 10 per cent reduction in water demand, includes reduced water for outdoor uses or leak detection and repair, there will be little impact on the wastewater system. If, however, the DM program is focussed primarily on indoor uses, then wastewater flows will be reduced. If wastewater flow reduction is the primary goal of the DM program, then its focus may be on I/I control, as well as indoor uses. This again provides a reminder of the need to tailor DM programs to the goals of the community. It also suggests that both water demand and wastewater flow projections be completed to assess the impact of DM from an integrated perspective.

In some cases, the need for expansion will be imminent and DM cannot be implemented quickly enough to meet the need. It will still be worthwhile to calculate the economic impacts of DM into the future, particularly if capacity can be provided in stages and the life of the first stage expansion can be extended.

It is often true that some of the least costly and most effective DM actions, such as rate structure modifications, make sense to implement immediately even while capacity-expansion projects are being planned. Sequencing small incremental projects and conservation measures first also gives a municipality time to assess any changes in its overall business strategy and to adapt to new circumstances before undertaking major capacity expansions.

"Levelled" cost

A related procedure to the net present value economic analysis is to convert the capital deferral to a "levelled" cost of savings ($\$/m^3$) so all conservation measures can be judged against capacity expansions. "Levelled" cost is the cost of implementing a conservation measure (hardware, materials, labour and program administration) divided by the volume of water saved, discounted over the lifetime of the project. It is helpful to calculate "levelled" costs for individual conservation measures, groups of conservation measures and the capital projects these DM measures are intended to defer.

7 CONCLUSIONS

Historically, water and wastewater systems were designed according to available materials and health and environmental standards, as well as the population requirements of the day. Today, our standards are higher: we expect drinking water to be extremely pure, and wastewater effluent to have a negligible or even beneficial impact on receiving streams. Much of the emphasis on infrastructure needs is on bringing older systems up to current standards. In growth areas, state-of-the-art infrastructure is required to accommodate new development.

One of the most important lessons from this study is the need for planners, engineers and administrators to look at the community being planned for in terms of its history (age of the system, materials used, water/wastewater practices), user make-up (residential, ICI, leakage), and future requirements (growth, changing standards). DM programs need to be aligned with the community's history, objectives, capabilities and environment.

By their nature, water and wastewater infrastructure projects are long term. They result in permanent capital assets that affect many people and economic activities. The risks inherent in long-term planning must be managed carefully since the stakes are high.

The study found that the highest priority for DM is to reduce peak water demand and wastewater flow, for the following reasons.

- Water treatment plants will not be stressed during peak-demand periods, and water withdrawal will be more sustainable if supply coming from groundwater or storage capacity (e.g., reservoir) is limited.
- Wastewater treatment plant bypasses during wet weather will be reduced or eliminated.
- While DM may not be able to reduce significantly the scale of new water and wastewater treatment plants or conveyance systems, in some cases, it is capable of deferring the need for treatment storage capacity expansions.

Reducing average water demand and wastewater flow can provide the following benefits.

- Wastewater treatment plants will do a better job of treating sewage, and will produce better effluent.
- Groundwater supplies will be protected, which may help to maintain flow in wetlands and streams.
- Some small savings in operations and maintenance may be achieved.

What is evident from the literature review and case studies completed for this project is that DM programs are rarely initiated to address wastewater systems. Rather, they generally focus on achieving water demand reductions. By focussing exclusively on the water side, opportunities to achieve environmental gains through better management of wastewater flows may be overlooked. An approach that integrates water and wastewater objectives is preferred.

In growing communities, the life of facilities may be extended through DM. In slow to no-growth communities, wastewater treatment effectiveness will be improved. DM measures can be implemented individually or by combining measures which are mutually reinforcing. Savings are difficult to predict, however, and a commitment to monitoring and evaluation is needed to allow for review along the way.

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ENDNOTES

1 In comparison, the typical water use per residential customer in Ontario ranges from 597 L/day (low 50 per cent range) to 940 L/day (high 50 per cent range) (OWWA, 1997). Urban lot sizes are typically between 370 and 835 m^2 (4,000 and 9,000 sq. ft.).

PART II

CASE STUDIES

Detailed case studies were undertaken to illustrate the principles discussed in the Guidebook. Many factors contribute to water and wastewater servicing circumstances, and one cannot generalize from one community to another.

The diversity alluded to is captured in the case studies. For example:

- Some communities surveyed are upper- and some are lower-tier municipalities, with differing responsibilities.
- Some communities have extensive periods of dry weather, and some have wet.
- Some are older communities with ageing infrastructure, and some are fast-growing new communities, with more contemporary infrastructure.
- Some DM programs are motivated by water supply limitations, while others are initiated to reduce wastewater flows.
- Some areas surveyed are predominantly residential communities, and others support very large industrial sectors.
- Water bills vary considerably from one community to another (i.e., from $9 to $24 per month for the average residential water bill).

Figure 9-1:
Relationship of Overall Water Use to Percentage of Annual Residential Water Sales in the Case Study and Other (Ontario) Communities

Legend:		
	1	City of Windsor, ON
	2	City of Barrie, ON
	3	Regional Municipality of Waterloo, ON
	4	City of Edmonton, AB
	5	Greater Vancouver Regional District, BC
	6	Regional Municipality of Ottawa-Carleton, ON
	7	City of Regina, SK
	8	Communauté Urbaine de l'Outaouais, QC
	9	Town of Port Elgin, ON

\+ Communities surveyed in OWWA, 1997.

The case studies elaborate on these significant influences over water demand and wastewater flow. A detailed comparative analysis of the communities was not completed, as the sample size was not sufficient to capture trends. However, the discussion below summarizes findings, while Figure 9-1 illustrates how the residential/ICI split in a community may influence water demand. The graph also shows how the communities fare relative to the "lower limit of experience." (Chapter 4 in Part I of this report for further explanation.) What it does not show are the reasons behind the differences, which are provided in the narratives on each community.

What is evident from the case studies is that the communities facing water treatment plant conveyance system expansions are most active in implementing DM programs. Extending the life of existing infrastructure is the prime motive behind the initiatives. Often, however, programs are directed toward the water system, with integration of wastewater considerations lacking. The Barrie program is the exception.

All communities surveyed are at least partially metered. Education-related initiatives are by far the leading DM measures being implemented. Education is also the approach municipalities are frequently planning to take in future endeavours. Education can lead to, or be combined with, many other initiatives. Only two communities reported using financial penalties for overconsumption (e.g., via summer excess rates), but the reduction in peak demand directly attributable to this measure appears to be major. Initiatives specifically tailored to address a particular community's needs also seem to be very successful, such as large-scale xeriscape workshops in a very dry community.

The municipalities surveyed reported savings in average water demand from four per cent to 25 per cent, and reduction in peak water demand between two per cent and 50 per cent. Only two communities provided wastewater flow reduction estimates. Most programs are evaluated according to their impact on water supply, rather than on the wastewater system. This may be due in part to the difficulty in measuring the impact of water conservation on wastewater flow, because of the influence of inflow/infiltration (up to 50 per cent of total wastewater flow in two of the municipalities surveyed).

The analysis of water demand and wastewater flow described in Chapter 4 can assist in taking a more integrated approach to water and wastewater servicing, and is a useful tool for measuring progress into the future. This analysis was completed in Barrie, Port Elgin and Windsor, thereby assisting in understanding the approximate amount of water used for irrigation and the contribution of inflow/infiltration into the sewer system. This information can assist in predicting what the impact of various DM measures might be on both the water and wastewater systems on a community-wide basis.

The communities surveyed all evaluate their DM programs differently. Some compare changes in annual water use from one year to another, while others complete detailed program assessments right down to the household level. Variables such as weather or changes in the local economy may or may not be factored in. Without an adequate context for understanding the differences, making community-to-community comparisons is not very useful.

City of Barrie, Ontario

Background

Barrie is one of the fastest growing communities in Ontario, with an annual growth rate of six per cent over the last five years. Its current population is approximately 90,000. Most of the community has been developed over the last 50 years, so its water and wastewater infrastructure is relatively new. Topographically, Barrie is undulating to rolling, with a combination of well-drained and imperfectly drained soils. Precipitation is 950 millimetres per year.

Water supply system

The Barrie Public Utility Commission operates the water treatment plant and is responsible for the trunk and local distribution systems. This Commission also operates the power supply system. At present, all its water supply comes from groundwater, but this supply is limited. Within 10 years, there may be a need to move from groundwater to a surface water source (i.e., Lake Simcoe).

Average water demand is 34.6 ML/d, with the maximum day peaking ratio at almost 2.0. On a per capita basis, water demand is about average, at 493 Lpcd. The community is fully metered, with readings done on a monthly basis. Total water sales are split equally between the residential and ICI sectors, with the Molson brewery using about 20 per cent of Barrie's total water demand. Unaccounted-for water is approximately 10 per cent of total water produced. Demand for water for irrigation purposes is between five and 10 per cent of total annual water use.

Water is billed based on a decreasing block rate structure, with the average monthly residential bill being approximately $9.70.

Wastewater system

The wastewater service area is the same as the water service area. The city is responsible for both wastewater treatment and collection. Average daily flow is 57.1 ML/d (about 540 Lpcd), with flows almost doubling during peak periods. Wastewater effluent discharges into a sensitive receiver (Lake Simcoe) with strict pollution loading limits. Approximately 25 per cent of total wastewater flow comes from inflow and infiltration into the sewers. The WWTP is currently undergoing an expansion to 106 ML/d, which will almost double its capacity.

Wastewater costs are recovered by a 100 per cent charge against the water bill.

The main driver of Barrie's water efficiency program was the desire to defer WWTP expansion, as recommended in the 1993 long-term wastewater treatment strategy. The retrofit program was jointly funded by the Ontario Clean Water Agency and the City of Barrie.

Impact of the DM programs

The city estimates that its DM initiatives have resulted in the following reductions:

- 4.3 per cent reduction in average daily water demand (with an additional 2.5 per cent reduction targeted in the future);
- 2.2 per cent reduction in peak water demand; and
- two per cent reduction in wastewater flow (with an additional 4.2 per cent reduction targeted in the future).

A formal evaluation of the city's retrofit program has been completed.

Observations

As a fast-growing community facing the need to move to a new water supply, Barrie would appear to have an incentive to reduce water demand.

Table 10-1:
Barrie Demand Management Programs

Initiatives	Under Way	Planned for Future
Water efficiency co-ordinator	x	
Utility-Based Measures		
Metering	x	
I/I control program	x	x
Lawn watering restrictions[1]	x	
Xeriscape demonstration gardens		x
Regulations restricting once-through cooling water[2]	x	
Conditions on new development		x
Plumbing code	x	
Land-use planning[3]	x	
Customer-Based Measures		
Retrofit kits	x	
Toilet replacement[4]	x	x
Irrigation devices[5]		x
Pamphlets/bill stuffers	x	x
Ads in newspapers	x	x
School programs[6]		x
ICI audits[7]	x	
Other ICI programs[8]		x
Other customer-based measures[9]		x

Notes:
1 Via by-law.
2 Cooling water restricted from sanitary sewers.
3 In-fill development encouraged in older section of city.
4 14,000 toilets replaced through rebate program.
5 PUC considering promotion of water-saving sprinkler systems.
6 Planned for 1998.
7 Funding available from city for audits.
8 Toilet replacement in institutions under consideration.
9 City considering promoting water-efficient washing machines; PUC considering retailing water-efficient appliances.

However, the main motivation behind the city's DM initiatives to date has been deferral of the wastewater treatment plant. Savings have been realized as a result of this.

City of Edmonton, Alberta

Background

Edmonton's growth rate over the last 40 years has been very high. While today's population is 620,000, in 1956 it was only 250,000. Most of the city's water and wastewater infrastructure is, therefore, relatively new. Edmonton's water and wastewater service areas differ (see service populations below). Soils in the Edmonton area are imperfectly drained and topography is level to depressional. The average precipitation is 400 millimetres per year.

Water supply system

The Edmonton water service area population is 800,000. The city draws water from the North Saskatchewan River to its two water treatment plants. Supply is limited by water treatment plant capacity. The water system is operated by a private sector company, which is wholly owned by the City of Edmonton. Water demand is 396 ML/d on average for all uses (residential and ICI), with maximum day demand at 626 ML/d (ratio of 1.6) due primarily to irrigation demand in the summer. Per capita water use is approximately 495 Lpcd. Residential demand makes up about 50 per cent of total water demand, ICI sectors use 37 per cent and outside customers 13 per cent. Major wet industries use about 28 per cent of the city's total water consumption. Unaccounted-for water is estimated at four per cent of total water produced. It is estimated that additional water treatment plant capacity will be required in the year 2005.

Edmonton is fully metered, with residential meters read bimonthly and ICI meters read on a monthly basis. The average monthly residential water bill is $24.30.

Wastewater system

Edmonton's wastewater service area population is 630,000. The City of Edmonton has responsibility for all aspects of the wastewater system (i.e., trunk and local sewers, as well as treatment). The Gold Bar Wastewater Treatment Plant has 910 ML/d of peak primary treatment capacity and 310 sustained ML/d peak secondary treatment capacity. Peak secondary capacity is 420 ML/d. Average dry weather flow is 242 ML/d (or 328 Lpcd). However, since 16 per cent of the city has a combined sewer system (installed 50 years ago), flows to the plant increase dramatically during wet weather. Edmonton is implementing various measures to address this situation, and is considering increasing primary treatment capacity. Plant bypassing rarely occurs, but secondary treatment bypassing occurs about 60 times a year during wet weather. The plant is currently being upgraded to a tertiary treatment facility. Effluent is discharged into the North Saskatchewan River on the east side of Edmonton.

The average monthly sewage bill is currently $19.85 for household water use.

Edmonton's DM initiatives were selected on the basis of a cost–benefit analysis and public consultation. An evaluation program is in place.

Impact of DM programs

The city estimates that its DM initiatives have resulted in the reduction of average water demand by 14 per cent, and peaks have been reduced by 18 per cent. Winter wastewater flows over the last 10 years have declined by 1.2 per cent.

Observations

Edmonton is successfully using water rates and a number of other initiatives to reduce water consumption. Prolonging the time before the water treatment plant needs to be expanded is a main driver of the DM program. On the wastewater side, DM initiatives do not appear to be having a significant influence in cost reduction or delay, since reductions associated with DM are overshadowed by the dramatic increase in peak flow from normal flow as a result of the combined sewers. Flows have, however, reduced slightly over the last 10 years.

Greater Vancouver Regional District, British Columbia

Background

The Greater Vancouver Water District (GVWD), a division of the Greater Vancouver Regional District (GVRD), encompasses 18 municipalities. The Greater Vancouver Sewerage and Drainage District (GVS&DD), also a division of the GVRD, encompasses 17 municipalities. The GVWD and the GVS&DD are distinct entities, legally separate from the GVRD, but both operate as departments of the GVRD and employ GVRD staff.

Table 10-2:
Edmonton Demand Management Programs

Initiatives	Under Way	Planned for Future
Water efficiency co-ordinator	x	
Advisory committee	x	
Utility-Based Measures		
Metering	x	
Leak detection and control (water system)	x	
I/I control program (sewer system)	x	
Pressure regulation	x	
Lawn watering restrictions	x	
Xeriscape demonstration gardens	x	
Regulations restricting once-through cooling water		x
Conditions on new development		x
Plumbing code		x
Additional regulations to provincial plumbing codes		x
Land-use planning (e.g., zoning to promote multi-unit development)	x	
Water/sewer rates that promote conservation	x	
Other utility-based measures		x
Customer-Based Measures		
Retrofit kits	x	
Fixture leak detection	x	
Fixture leak repair	x	
Toilet replacement	x	
Home water audits	x	
Irrigation devices	x	
Car washing restrictions	x	
Pamphlets/bill stuffers	x	
Ads in newspapers	x	
Plant tours for schools	x	
School programs	x	
ICI audits	x	
Other ICI programs	x	
Other customer-based measures	x	x[1]

Note:
1 Re-use of disinfected effluent for industrial purposes under consideration.

In addition to a local population of about 1.8 million, the area attracts many overnight visitors, estimated at some 7.6 million per year. The population has increased dramatically in recent decades, with a more than doubling of population between 1965 and today. The average growth rate over the last five years has been 2.7 per cent.

Average annual precipitation, in the northernmost portion of the region, is 2,200 millimetres. Topography and soils vary considerably across the GVRD.

Due to the distinct nature of the water and sewer systems in the GVRD, a clear distinction has been made between them in this section. All water demand management programs are implemented by the GVWD.

Water supply system

The GVWD is responsible for water storage, transmission and treatment, while the local municipalities are responsible for the local distribution system. Water is supplied from the Capilano, Seymour and Coquitlam reservoirs, which store rainfall and snow melt from the surrounding mountains. GVRD has sufficient water supply to meet the need to the year 2022, but significant infrastructure enhancements are required to obtain that water and distribute it to where it is needed. Due to low summer rainfall and limited storage capacity, lawn sprinkling regulations are implemented each summer. Average daily water demand is 1.1 billion litres per day, with an average maximum day peaking ratio of 1.7. The estimated split between water uses is 55 per cent residential, 35 per cent ICI and 10 per cent unaccounted-for water. Several wet industries or significant users are located in the GVWD service area, including a brewery, ports, a de-inking plant, pulp and paper mills, and oil refineries. Approximately three per cent of total water demand is used by these customers. Per capita water consumption (for all uses) is less than 600 Lpcd when visitors are factored in.

While almost all ICI customers are metered, only seven per cent of residential customers are. For the ICI sectors, the frequency of meter reading varies from monthly, bimonthly, quarterly, once every four months, to semi-annually among the municipalities. Residential customers with metering have their meters read once annually. While the area municipalities vary in their billing method and rates, the average residential bill may be roughly $9 per month based, most frequently, on flat-rate billing.

Impact of water DM programs

The GVWD estimates that average daily consumption of water has been reduced by 13 per cent, with peak daily water consumption down by 20 per cent as a result of DM. A long-term water conservation plan is being completed, and this will set future reduction targets. This plan will have a monitoring and evaluation component. All programs currently implemented are evaluated. Water consumption by sector is monitored and reported biannually in the GVRD's sector demand study. Actual consumption and demand projections are reviewed annually.

Wastewater system

The Greater Vancouver Sewerage and Drainage District (GVS&DD) operates four WWTPs: Annacis, Lulu, Iona and Lions Gate. Their attributes are summarized below in Table 10-4.

Observations

The GVWD has been very active in implementing DM, and its upcoming long-term water conservation plan will prescribe future endeavours. With the split in responsibilities between the municipalities and the GVWD, and variability in topography and community make-up across the District, DM practices vary significantly.

All the District's WWTPs appear to stand to benefit from flow reduction, since the plants do not have substantial surplus capacity. Applying DM to help reduce overflows would also be beneficial. However, the current DM program appears to be geared more toward meeting water system goals.

Regional Municipality of Ottawa-Carleton, Ontario

Background

The Regional Municipality of Ottawa-Carleton comprises Gloucester, Kanata, Nepean, Ottawa, Vanier, Township of Cumberland, Rockcliffe Park, Township of West Carleton, Township of Osgoode, Township of Goulbourn and Township of Rideau, with a combined population of approximately 693,000 (1996). The serviced area of Ottawa-Carleton has a population

Table 10-3:
Greater Vancouver Water Demand Management Programs

Initiatives	Under Way	Planned for Future
Water efficiency co-ordinator	x	
Advisory committee	x[1]	
Utility-Based Measures		
Metering	x[2]	
Leak detection and control (water system)	x[3]	
Lawn watering restrictions	x	
Xeriscape demonstration gardens	x[4]	x[5]
Regulations restricting once-through cooling water	x[6]	
Conditions on new development	x[7]	
Plumbing code		x[8]
Additional regulations to provincial plumbing codes	x[9]	
Land-use planning (e.g., zoning to promote multi-unit development)	x[10]	
Water/sewer rates that promote conservation	x[11]	x[12]
Customer-Based Measures		
Retrofit kits	x[13]	
Home water audits	x[14]	
Pamphlets/bill stuffers	x	
Ads in newspapers	x	
School programs	x	
ICI audits	x	
Other ICI programs	x	
Other customer-based measures	x[15]	

Notes:

1 For all water issues, not just conservation.
2 By all municipalities in some sectors; GVWD meters water sales to all municipalities.
3 In some municipalities.
4 By some municipalities.
5 By the GVWD.
6 By one municipality.
7 By some municipalities.
8 Provincial plumbing code currently being rewritten.
9 In one municipality.
10 Liveable Region Strategic Plan.
11 Some municipalities have increasing block rate structures.
12 Currently studying wholesale seasonal rates.
13 Pilot project completed in 1997.
14 Pilot project completed in 1997.
15 Exhibits in home and garden shows.

Table 10-4:
Greater Vancouver Wastewater System

	Annacis	Lulu	Iona	Lions Gate
Average daily flow (ML/d)	441	65	567	108
Maximum day flow (ML/d)	811	122	1,183	211
Peaking factor	1.8	1.9	2.1	2.0
Plant or process bypassing (#/year)	4	2	140 (combined sewer overflows)	4
Discharge location	Fraser River	Fraser River	ocean	ocean
Years until capacity required	8	5	depends on pricing and source control work	depends on pricing and source control work

of 678,200 (1991), comprising Gloucester, Kanata, Nepean, Ottawa, Vanier, Township of Cumberland, Rockcliffe Park and Township of West Carleton. The topography is generally level and soils are predominantly poorly drained clays. The average annual precipitation is 870 millimetres.

Water supply system

The RMOC provides for both treatment and distribution of water. Water is treated at two plants: Britannia and Lemieux. More than 99 per cent of the water supply is drawn from the Ottawa River, with the rest coming from communal wells. Average daily water demand is 278 ML/d, with maximum daily water demand at 520 ML/d (i.e., a peaking factor of 1.6). Peaking is largely a result of demand for outdoor water use. Approximately 65 per cent of total water sales go to the residential sector. The ICI sectors use the remaining 35 per cent. About 25 per cent of total water produced is unaccounted for (e.g., leakage, fire fighting, street cleaning). Per capita water use is approximately 490 Lpcd overall consumption, but 278 Lpcd for residential use. An expansion of the filters at the Lemieux Water Treatment Plant is expected to be required in the year 2011.

The areas serviced by the RMOC are fully metered. Residential meters are read biannually, while ICI meters are ready bimonthly. The average residential water bill is $10.30 per month.

Wastewater system

The Regional Municipality of Ottawa-Carleton is responsible for trunk sewers and wastewater treatment, while the lower-tier municipalities take care of local sewers. Average daily wastewater flow is 440 ML/d. With maximum day flow at 1,000 ML/d, the peaking factor is approximately 2.3. Inflow/infiltration is estimated at 25 per cent of total flow to the plant. Total per capita wastewater flow is about 650 Lpcd. This high flow is partially attributable to the combined sewers that still service parts of the Region. A sewer separation program is in place to address this. The only time plant bypassing occurs is during a power failure. Treated effluent is discharged into the Ottawa River. It is expected that the wastewater treatment plant will have sufficient capacity to meet the need over the next 15 to 25 years.

These DM initiatives were implemented to defer both water and wastewater treatment plant expansions. The cost to implement water efficiency was considered lower than the cost of increasing supply or treatment capacity. DM was also identified as beneficial to the customer since it reduces operating costs. The specific measures were identified in two key studies: *Water Demand Study* (1994) and *Water Master Plan* (1997). A cost–benefit analysis was completed for the pilot project. The RMOC has identified plumbing code requirements as the greater contributor to reducing future per capita

Table 10-5:
Regional Municipality of Ottawa-Carleton Demand Management Programs

Initiatives	Under Way	Planned for Future
Water efficiency co-ordinator	x	x
Utility-Based Measures		
Metering	x	x
Leak detection and control (water system)	x	x[1]
I/I control program (sewer system)	x	x
Pressure regulation	x	x[2]
Lawn watering restrictions	x[3]	
Xeriscape demonstration gardens	x[4]	x[5]
Regulations restricting once-through cooling water	x[6]	x
Other utility-based measures	x[7]	x
Customer-Based Measures[8]		
Retrofit kits	x	x
Fixture leak detection	x	x
Fixture leak repair	x	x
Toilet replacement	x[9]	x
Home water audits	x	x
Irrigation devices	x	x
Pamphlets/bill stuffers	x	x
Ads in newspapers	x	x
Plant tours for schools	x	x
ICI audits	x[10]	x
Other ICI programs	x	

Notes:
1 By pressure zone (especially in older areas).
2 Pressure districts have been identified and will be monitored.
3 No restrictions, but education on how to do better (i.e., water once a week).
4 Demonstration garden located at Britannia Water Purification Plant.
5 Continuation of existing education component.
6 Current limits outlined in Regional Regulatory Code.
7 Pilot rain barrel programs in two communities on well water; a total of 350 homes participated.
8 All existing and future endeavours identify a public education component to encourage the public to adopt better ways to use water (i.e., no financial incentives or give-aways).
9 Pilot programs directed at multi-unit residential housing.
10 Cost-sharing program operated in past; current emphasis is on promotion and education.

water demand. I/I control is expected to have the most significant influence over future wastewater flows.

Impact of DM programs

In the future, the Regional Municipality of Ottawa-Carleton is targeting a 20 per cent reduction in average water demand through its various DM initiatives. A realistic target for wastewater flow reduction has not yet been set.

Observations

This region has been extremely active over the years in promoting water use efficiency. Its main focus has been on effective public education and it plans to continue this approach.

Communauté Urbaine de l'Outaouais, Quebec

Background

The Communauté Urbaine de l'Outaouais, comprising Aylmer, Buckingham, Gatineau, Hull and Masson-Angers, has rolling topography and predominantly poorly drained soils. Average annual precipitation is 900 millimetres. The water and wastewater service areas differ, as is evident by the populations noted under each below.

Water supply system

The water service area population (comprising the communities noted above) is approximately 219,600, increasing by about 24,000 (11 per cent) due to tourism in the summer. The upper-tier municipality supplies water to the cities, which distribute the water to the customers. Water is drawn from the Ottawa River. Average water demand is approximately 131 ML/d, while the maximum day water demand is 182 ML/d. The maximum day peaking factor is 1.4, which may indicate relatively low demand for water in the summer for irrigation purposes due to the poorly drained soils. Total water sales are divided between residential and ICI customers 65 per cent/35 per cent respectively. The large industries generally draw their own water from the Ottawa River rather than use municipally supplied water. About 10 per cent of total water produced is unaccounted-for water. Per capita water use is likely to be approximately 570 Lpcd (when the seasonal population is factored in). An expansion of the water treatment plant is currently under way, providing enough capacity until about 2026.

About 25 per cent of ICI customers are metered. Meters are read biannually. Water services are paid for through property taxes. The average annual residential water bill is between $95 and $115 a year.

Wastewater system

The wastewater service area comprises the communities of Aylmer, Gatineau and Hull with a combined population of 170,000 and a summer population of 189,000. The remaining municipalities within the region have their own wastewater services. The local municipalities are responsible for the wastewater collection system, while the upper-tier municipality is responsible for wastewater treatment. Average wastewater flow is 136 ML/d (or about 789 Lpcd on a per capita basis), with maximum day flows at 498 ML/d (i.e., peaking factor of 3.7). This high peaking factor is due, in large part, to the combined sewers that still service approximately 30 per cent of the area. Effluent is discharged into the Ottawa and Gatineau rivers. The WWTP is currently under expansion. It is expected to provide sufficient capacity to meet the need to 2016.

Wastewater services are paid for through property taxes, at between $85 and $105 per year for residential customers.

These DM measures have been implemented to defer both water and wastewater treatment plant expansions. Pressure reduction is the most significant component of the DM program in the Communauté Urbaine de l'Outaouais.

Impact of DM programs

Average water demand has been reduced by approximately 15 per cent, due primarily to pressure reduction.

Observations

The Communauté Urbaine de l'Outaouais has been actively pursuing DM to extend the life of its existing treatment facilities. Even once the expanded facilities are operating, it will continue with efforts to reduce pressure. Pressure reduction in the water supply system reduces wastewater

Table 10-6:
Communauté Urbaine de l'Outaouais Demand Management Programs

Initiatives	Under Way	Planned for Future
Utility-Based Measures		
Metering[1]	x	
I/I control program (sewer system)	x	
Pressure regulation[2]	x	x
Lawn watering restrictions	x	
Regulations restricting once-through cooling water	x	
Land-use planning (e.g., zoning to promote multi-unit development)[3]	x	
Financial penalties for over-consumption[4]	x	
Customer-Based Measures		
Retrofit kits	x	
Car washing restrictions	x	
Pamphlets/bill stuffers	x	
Ads in newspapers	x	
Plant tours for schools	x	

Notes:

1 ICI sectors.
2 Pressure is being reduced from 95 p.s.i. to 72 p.s.i.
3 Zoning is used to require installation of water-efficient fixtures in new developments.
4 Fines are imposed for violating by-laws.

flows as well. However, with combined sewers in some parts of the region, high wet weather flows will likely blunt the effect of reduced average water use and resultant wastewater flows to the WWTP.

Town of Port Elgin, Ontario

Background

The Town of Port Elgin is a small community on the shores of Lake Huron, with a permanent population of 7,000. The resident population rises to 10,000 during the summer months. Its population in 1950 was about 2,500. The present rate of growth is about two per cent. It follows, then, that most of its sewage and water system is relatively new. The topography of the town site is predominantly flat with some hilly sections, and soils are generally well drained. Average annual precipitation is approximately 870 millimetres.

Water supply system

The water system is operated by the local municipal government. Water is drawn from Lake Huron and treated at a water purification plant, which was last expanded in 1974. The present plant capacity will accommodate the area for many years. Average water demand is 2.2 ML/d, with a maximum day peaking factor of 1.8. Because of the major impact on the system from the seasonal increase in town population, it is not clear what the per capita consumption is. It is likely in the order of 325 Lpcd. The Town of Port Elgin is predominantly residential, with some light commercial. It is likely that the low per capita rate is due, in part, to the limited sales to the ICI sector.

The town has recently become fully metered, and this has contributed much to this low per capita consumption rate. From an analysis of the records, it seems that the amount of water used for summer irrigation is in the order of six per cent of the total water used per year. Data from 1991 show that before the institution of meters, the per capita consumption was about 470 Lpcd and irrigation about 13 per cent of the annual water use.

Water and sewage rates are based on a constant rate of $1.90/m³, and the average monthly residential bill for both services is $38 (based on 20 m³ of water used per month).

Wastewater system

The service area for this system is about the same as for the water supply system. The municipal council is also responsible for the sewage system. The average daily flow is about 4.95 ML/d with peaks rising to 2.5 times this amount. The treatment plant effluent is discharged into the Saugeen River, which eventually flows into Lake Huron. Inflow and infiltration rates are quite high, ranging around 50 per cent of the total annual flow treated. Average per capita wastewater flow is approximately 620 Lpcd.

The cost of operating the sewerage system is recovered by a 109 per cent charge on the water bill.

Impact of DM programs

The major impact of the DM measures relates to the water supply system with reductions in water consumption on average days of 25 per cent and on peak days of 50 per cent. There does not seem to be a parallel impact on the sewage system flows.

Table 10-7:
Port Elgin Demand Management Programs

Initiatives	Under Way	Planned for Future
Utility-Based Measures		
Metering	x	
Leak detection and control (water system)	x	
Lawn watering restrictions	x	
Customer-Based Measures		
Retrofit kits	x[1]	
Toilet replacement	x[2]	
Pamphlets/bill stuffers	x	
Ads in newspapers	x	
Plant tours for schools	x	
School programs	x	

Notes:
1 Retrofit kits were provided at a discount rate to all customers; participation rate was about 80 per cent.
2 The move to full metering prompted many customers to purchase ultra-low-flow (ULF) toilets

Observations

The major impetus for the town's DM measures was to reduce the size of the new water treatment plant. This was achieved. Both treatment plants seem to have ample capacity, so there may be no urgency to reduce sewage flows.

City of Regina, Saskatchewan

Background

The serviced population of Regina is 190,000. Most of the city and its infrastructure is relatively new, with an almost tripling of population between 1950 and today. Growth has moderated recently, with the current annual growth rate at 0.6 per cent. Regina has flat terrain with imperfectly drained soils. The city is quite dry; average annual precipitation is 300 millimetres.

Water supply system

The City of Regina owns and operates the entire water supply system. Water for this system is drawn from surface water (90 per cent) and wells (10 per cent). The surface water is piped from Buffalo Pound Lake, some 70 km west of Regina. Water supply is limited by the size of the pipe to transmit this water. Twinning of this pipe is a long-term project. It is estimated that the capacity of the existing water treatment plant itself is sufficient to meet the need over at least the next 20 years.

Average water demand is approximately 75 ML/d, with maximum day demand at 150 ML/d (peaking factor of 2.0). Peaking is attributable to demand for outdoor water use. Average per capita water use is about 395 Lpcd. Total demand is divided between residential customers (50 per cent), ICI uses (30 per cent), out-of-town customers (two to three per cent) and unaccounted-for water (between 10 and 15 per cent), with the remainder used for other unmetered purposes such as park use. Regina supplies water to wet industries, which consume 11.5 per cent of all water sold. The three largest users are a steel plant, a heavy oil refinery and the University of Regina.

Both residential and ICI customers are fully metered, with meters read bimonthly. The water rate is set at a constant rate per cubic metre consumed, based on meter size. The average residential water bill is $23.50 per month.

Wastewater system

The wastewater system is also owned and operated by the City of Regina. The average daily flow treated at the wastewater treatment plant is 77 ML/d (404 Lpcd), with maximum day flow reaching only 100 ML/d (peaking factor of 1.3). This indicates that the contribution of inflow and infiltration into the sewers is likely minimal, as can be expected from a relatively new sewer system. Treatment plant or process bypassing does not occur. Treated effluent is discharged into the Qu'Appelle River system.

Wastewater treatment costs are billed to customers via an 82 per cent surcharge on the water bill.

These DM measures were initiated to defer water and wastewater treatment infrastructure expansion. The cost of DM was identified as less than the cost of increasing supply, distribution or treatment capacity. The Long Term Water Study (1992) identified DM as part of the solution to meet water needs. An annual review is completed of the water conservation program, and public surveys are undertaken periodically.

Impact of DM programs

Since 1991, Regina's average water demand has been reduced by six per cent. This reduction is expected to reach 10 per cent by the year 2001.

Observations

Regina has been very active in increasing water use awareness through its various education initiatives. Reducing outdoor water use has been the main objective. Metering and water rates are

Table 10-8:
Regina Demand Management Programs

Initiatives	Under Way	Planned for Future
Water efficiency co-ordinator	x	
Utility-Based Measures		
Metering	x	
Pressure regulation	x[1]	
Lawn watering restrictions	x[2]	
Xeriscape demonstration gardens	x[3]	x[4]
Land-use planning (e.g., zoning to promote multi-unit development)	x[5]	
Water/sewer rates that promote conservation	x	
Customer-Based Measures		
Pamphlets/bill stuffers	x	
Ads in newspapers	x	
Plant tours for schools	x	
School programs	x	

Notes:
1 Water pressure adjusted during the day according to demand.
2 Odd/even day outdoor watering on voluntary basis.
3 Workshops held on xeriscaping, with a total of 1,600 people attending the various sessions.
4 Conversion of schoolyards to xeriscapes under consideration.
5 Conversion of old institutions to multi-unit developments.

also key to the city's successful deferral of the need to expand the water and wastewater systems. The city's commitment to program evaluation helps in tracking the impact of DM and in developing ongoing communications with water users.

Regional Municipality of Waterloo, Ontario

Background

The Regional Municipality of Waterloo comprises Kitchener, Cambridge, Waterloo, North Dumfries, Wellesley, Wilmot and Woolwich. The permanent population within the Integrated Urban System of the Regional Municipality of Waterloo is 366,500 (Water and Wastewater Monitoring Report, 1997), which comprises Kitchener, Waterloo, Cambridge, Elmira and St. Jacobs. Students from the University of Waterloo and Wilfrid Laurier University add some 6,460 to 18,470 people to the population, depending on the semester. In 1950, the population of this area was only 126,000. The growth rate over the last five years has been about 1.5 per cent per year. The topography in the Region is predominantly level, and soils are well drained. Average annual precipitation is approximately 850 millimetres.

Water system

The Region has responsibility for water mains and water treatment, while the area municipalities take care of the local distribution system. The Region wholesales the water to the area municipalities which retail water to individual customers. The source of water supply is 72 per cent groundwater and 28 per cent surface water (i.e., the Mannheim Aquifer Storage and Recharge Facility). The average daily water demand in the Integrated Urban System is 145 ML/d, with the maximum day peaking factor ranging from 1.2 to 2.0 depending on the community. Residential customers use approximately 55 per cent of all water sold, while ICI sectors use the remaining 45 per cent. Unaccounted-for water is estimated at 11 per cent of the total water produced in Kitchener and Cambridge, and only two per cent in Waterloo. Average water demand is 394 Lpcd. DM, together with industrial closures, has reduced water consumption in recent years. Additional water supply is expected to be required in 20 years.

All water customers in the Regional Municipality of Waterloo are metered, with residential meters read at varying intervals depending on the area municipality. Generally, ICI sector meters are read monthly. The average residential water bill also varies among area municipalities, but is $16.28 per month on average. Currently, billing is based on a constant rate per cubic metre consumed, plus a maintenance fee or service charge in some communities.

Wastewater system

The Region has responsibility for some sewage pumping stations and all wastewater treatment plants. It has contracted the Ontario Clean Water Agency to operate its wastewater treatment plants. Each community within the Integrated Urban Area has its own wastewater treatment plant. Treated effluent is discharged into the Grand River or its tributaries. The average daily wastewater flow in the Integrated Urban Area is 169 ML/d, with the maximum day peaking factor being, on average, 2.1. This varies considerably from one community to another. Inflow/infiltration ranges from six per cent to 50 per cent across the Region, with the average being 29 per cent. The Region is targeting the areas with the highest I/I for intensive remediation (e.g., Elmira). Within the Integrated Urban Area, Elmira is the only wastewater treatment plant that overflows during wet weather events. The Elmira, St. Jacobs and Baden–New Hamburg wastewater treatment plants are slated for expansion within the next two years, while the Ayr plant is expected to require expansion within about nine years. Per capita wastewater flow in the Region is approximately 450 Lpcd.

The average residential wastewater bill also varies among area municipalities, but is $16.28 per month on average. Currently, billing is based on a rate per cubic metre, plus a service charge in some communities. The monthly residential water plus sewage bill equals approximately $28.49.

These initiatives were implemented to extend the life of current water supplies, and to extend the life of wastewater treatment plants in some communities. The Region is currently undertaking a water efficiency master plan, which includes an economic analysis of various water efficiency scenarios. Subject to the results of this study, it is expected that the Region will focus on public education, residential toilet replacement and, perhaps, ICI programs, in the future.

Impact of DM programs

The Region expects that DM will reduce total water demand by 6.8 ML/d by the year 2009. This is about a four per cent reduction in total water demand.

Observations

As one of the first areas in Ontario to implement large-scale retrofit and toilet replacement programs, the Region has long been regarded as a leader in DM. In the future, the expectation is that public education will be the major emphasis of the Region's program. The Region has been effective in keeping per capita water consumption among the lowest in the country.

Table 10-8:
Regional Municipality of Waterloo Demand Management Programs

Initiatives	Under Way	Planned for Future
Water efficiency co-ordinator	x	
Advisory committee	x	
Utility-Based Measures		
Metering	x	
I/I control program (sewer system)	x[1]	
Lawn watering restrictions	x	
Xeriscape demonstration gardens	x[2]	
Regulations restricting once-through cooling water	x[3]	
Plumbing code	x	
Water/sewer rates that promote conservation		x[4]
Customer-Based Measures		
Retrofit kits	x[5]	
Fixture leak detection	x	
Fixture leak repair	x	
Toilet replacement	x[6]	
Irrigation devices	x	
Pamphlets/bill stuffers	x[7]	
Ads in newspapers	x[8]	
Plant tours for schools	x	
School programs	x[9]	
ICI audits	x[10]	
Other ICI programs	x[11]	x

Notes:
1 Major focus on St. Jacobs and Elmira.
2 Greenbrook.
3 Via by-law.
4 Recommendation for further study as part of the Water Efficiency Master Plan.
5 In 1990 and 1991, kits were distributed to 17,000 homes in the City of Waterloo and 30,000 homes in the City of Cambridge.
6 14,500 conventional toilets replaced with ULF toilets via rebate program since 1992.
7 Pamphlets on e.g., gardening, rain barrel use, water softeners, water use habits.
8 Lawn watering index printed in local newspaper.
9 Curriculum packages were developed for both public and separate school systems.
10 These were undertaken in the past.
11 Workshops held in the past; publication and distribution of "Guidelines for Industry to Conduct a Water Audit."

City of Windsor, Ontario

Background

The City of Windsor has a population of 226,000 people, with much of its change in size (more than 35 per cent) in the last 50 years coming partially from growth and partially from expanding its service areas. The water system serves areas in La Salle and Sandwich South, while the wastewater systems serve these two outside municipalities plus Tecumseh and

St. Clair Beach. The city today is experiencing much economic growth. It is situated on fairly flat land with imperfect surface drainage features (i.e., clay soils). Precipitation is about 830 millimetres per year.

Water system

The water supply system is entirely owned and operated by the Windsor Utility Commission which also operates the power distribution system. Water for this system is drawn from the Detroit River at one plant. This plant has been recently expanded with a new set of filters and pre-treatment tanks. The older filters, some dating back to the mid '30s and '40s are being renovated as needed to meet projected changes in water demand. The plant complex has sufficient capacity for many years of growth.

Average water demand is about 147 ML/d, with a maximum day peaking factor of about 1.5. On a per capita basis, water demand is about 650 Lpcd on average. This is somewhat higher than average, most likely due to major water demands from industry. The unaccounted-for water is between 10 and 15 per cent of the total water produced. The summer excess water usage for irrigation is about eight per cent of the total water produced each year.

The system is 100 per cent metered, with residential customers billed bimonthly and ICI customers billed monthly. Water is billed based on usage on a single rate basis for all users, with a 100 per cent summer surcharge for each individual customer for water used above average winter usage. This new rate structure has been in place for several years and has reduced maximum day ratios significantly below those in most Ontario municipalities. The average residential bill is about $14 per month.

Wastewater systems

The wastewater service area in Windsor is approximately the same as the water service area. The City is responsible for operating all the wastewater system. The sewage is treated at two plants, one discharging into the Detroit River

Table 10-10:
Windsor Demand Management Programs

Initiatives	Under Way	Planned for Future
Utility-Based Measures		
Metering	x	
Leak detection and control (water system)	x	
I/I control program (sewer system)	x	
Water/sewer rates that promote conservation	x[1]	
Financial penalties for over-consumption	x	
Customer-Based Measures		
Pamphlets/bill stuffers	x[2]	
Ads in newspapers	x	
Plant tours for schools	x[3]	

Notes:
1 Summer excess rates.
2 A public awareness program was launched before implementation of the summer excess rate structure.
3 All Grade 5 classes.

and the other into Little River, which flows into the Detroit River. The average daily flow for the year, considering both plants, is 176 ML/d (or 780 Lpcd on a per capita basis), with maximum daily sewage flows 2.8 times the average daily flow. Because a major part of the system is combined sewers, overflows to the receiving waters occur about 50 times a year. Present flows are about 75 per cent of the combined plant capacities.

The annual cost recovery system in place is via a 100 per cent surcharge on the water bills.

The most significant and very successful measure is the designing of a water rate schedule and invoicing system that considers normal water demands and automatically records and invoices for water consumption that is above this normal water demand on a customer by customer basis.

Impact of the DM programs

The Windsor Utilities Commission estimates that it will achieve a reduction in average day consumption of 15 per cent and a peak day consumption of 25 per cent. They have already gone a long way toward meeting these goals.

Observations

The reduction in water consumption has been a major achievement by the Windsor Utilities Commission. Reductions in flows to the wastewater treatment plants are difficult to achieve because of the substantial size of the combined sewer system. Reductions in water use do not seem to reduce the sewage flows significantly, especially those that are treated at the West Windsor plant, which is the larger of the two.

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APPENDIX A:

STEPS IN DEVELOPING A DM STRATEGY

The following provides an outline of the steps to be followed in developing a demand management (DM) program.

Step 1: Collection of Background Information

The first step in developing a water efficiency strategy intended to benefit both the water supply and wastewater treatment aspects is to gather background information on:

- existing infrastructure (e.g., supply, treatment and distribution system) and future needs, upgrades required, cost of treatment, etc.;
- peak demand (i.e., seasonal/daily fluctuations) and the impact on infrastructure sizing;
- consumption (by sector, indoor/outdoor use);
- future population growth;
- rate structure;
- water supply and potential environmental impacts from increasing supply;
- septic systems (location, number, problems associated with);
- local water efficiency initiatives; and
- potential sources of funding.

Step 2: Establishing Goals

Goals are based on the needs identified in Step 1. Clearly defined goals can be used to screen water efficiency options. These goals may need to be refined following public consultation.

Step 3: Involving the Public

The third step is to involve the public. Of particular interest to the public are environmental impacts, cost considerations (e.g., payback period, funding possibilities) and potential energy savings. It is generally beneficial to establish a public liaison/advisory committee to guide the process, increase the project profile and gain public acceptance of the program. Other means of involving and informing the public include surveys, workshops, press releases and displays.

Step 4: Identifying, Evaluating and Selecting Options

The fourth step is to identify, evaluate and select options for achieving water efficiency. Many of the items included in this step are based on an evaluation system developed by Planning and Management Consultants, Ltd.

Identify technically feasible reduction methods

The universe of measures for achieving water efficiency is identified, and each method is screened according to the goals identified. For example, if the goal is strictly to reduce wastewater flows, implementing lawn watering bans would be eliminated from further consideration. This may need to be determined by field testing or pilot studies. The technology or knowledge required to implement the option, or the product, to be used must be reasonably available to pass the test of technical/feasibility. Furthermore, compatibility with policies (i.e., provincial, regional and local) is a criterion for technical feasibility.

Determine social acceptability/support

With the assistance of a public advisory committee and feedback obtained from the general public and organizations, options can be evaluated. Potential coverage (i.e., market penetration) can be estimated from this feedback, though usually with a low level of certainty. Concerns and issues for exploration can be identified for further study and incorporated into the social evaluation.

Determine effectiveness of options

Potential water savings are measured by the fractional reduction of water use, the market penetration and baseline water use. The user sector (i.e., residential, industrial, commercial, institutional), specific water use dimension (e.g., indoor, outdoor or peak use) and overall market penetration are factored into the calculation of savings. Reliable estimates of water savings are difficult to make without empirical data. A number of variables, including demographic conditions, water pressure, average household size, household composition, income, education and so on can greatly influence water use. Pilot studies or extrapolations from reliable studies in other jurisdictions may be needed to estimate the water volume reduction that is achievable. This is compared to unrestricted demand projections.

Implementation requirements (e.g., target population, program contents, coverage, incentives such as rebates or subsidization, implementation schedule, agency involvement, the need for a pilot study and program evaluation) must be identified for each option before the overall effectiveness can be determined.

Analyze benefits and costs

Cost–benefit analysis can be highly complex due to the number of considerations, but is needed to compare alternatives fairly. Detailed descriptions of how to perform this analysis are provided by Planning and Management Consultants and the California Energy Commission and California Public Utilities Commission. Cost–benefit analysis includes qualitative as well as quantitative effects. The qualitative side involves an impact analysis of environmental, social/political/legal institutions and customer equity and acceptability.

Weighting of these factors in terms of local priorities may be required to complete the analysis.

The payback period is often used to determine the cost effectiveness of implementing water efficiency strategies. Research has shown payback expectations to vary according to the "payer." Homeowners expect a six-month to three-year payback period on their investments; businesses expect a one- to seven-year payback; while utilities typically can accommodate a 15- to 20-year payback. Supply-side investments normally have 20-year paybacks.

Select optimal combination of methods

Based on the results of the cost–benefit analysis, a slate of candidate water efficiency options can be prepared. Selection of a combination of initiatives will require an analysis of the cumulative economic as well as environmental and social benefits, and costs of doing so. The benefits of implementing more than one complementary initiative typically include a reduced staffing and education cost per initiative. The most advantageous timing of implementing a variety of water saving initiatives (i.e., staging) should also be determined, and often depends on budgets, project momentum, staff work load, evaluation plans and objectives, and the overall ability to meet the goals or targets identified. A comparison between the total benefit/cost of implementing a package of water saving options and corresponding supply plans without these options should be made.

Step 5: Implementation

The fifth step in developing a water efficiency strategy is to implement the optimal combination of methods selected. To be successful, implementation will need to include a significant public education component.

Implementation should always be accompanied with ongoing monitoring of successes, problems, public opinion and market penetration. Ability to meet the expected water reduction goals should be determined; review of the cost–benefit analysis and the ability to sustain benefits over the long term are useful evaluation criteria.

Due to the difficulty in predicting the effects of reduced water use on the wastewater treatment side and the impact on wastewater strength and volume, the impacts on sewers, pumping stations and treatment plant should be tracked. Project refinements can be made following this evaluation.

APPENDIX B:

MUNICIPAL INFRASTRUCTURE REQUIREMENTS

Water Treatment and Distribution Systems

Approaches to water treatment and delivery

Existing or new, water treatment and distribution systems in Canada are designed to meet the water demand requirements of communities based on the size of the community, anticipated growth projections and the type of growth expected, be it for residential, industrial, commercial or institutional purposes.

Water supply can be provided to small rural residential populations by communal systems or private wells. Larger urban communities with a mixture of residential, industrial, commercial and institutional water users normally build in storage and pressure requirements.

Provincial environment agencies and municipal authorities across Canada set standards and guidelines for water treatment and conveyance that help to ensure protection of public health and the natural environment.

Municipal water demands

Municipal water supply systems are usually designed to meet the peak demand for water use within the customer service area.

Peak demand is defined as the average water usage rate on the maximum day of water use for the entire service area. In addition to the maximum day demand, servicing is normally provided to allow capacity for fire flow.

Calculation of the peak demand requirements for the service area is usually carried out taking the ultimate service area and a 20-year design horizon into consideration. Large municipalities may use a shorter time horizon. Municipal planning information including population and housing data, and industrial, commercial and institutional growth projections are used to calculate the peak water demand.

Typically, the largest daily water demand occurs during the drier periods of the summer months as indicated in Figure B-1, which illustrates typical rates of seasonal water demand.

Residential water demands

Residential water demand rates are quite variable depending on the climatic conditions in the service area and the type of development that predominates. Demand rates are based on either per capita estimates or on measured quantities. New development area estimates can be derived based on the service area location, the density of the development and the types of water use that make up demand, including domestic uses (washrooms, dishwashing and laundry facilities) and outdoor use for lawn watering and car washing.

ICI water demands

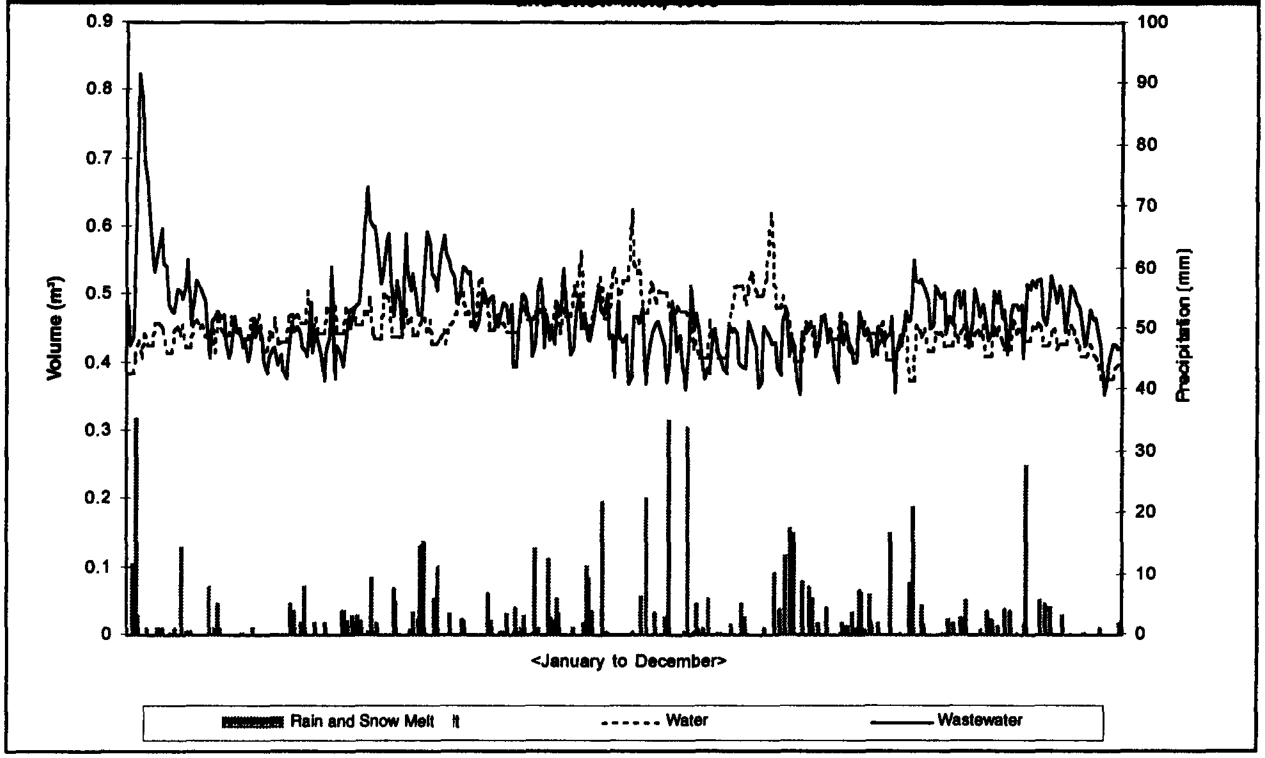
ICI water demand rates can also be quite variable depending on the type of ICI development. Demand rates can be estimated based on monitoring of usage rates or water audits.

Some useful benchmarks for describing water demands in commercial or institutional facilities based on measured results in similar communities may include litres per bed per day for hospitals, litres per square metre per day for shopping areas and litres per student per day for institutions such as schools. Often, water demands in the ICI sectors are expressed in terms of the "population equivalent." Industrial water demand rates are sometimes estimated using different factors for light, medium and heavy industry.

Water treatment requirements

Water supplies in Canada are derived from either surface water or groundwater sources. Most of these sources require some form of treatment to ensure delivery of clean potable water to

Figure B.1:
Daily Per Capita Water Demand, Wastewater Flow, and Rain and Snow Melt, 1993*



consumers. The principal concern in the delivery of water to customers is protection of public health. Aesthetic issues are also quite important in the guidelines for water quality.

The minimum treatment requirement for surface water is normally removal of solids through some method of filtration and the disinfection of the water supply to remove any bacteria present. More recently, the removal of *Giardia lamblia* and other organisms found in raw water has been a major issue in water treatment. In most cases, this level of treatment ensures a supply of clean potable water. Treatment of groundwater supplies, if required at all, varies considerably and depends on the quality of source water. In most cases, well water is chlorinated for disinfection.

Water treatment plant intakes and plant site requirements are normally designed to accommodate ultimate population service areas. Treatment plants, reservoirs and pumping stations for large service areas can be designed and built in increments to suit the rate of growth of demand. This is not always possible for small communities.

Water distribution requirements

Water distribution systems differ considerably from municipality to municipality. The distribution network can be constructed using various types of pipe that range from cast iron or ductile iron to high-density polyethylene to polyvinyl chloride and concrete pressure pipe. Distribution systems can be designed with varying amounts of storage to assist in meeting peak water demands and with emergency storage for fire flows and system failure.

All municipal distribution systems are designed, however, based on hydraulic calculations that determine the required pipe sizes, storage requirements, pressure requirements and the grid or pipe network design that will ensure adequate delivery of water to each local service area over the long term.

Wastewater Collection and Treatment Systems

Approaches to municipal wastewater collection and treatment

As noted, most wastewater treatment plants in Canada were built after 1950. Guidelines and standards for treatment have changed considerably since the early 1970s, and many older facilities are now being utilized below their initial rated capacity because of the de-rating required to meet increasingly stringent process and effluent requirements. Many communities are now faced with having to invest capital in the upgrade or expansion of these existing facilities.

Treatment of municipal wastewater before discharge to a receiving stream protects the public health needs of the community and the natural environment from degradation.

Sewer systems were designed to convey wastes and prevent flooding that could potentially impact public health and cause serious damage to property. Many sanitary sewers built before the advent of wastewater treatment plants were built as combined sewers. There was no need to limit the flow of infiltration and inflow into the sewer because the wastewater was not treated before discharge. These combined systems were constructed from materials that were prone to cracking and leaking.

Wastewater collection and treatment systems are designed to meet the sanitary discharge requirements of communities based on anticipated growth projections and the type of development expected, as well as the quality requirements of the effluent related to the particular body of water receiving the effluent. Today, the objectives of municipal wastewater collection system designers are to prevent flooding of sewer systems, which could potentially impact public health and cause serious damage to property, and also to provide sufficient capacity within the sanitary collection system to convey sanitary sewage to treatment facilities. The addition of treatment facilities introduced the need to control both leakage of the sewers and stormwater input to limit the size and therefore the cost of treatment facilities.

Collection of sanitary wastes

Generally, because of the need to limit extraneous flows into sewers, only completely separate collection systems are designed in most areas across Canada. Since the early 1970s, construction methods and pipe materials for both the private drains and the public sewers have improved considerably to meet new and more stringent guidelines that result in tighter sewers with a minimum of infiltration and inflow.

Even in completely separated collection systems, sanitary sewage flows comprise flows from a number of sources. Sewers must be designed to carry the peak flows that are anticipated to occur in the sewer to prevent flooding and to prevent sedimentation and build-up of solids.

Residential sewage flows

Residential wastewater flows contribute to the baseline flow in sanitary sewers and are based on the population serviced by the sewer or through direct monitoring of flows. Wastewater generated through indoor domestic use includes toilet flushing, clothes washing, dishwashing, and showers, bathtubs and sinks. Outdoor contribution may include inflow from downspouts, and footing drains, and possible infiltration from lawn watering.

Sewer capacity can be calculated using various formulas that account for the peak flow of domestic wastewater at certain periods of the day and the peak extraneous flows that enter the sewer through inflow and infiltration. Typical daily fluctuations of domestic sewage flows during dry weather periods or periods of minimal infiltration and inflow, and during wet weather periods or periods of maximum infiltration and inflow are shown in Figure B-2.

ICI sewage flows

ICI sewage flows vary considerably based on the type of development or the nature of the operations. Because land use can change over time, conservative factors are generally used for projections of wastewater discharges for undeveloped ICI-zoned lands.

The best method of determining industrial flows is to measure actual industrial discharges. Alternatives that are used in most cases involve determining the type of industry anticipated in the sewer drainage area and the size of the industrial complex to be serviced, and establishing the anticipated flow rates based on similar industry already in operation in other parts of the country. The quality and quantity of industrial waste discharges are often regulated by municipal by-laws. The volume of wastewater generated by industry can also vary considerably based on the output and destination of cooling water used in the industrial process. Often, water that is relatively uncontaminated is discharged needlessly to the sanitary sewer system.

Wastewater treatment

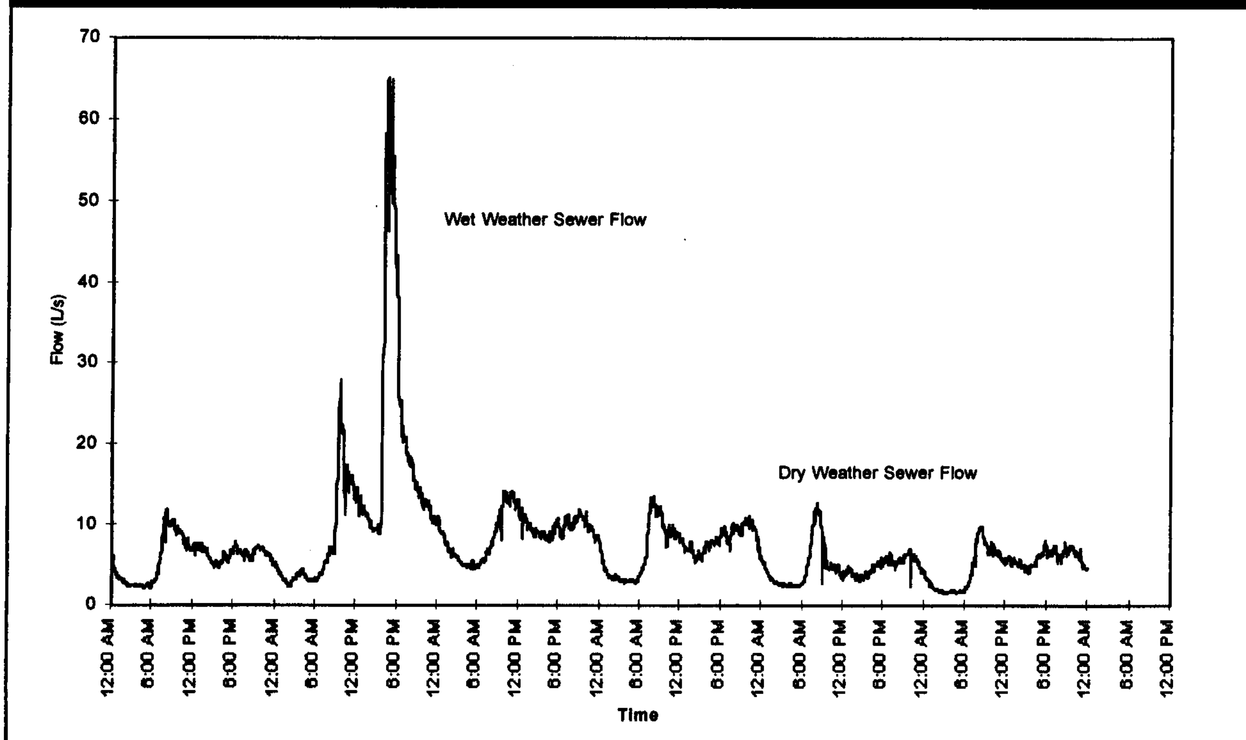
The range of available technologies includes:

- individual dwelling systems and very small developments of less than five to 10 dwellings—septic tank/holding facilities and weeping beds; and
- municipalities—wastewater stabilization ponds, aerated lagoons or mechanical treatment plants.

Treatment capacity

Municipal wastewater treatment facilities are typically constructed to treat all the wastewater generated over a 20-year design period. Plants in larger communities are usually built in phases that accommodate growth in the community.

Figure B.2:
Example of Possible Diurnal Variation in Wastewater Flow



Adequate provision must be made in the design of wastewater treatment facilities for the variations in flows that are received at the plant during normal daily fluctuations and those extremes in flow that occur during wet weather periods as a result of infiltration and inflow. Not accommodating these flows adequately will result in poor treatment efficiency. This results in poor effluent quality, perhaps in excess of regulated levels of contaminants, or in bypasses of plant processes altogether, which would result in direct discharge of untreated or only partially treated wastewaters.

The most significant factor in the design of the size or hydraulic capacity of the wastewater treatment facility is the flow that enters the facility during periods of wet weather. This infiltration and inflow component of the influent wastewater can greatly exceed the maximum daily peak flow attributed to fluctuations in domestic wastewater, as illustrated in Figure B-2.

Effluent quality

Effluent quality varies with the type of treatment process used to treat the wastewater, the quality and volume of the influent raw wastewater, and the operation of the plant. Municipal sewer use by-laws regulate discharges to sanitary sewers. This controls the quality of the wastewater entering the treatment plant, which is a significant factor in determining the final discharge quality. Effluent guidelines and requirements for final discharge are set by provincial environment ministries for components such as total suspended solids, total phosphorus and biochemical oxygen demand. Other effluent limits, such as toxicity to aquatic organisms, are based on requirements at individual treatment plants. The effluent limits are set to protect the health of the community and the aquatic ecology of the downstream receiving environment. These limits vary depending on the receiving water.

The Applicability of DM to Water System Planning

Water treatment plants

Water treatment plant sizing for development of new treatment facilities

For new service areas or for new water treatment plants servicing existing areas, a reduction in the peak day demand projections within a water service area would allow municipal planners and utility managers to limit the size of the required water treatment facility to meet the new peak demand estimates. A reduction of 10 per cent of the peak water demand could result in a similar 10 per cent downsizing of the required water treatment facilities as long as the demand reduction is permanent. The actual capital savings achieved would be a function of the economies of scale, fixed costs, unit process sizes and contingencies.

Timing of expansions for existing water treatment plants

The requirement for existing water treatment plant expansions is also based on projected peak day water demands in the service area. If demand management can reduce the peak daily rate of water use, the requirement for additional water treatment plant capacity may also be reduced. The water utility is, in essence, "buying back" some of the treatment capacity that has already been built and it may be possible in some instances to delay expansion of existing water treatment facilities for years.

The number of years that plant expansions can be delayed is directly related to the success of the DM program and the degree to which peak demands and total water demands have been lowered below the operating capacity of the water treatment facility. The other important factor in the delay of water treatment facility expansions is the rate of growth projected for the community. If the growth rate is flat, the number of years over which the delay of capital expenditures can be extended may be very significant. If population projections suggest significant growth, delaying plant expansions may not be possible. Chapter 6 describes how the timing of plant expansion can be affected by DM.

Operating costs

Operating costs at water treatment facilities can be attributed mainly to:

- energy costs;
- chemical costs;
- labour costs;
- maintenance costs;
- management costs;
- taxes; and
- insurance.

A reduction in the total water demand placed on the treatment facility can have an impact on energy costs. The most significant energy reduction may be a result of reduced pumping operations. If the demand reduction experienced in the service area is mostly a reduction in peak use rates and not total annual demand, then the total volumes of water treated at the plant may not change significantly and the impact on operating costs may not be significant.

A reduction in the water demand placed on the treatment facility can have an impact on chemical costs. The use of chemicals for disinfection, coagulation and flocculation is directly related to the volumes of water treated. If the demand reduction experienced in the service area is mostly a reduction in peak use rates and not total annual demand, then the impact on chemical costs may not be significant.

Operating costs related to labour and maintenance requirements are often a function of minimum staffing requirements and maintenance schedules. These factors are not affected significantly by a reduction in water demand. Because a reduction in total water demand would normally result in less water being treated at a treatment facility, maintenance requirements based on usage rates may experience a nominal decrease in required maintenance and associated labour and equipment requirements.

Water quality

Water quality in municipal treatment systems is not impacted by DM. However, in small communal well systems or individual well systems, there may be a positive benefit in terms of the sustainability of the local well field through both peak reduction and total demand reduction.

Water distribution systems

As previously discussed, municipal distribution systems are designed based on hydraulic calculations that determine the required pipe sizes, storage requirements, pressure requirements and the grid or pipe network design that will ensure adequate delivery of water to the community.

The design calculations for distribution system components are based on, among other criteria, the water demand within the service area as a whole and for each individual customer serviced by the network. Rarely can sizing of pipes in the distribution system and related service expenses be reduced based on the impact of a DM program.

There are, however, other design criteria such as minimum pipe sizing for service connections and the requirements for fire protection and adequate pressure, that must be considered in the overall design of the distribution system. Overall, consideration of a comprehensive set of design guidelines would suggest that DM would have very little impact on the design of water distribution systems.

Conclusions on the applicability of DM to water system planning

Demand management can have an impact on the design, construction and cost of water treatment facilities and, possibly, trunk water mains in large municipalities, but may have very little influence on the requirements of water distribution systems. In determining the impact of DM, it is important to recognize the difference between large municipal systems and the requirements associated with the delivery of water, and smaller systems that may not have the same storage or supply available to meet fluctuations in peak demands. It is also important to examine, from a historical perspective, the development of the existing system and to understand what impact other system requirements will have on the effectiveness of DM. The individual needs of the community must be clearly assessed before any projections of DM impacts are used to modify system requirements.

There is also a significant difference between communities that are building new treatment facilities and those that only need to expand existing facilities. There may be a delay of capital investments experienced in municipalities that are approaching the design capacity at an existing treatment facility, due to the potential to "buy back" treatment capacity through DM.

Perhaps the most important consideration in assessing the impacts of DM on water treatment facility design and distribution system design is a comprehensive analysis of the risks associated with each individual community in conjunction with the goals established for community growth and delivery of services.

Applicability of DM to Wastewater System Planning

Wastewater treatment plants

Water treatment plant sizing for development of new treatment facilities

Reductions in dry weather sanitary flow generated in the service area tributary to a wastewater treatment facility can potentially impact the sizing of planned facilities and the timing of upgrades and expansion requirements of existing facilities.

In new development areas, a factor that influences the design of required wastewater treatment facilities is the anticipated volume of sanitary wastewater generated by the population serviced by the plant. Estimates of wastewater volumes generated on a per capita basis may be reduced from typical design standards through evidence that a successful and aggressive DM management program is permanently reducing flows.

The impact of wet weather flows tributary to the plant through infiltration and inflow must also be considered in the overall design of the wastewater treatment facility. Programs directed toward a reduction in these flow components would enable the impact of domestic wastewater flow reductions to be much more significant in the overall sizing of the facilities.

Water conservation efforts may be able to reduce the volume of generated domestic wastewater, thus reducing the size and cost of constructing and maintaining the required treatment facility.

Timing of expansions for existing facilities

In established municipalities, the planned expansion of existing wastewater treatment facilities to accommodate new development can be directly offset by reducing the domestic wastewater flows, and infiltration and inflow generated in the community. Reductions in wastewater flows generated through a DM program result in an increased availability of dry weather capacity at the treatment plant, which can be used to accommodate new development and meet new effluent standards and, therefore, offset the need for, or delay, capital expansions. The analysis of water conservation impacts on the Hamilton, Ontario, Woodward Water Pollution Control Plant (Hydromantis, Inc., 1993) indicated that a 10 per cent reduction in average sanitary wastewater flows would result in a 14-year delay in any required capital expansions. A 20 per cent reduction in sanitary wastewater flows would result in a 30-year delay in any required capital expansions, and a 30 per cent reduction in sanitary wastewater flows would result in a 55-year delay in any required capital expansions.

Wastewater treatment capacity

A reduction in domestic wastewater flows provides for an increase in the ability of the treatment facility to accommodate wet weather flows during rain events. The increase in available treatment capacity at the plant can, in some instances, reduce the volumes of untreated or partially treated wastewater that are bypassed from the plant, thus reducing the contaminant loading to receiving waters and improving the removal process.

Wastewater treatment system performance

Reductions in domestic wastewater flows achieved through a DM program within the sanitary drainage area tributary to a wastewater treatment plant can impact the treatment efficiency of the facility. The increase in treatment efficiency can be attributed to:

- an increase in available treatment capacity;
- a decrease in the effluent concentrations discharged from the facility; or
- a decrease in the total loading of contaminants discharged from the facility.

Simulation studies conducted on wastewater treatment plant performance under water conservation programs indicated that the performance of conventional treatment plants may improve in terms of lower effluent BOD concentrations and lower effluent suspended solids concentrations (Langschwager et al., 1991). Other studies (Gall et al., 1993; Patry and Takacs, 1990; DeZeller and Maier, 1980) on the impacts of hydraulic load reductions on treatment plant performance have concluded that flow reduction programs can result in significant improvements in effluent water quality. The biggest impact reported was the reduction of total mass loadings of BOD and suspended solids in final effluent.

Results from the analysis of treatment efficiencies at the Hamilton, Ontario, Woodward Water Pollution Control Plant (Hydromantis Inc., 1993) indicated that a 10 per cent reduction in domestic sanitary wastewater flows could result in an 11.9 per cent reduction in total suspended solid concentrations in the plant final effluent and a 5.8 per cent reduction in BOD concentrations in the plant final effluent. A reduction of 30 per cent in domestic sanitary wastewater flows could result in an 25.6 per cent reduction in total suspended solid concentrations in the plant final effluent and a 10.5 per cent reduction in BOD concentrations in the plant final effluent.

Reductions in domestic wastewater flows through demand management, coupled with an increase in effluent quality, results in significantly lower loadings of contaminants to receiving waters from treatment facilities. Furthermore, a decrease in both the hydraulic load reductions to the receiving stream (through reductions in untreated and partially treated plant bypass volumes) and a decrease in the final loadings from a wastewater treatment facility may result in significant increases in the overall treatment efficiency.

Impacts of DM on wastewater treatment plant operating costs

Similar to water treatment plants, operating costs at wastewater treatment facilities can be attributed to:

- energy costs;
- chemical costs;
- labour costs;
- maintenance costs;
- management costs;
- taxes; and
- insurance.

A reduction in the influent raw wastewater volumes at the treatment facility can have a significant impact on energy costs. Energy reduction may be a result of reduced process costs such as lower aeration rates and reduced pumping operations. A reduction in the hydraulic loading to the wastewater treatment plant can also have a significant impact on chemical costs. The use of chemicals for disinfection is directly related to the volumes of wastewater treated at the plant.

Operating costs related to labour and maintenance requirements are often a function of minimum staffing requirements and maintenance schedules. These factors are not impacted significantly by a reduction in wastewater flows. Maintenance requirements based on usage rates, such as pumping equipment, may, however, experience a nominal decrease in required maintenance and associated labour and equipment requirements.

Impact of DM on sanitary infrastructure sizing

Pipe sizing

As discussed earlier, the proper and effective transport of flows, taking into account both liquid and solid components of the flow, must be ensured. Sewers must be designed to carry the peak flows, which are anticipated to occur in the sewer during wet weather periods and to prevent sedimentation and buildup of solids in the sewers during dry weather periods. Adequate sewer systems are required to protect public health and property from flooding.

For new development areas, sanitary sewer systems are designed as separated systems and, therefore, less extraneous flow can be anticipated. However, design standards for sanitary sewers require that some component of infiltration and inflow be accommodated in the design of the sewers. Also, minimum velocities and slopes must be maintained in the sewers to ensure proper flow conditions under both dry and wet weather conditions. Maintenance of sewers also requires that minimum sizing be maintained as a design criterion. However, the reduction of dry weather sanitary flows through water demand reduction programs may, under some very limited conditions, allow for reduced sizing of trunk sewers.

Another potential benefit of an aggressive water DM program may be the ability to service new developments with existing capacity thereby reducing the capital costs of new development. This benefit is based on the theory that reducing flows in the sanitary sewer is, in effect, buying back capacity in the sewer, which can be used to service new developments. This option is followed only after extensive flow monitoring in the existing sewers has been carried out to confirm flow estimates.

Operational impacts

For existing sanitary collection systems, reductions in baseline dry weather flow volumes due to DM programs may cause sedimentation in sewers designed for larger flow volumes. Reduced flows cause longer retention times in sewers and wet wells, increased damping of solids by debris and grease, and less dissolved oxygen due to the increase in BOD. This increases the potential for hydrogen sulphide to build up in the sewers, causing odour and corrosion problems (Marshall and Batis, 1993). There may also be a need to increase the effort required to maintain these sewers.

Because sanitary sewers are designed to accommodate peak flows experienced during wet weather periods when significant amounts of infiltration and inflow can occur, it is not likely that long-term problems associated with increased rates of sedimentation would impact main sewer trunk lines. The increased flows occurring in wet weather would normally flush solids from the sewers. More lasting or long-term problems may be experienced in lateral connections or smaller-sized sewers that may not receive significant amounts of rainfall-induced inflow or infiltration.

Conclusions on the applicability of DM to wastewater system planning

Demand management can have an impact on the design, construction and cost of operating wastewater treatment facilities but may have very little positive impact on the requirements of wastewater collection systems, except perhaps for trunk sewers in some municipalities. It is important to examine the development of the existing wastewater collection and treatment systems from a historical perspective and to understand what impact other system requirements will have on the effectiveness of DM on limiting their size and costs. The individual needs of the community must be clearly assessed before any projections of DM impacts are used to modify system requirements.

There is also a significant difference between communities that are building new wastewater treatment facilities and those that only need to expand existing facilities. There may be more capital benefits experienced in municipalities that are approaching the design capacity of their wastewater treatment plant due to the potential to "buy back" treatment capacity through DM, resulting in a delay of capital expansions.

Perhaps, the most important consideration in assessing the impacts of DM on wastewater treatment facility design and collection system design is a comprehensive analysis of the risks associated with each individual community in conjunction with the goals established for community growth and the delivery of services.