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Discussion Paper

Water: The Potential for Demand Management in Canada

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WATER: THE POTENTIAL FOR DEMAND MANAGEMENT IN CANADA

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Each day Canadians use more than 2000 litres of water per person for domestic, commercial, agricultural, and industrial purposes. Only Americans use more. Such consumption has entailed massive interference with the natural drainage system to retrieve and store water, to move it from its source to where it is wanted, and to dump wastewater as required. The annual cost of maintaining and improving this sytem is around 3 billion dollars.

The traditional solutions to problems of water supply and quality -- increases in supply and treatment facilities -- are becoming technically difficult and costly to implement. New approaches to water problems include a change in water-use practices toward limiting the amount of water that we use and the degree to which we degrade it. Indeed, the need for this kind of approach is inescapable in the face of evidence of increasing ecological damage, the cost of maintaining the existing water system, and the need for careful husbandry of resources to ensure a sustainable economy.

As part of its study on water resources in Canada entitled, "Water Policy: Toward the Year 2020," the Science Council commissioned Marbek Resource Consultants to prepare this discussion paper on how the demand for water can be better managed to ensure the conservation and protection of Canada's water. It addresses three challenges: First, how can we price water at a level that reflects its true worth? Second, how can we expand the mandates of our water agencies to include managing demand? Third, how can we encourage more efficient use of water? The paper considers management strategies that not only reduce water use, but also lessen the contamination from wastewater.

The paper first reviews water-efficient appliances, fixtures, industrial equipment, and agricultural practices. Many of these technologies use up to 80 per cent less water without loss of effectiveness. It then reviews the tools available to governments for managing water demand, including pricing policies, education and information programs, licensing agreements, and minimum standards. In Canada, water reuse in industry and water-efficient appliances and plumbing fixtures show the most potential. The paper concludes with a preliminary water demand management strategy for Canada. This includes a list of needs -- for research, development, and data -- and a series of programs to provide regulations, information, and financial assistance that are compatible with political jurisdiction over water.

This paper is one of four discussion papers that are being published in support of a forthcoming policy report.

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Background

In August 1986, the Science Council of Canada announced its comprehensive study on water resources in Canada entitled "Water Policy: Toward the Year 2020." The Science Council sought to determine what research was needed and what government programs could be used to reduce demands on Canadian surface and groundwater and to reduce the cost of supplying potable water and treating waste water.

This report looks at Canadians' options in terms of reducing the demand for water and specifies what data, research programs, and government programs will be needed to cut down consumption. It also describes a preliminary Water Demand Management Strategy for Canada.

The 1986 Inquiry on Federal Water Policy documented the major agricultural, municipal, and industrial withdrawals of water in Canada, reviewed broad options as to how water demand might be brought under control, and estimated the savings possible through more efficient use of water.[1] This discussion paper builds on this work by:

- introducing the concept that water's assimilative and diluent capacity is a water demand
- reviewing water-efficient technologies and practices that are already available
- reviewing how water demand has been managed in Canada, the United States, and elsewhere
- documenting water withdrawal and consumption by end use and sector (agricultural, industrial, commercial, and residential), regardless of whether or not the sector depends on public utilities
- identifying the needs for data, research, and demonstrations of water-efficient equipment
- recommending programs to conserve water in those sectors with the greatest potential.

The paper looks at the management of the demand for water under normal climatic and operating conditions.[2]

The Importance of Managing the Demand for Water

Canada uses more water per capita than any other country except the United States. Despite our abundant supply, this wastefulness is already causing regional problems.

a) In some areas, freshwater sources are not adequate to meet expanding local demand. For example, in Kitchener-Waterloo, at current levels of consumption, use will soon outstrip supply. Augmenting current sources will mean constructing a water pipeline or an expensive groundwater recharge scheme, and expanding the region's sewage treatment plants. The alternative is to use water more efficiently. In the southern Prairies, there is not enough water for crop irrigation and residential use. To meet current demands without addressing water-use efficiency would mean building several interbasin transfer schemes.

b) In many areas, facilities to treat, distribute, collect, and discharge water are not adequate to meet expanding demand. Industrial and municipal consumers do not use water efficiently, partly due to the low prices that are charged for water. Many municipal water systems lose water, for example, through leakage from pipes and fire hydrants, and many sewage treatment plants cannot operate effectively during rainstorms because some runoff is directed into sanitary sewers. Meeting expanding demand without repairing leaks, minimizing storm runoff in sanitary sewers (infiltration), or encouraging users to be more efficient is costing municipal governments larger and larger proportions of their revenues.

c) Many freshwater sources are contaminated because of inadequate treatment of wastewater. Many users return almost all the water that they withdraw from surface and groundwaters, but they often return it contaminated. These users frequently demand too much from water's diluent and assimilative capacity. Some 18 per cent of the wells on Prince Edward Island are contaminated with pesticides. Sewage in many municipalities contains toxic chemicals that are not removed by treatment. The sheer volume of wastewater sometimes renders the cost of treatment prohibitive.

The traditional response to these problems has been to increase supply and build more treatment plants. This response stems partly from the under-valuing of clean water, which is reflected in its traditional low price and partly from the way water agencies are set up. Most have no mandate to encourage investment in more water-efficient practices, technologies, and processes. Finally, even if water were valued more highly, information, financial assistance and some regulation would still be necessary to persuade consumers to use water more efficiently.

It would make sense, therefore, to empower our water agencies to manage the demand for water, and to price water at a level that reflects its true worth. We should also be seeking other ways to encourage more efficient use of water.

For the purposes of this study, "water demand" is defined as the amount of water consumed plus the degree to which wastewater is degraded. "Water demand management" is defined as any measure that reduces average or peak withdrawals from surface or groundwater sources without increasing the extent to which wastewater is degraded. The management of "in-stream" water uses such as navigation and recreation is excluded.

Including the assimilative capacity of water as a "demand" is fairer to all users. Those who only consume small amounts of water but return badly contaminated wastewater should be considered to have demanded as much from a water resource as those who consume large quantities. Under this definition, for example, the setting of effluent standards becomes a demand management measure, because it encourages reuse of water as well as reducing pollution in return flows.

A Parallel with Energy

There are many analogies between the post-1973 experience with energy and what is now occurring with water. Both water and energy have been priced below true costs; in both cases, environmental damage occurs at the production and release stages; both are governed by institutions that are geared to augment supply rather than to manage demand; and both are so widely used that many people doubt that conservation can be an effective force. For these reasons, the authors often refer to the changes that have occurred in energy demand and in the government's approach to management of energy demand as an indication of what could and should occur with water.

Water-Efficient Appliances, Fixtures, and Equipment

Any appliance, fixture, or piece of equipment that uses water to provide a service is a water-using technology. Although the amount of water used to provide the service may vary with water pressure, and there may be some options for the user to use less or more water, in general the design of the water-using technology, not the user's behaviour, determines the amount of water used.

The efficiency of water-using equipment may be defined as follows:

$$\text{Efficiency} = \frac{\text{Minimum amount of water required to provide a service}}{\text{Water actually used by the equipment}}$$

This definition is not always useful, however, because the minimum amount of water required to provide a service, although straightforward for end uses such as watering livestock or cooling, is almost impossible to determine for end uses such as toilet flushing, showering, or dishwashing.

A more useful way to measure efficiency is to determine, for all models of a product, water use per capita, per cycle, per day, or other appropriate unit. Comparison of "water-use coefficients" among different models provides an indication of relative water efficiency and allows estimation of the savings that could be achieved by installing that model. If there are several generations of a model, each with a different water-use coefficient, then it is possible to compare cost-effectiveness between generations. The weighted average coefficient for a model can be calculated where several generations exist in the market together:

Weighted average water-use coefficient = Sum of (market shares x water-use coefficients) for each generation.

Unfortunately, most specifications and published analyses of water-efficient products only provide an estimate of the percentage savings that can be achieved over conventional technology, or else a water-use coefficient based on continuous use (e.g., litres per minute) rather than typical daily or annual use. Without water coefficients based on typical use for both conventional and water-efficient technologies, and weighted average coefficients where appropriate, it is difficult to estimate actual water savings.

Shower Heads

Conventional shower heads in homes and many institutions use between 13 and 19 litres per minute. More efficient products reduce the flow by aeration or other means without sacrificing performance.

Many new products now on the market use between 9 and 12 litres per minute; while the most efficient products spray between 5 and 7 litres per minute. Several units have pressure compensation, so they work well under fluctuating pressure, and valves to shut off or reduce flow during use.[1]

No data were found on which to base conversions of litres per minute to litres per capita in typical homes or institutions, although some estimates of the size of the daily savings associated with an efficient showerhead do exist (see Table 1). The most pressing research needs are, therefore, to establish a standard method of measuring water flow through showerheads, to monitor water use in typical households and institutions, and to relate the continuous flow data given for each model to typical per capita water use. To estimate potential savings, data will also be required on the current market share of conventional and efficient units.

Faucets

Conventional faucets deliver between 11 and 13 litres per minute during normal use. More efficient units[2] reduce the water used by aeration, by limiting the maximum flow, or by automatically shutting off. Flows as low as 0.5 litres per minute can be achieved without sacrificing performance. This can cut by up to 85 per cent the water used for washing. In commercial buildings, efficient units use less than half the maximum amount allowed under ASHRAE (American Society of Heating, Refrigeration, and Air Conditioning Engineers) standards, which means that the size of some wastewater treatment systems can be reduced.

Standard methods of measuring faucet water use and more comprehensive monitoring of faucet use in homes, businesses, and institutions to determine typical use and the degree of market penetration of water-conserving units are required.

Toilets

Standard tank type toilets use approximately 20 litres per flush. Improved design of the toilet has reduced that to 5-10 litres per flush and many of these units are now routinely installed in new buildings. The most efficient tank model uses only 4-6 litres per flush while a tankless unit manufactured in Canada and approved by the Canadian Standards Association uses between 0.5 and 4 litres per flush as selected by the user.[3]

Several retrofit products, which in effect reduce the volume of water used per flush in standard toilets, are also available. Given that the amount of water required usually matches the design of the toilet, these products often result in the toilet not functioning properly.

Water used in toilets in homes averages about 90 litres per day per capita using conventional technology. At 20 litres per flush this is equivalent to 4.5 flushes per

Table 1. Observed Water Savings by Installing Water-Conserving Technology

Water-Conserving Technology	Observed Water Savings[a] (gallons per capita per day)
3-gpm[b] shower head	7.2
0.5-gpm shower head	13.8
3.5-gallon/flush toilet	8.0
0.5-gallon/flush toilet	19.6
Water-efficient dishwaters	1.0
Water-efficient clothes washer	1.7

Source: United States Department of Housing and Urban Development Office of Policy Development and Research, Building Technology Division, Residential Water Conservation Projects: Summary Report, June 1984, 1-7.

[a] Savings are compared to conventional fixtures and appliances.
[b] Gallons per minute.

day per person. At an average of 2 litres per flush using state-of-the-art water-efficient technology, residential water use in toilets could be reduced to 9 litres per day per capita. Similar savings can be expected in commercial buildings, but current levels of use are unknown.

Further research is needed on water use by toilets in the commercial sector and also on the market shares and cost premiums of the various generations of water-efficient toilets in each sector. A method for measuring water use in toilets was considered by the Canadian Standards Association in 1980, but was not written. Consequently, there is no standard method.

Dishwashers and Clothes Washers

These technologies are reviewed together for convenience. Both are tested for energy consumption under the United States and Canadian appliance efficiency programs, so that the test data for each model contain estimates of average water use per cycle and per month under typical use. Canadian standards assume that both dishwashers and clothes washers are used on average 34 times per month (34 cycles per month).[4] Water use by a dishwasher is between 1200 and 2000 litres per month, and by a clothes washer between 1000 and 2000 litres per month.[5] Assuming four persons per household, this approximates 12 litres per capita per day for each appliance.

Water use by dishwashers and clothes washers depends on size and design. New dishwasher designs with more powerful spray action use less water. Front load washing machines used in commercial laundries and by homeowners throughout Europe use significantly less water than top load machines.

Research is needed to determine typical water usage rates in the commercial sector. Research should include comprehensive analysis of water-intensive commercial establishments (such as restaurants, laundries, hotels, and hospitals) to discover correlations between water use and floor area, or number of users. Technical changes to dishwashers and clothes washers to reduce energy consumption will also reduce water use and vice versa. Research in these two areas should be integrated.

Lawn and Yard Watering

Residents with private yards can use up to 80 litres per capita per day for lawn watering. Conventional sprinkler systems waste much of this through evaporation and misdirected flow. New "soaker hoses" use up to 50 per cent less water.[6] Timers can be used to control the length of water use. More consumer products are needed in this area. Research to document drought-resistant plant and grass varieties suitable for each region of the country would also be useful.

Irrigation

Wheel roll and centre pivot irrigation systems (sprinkler and flood irrigation methods used for field crops) are 40 per cent to 80 per cent, and 75 per cent to 85 per cent, more efficient than conventional total coverage methods. Drip irrigation methods, which are suitable for some vegetable, orchard, and soft fruit crops, are even more efficient -- 60 per cent to 92 per cent -- and are becoming more useful to commercial growers as clog-free porous "soaker hose" technologies come onto the market.

Research needs for irrigation include the development of more drought-resistant plant varieties, more automation of irrigation technology (see also "Irrigation Practices" in the next section), and documentation of typical water-use coefficients for various irrigation technologies through monitoring programs.

Waste Treatment

Conventional waste treatment technologies are usually classified as primary (removal of solids), secondary (breakdown of biological material), and tertiary (removal of nutrients and other inorganic and organic substances). Most developments are taking place in the tertiary class, although there are several new compact technologies that incorporate all three waste treatments.

An example of improved tertiary treatment is membrane separation technology. Ultra-filtration and reverse osmosis principles are used to remove dissolved salts and organic substances. Although mainly used at present for heating water for use in kidney machines and the pharmaceutical industry, larger units are being developed for waste treatment and concentration in heavier industries. The advantage of the technology is that it can remove small quantities of potentially toxic substances, and separate water and dissolved substances without heat. It has potential for cost-effective treatment of wastewater so it can be reused, greatly reducing water intake and discharge needs, while also reducing the amount of pollutants discharged.[7]

Another example of improved waste treatment technology is the integrated treatment unit, which enables businesses and industries to reuse more of their water.[8] Up to a 95 per cent reduction in water use is possible, and the amount of pollutants discharged to receiving water is also reduced.

More R&D is needed in this area. The greatest challenge is to develop large-scale membrane separation and integrated treatment systems.

Water-Efficient Practices and Processes

In a household a water-efficient practice might be to reduce lawn size to save water. In a commercial or industrial establishment it might be to reduce water use through employee awareness programs, installation of timers, reuse of cooling water using cooling towers, or finding and repairing leaks. At the municipal level it might mean finding and repairing leaks. It does not include buying more efficient products.

A water-efficient process is really a special case of an industrial water-efficient practice in which a new or modified manufacturing or mineral extraction process is installed that, by design, uses less water to produce a tonne of product.

Recirculation of Cooling Water

Large quantities of water are used for process cooling in the industrial power generation sector and in the condensers of air conditioners and chillers in the commercial sector. The most common recirculation practice is to use a cooling tower. Cooling towers use the evaporative cooling principle, which brings the water in direct contact with air.

Water consumption can be cut by up to 90 per cent using cooling towers. Large conical cooling towers are common at most European and United States thermal power plants. In Canada, however, recirculation of cooling water in power plants is practised only in Alberta. In the industrial sector, only the rubber and plastics, wood, non-metallic mineral products, and petroleum and coal products industries (none of them highly water-intensive) have cooling recirculation rates greater than two.[9]

Where smaller volumes are involved, conventional air/water heat exchange may replace cooling towers.

Water Reclamation

In many manufacturing processes, water is used to wash parts or products, or to cool cutting or moulding machines. Large quantities of water can be saved by reusing the water that has been filtered and/or cooled. Research is needed to redesign machines so that there is less wastage, e.g., matching spray width to target and optimizing assembly line speed and water flow.

Water Control Practices

Most commercial buildings and industrial plants do not have many controls for closely monitoring water use and matching supply precisely with demand. Research is needed on the following water-saving practices:

- better mapping and metering of pipe systems and centralized displays
- using automatic shutoffs to limit single function uses (e.g., faucets, product washers)
- optimizing the operation of water-using equipment with better flow and temperature controls
- automating wastewater, recirculation, and reclamation systems so that only

water of less than a certain quality is treated and discharged
- controlling or reducing water pressure.

Leak and Infiltration Detection and Repair
Industrial water and steam systems often leak badly at valves, joints, traps, and so on. Improved inspection and maintenance procedures can greatly reduce leakage in above-ground systems. Below ground, more sophisticated methods, such as tracer dyes and ultrasonic detection devices must be used.

For municipalities with aging water systems, leakage from public water facilities, such as fire hydrants, and from the water distribution system is also a major problem. Chapter 3 gives examples of how leakage in municipal systems can be reduced.

Storm runoff that enters sanitary sewers (infiltration) is also a problem for municipalities. Many storm and basement drains are connected to sanitary sewers because they are located deep under the street below storm sewers. Either waste treatment plants must be large enough to handle peak capacities due to storm runoff or wastewater must at times be discharged without treatment. Solutions to infiltration are expensive. Storm drains connected to sanitary sewers must be located and reconnected. In many cases a pump is needed to lift water to the level of the storm sewer. Research that showed how to keep down the cost of sewer separation would be useful.

Process Changes
Many new industrial processes use water more efficiently than earlier ones. This is partly by design and partly due to a change in demand. For example, steel is being made more often in smaller, specialty steel plants that require less water. Water-use intensities vary between 5000 and 200 000 litres per tonne of steel, depending on the type of process used and the degree of recirculation practised.[10] The manufacture of products from scrap instead of virgin ore also reduces the amount of water required -- up to a 97 per cent reduction in the case of aluminum.[11]

Research is needed to determine how much water it takes to produce a tonne of product for each process used in the water-intensive industries -- food/beverage, paper/allied, primary metals, chemicals, and minerals processing; and to design new water-efficient processes.

Irrigation Practices[12]
Maintenance and scheduling of irrigation systems are important water-saving practices in irrigated agriculture. Lining irrigation canals reduces seepage; locating ditches for quick transfer reduces weed growth and evaporation losses. Scheduling practices involve measuring and matching delivered water and crop need.

Recent innovations include the use of lasers to check field levels so that there is more efficient coverage, increased use of local weather forecasting (using radio receivers) to avoid unnecessary water use, and water reuse pumps. These new techniques are widely used in the United States, but they have not been applied widely in Canada. Research should focus on ways to promote them.

Lifestyle Changes
Lifestyle changes may be defined as conscious decisions by consumers to use less water by reducing waste or reducing the demand for a water service. These would include washing the car less often, reducing lawn size (or letting the lawn dry out), and reusing water from clothes washers (for a second wash or on the garden). People do these things now in response to legal restrictions (e.g., in a drought situation), economic incentives (e.g., summer surcharges), or based on a private moral decision about the need to conserve. Awareness and education programs are the key to permanent changes throughout the population.

<u>Cost Reduction due to Water-Efficient Technology</u>
Studies have shown that businesses and industries that adopt water-efficient

practices and processes stand to benefit financially.[13]

- A Polaroid plant in Waltham, Massachusetts, began a program in 1980 that included employee awareness, mapping of pipes, metering, retrofitting, pressure reductions, spray nozzle conversions, timers, shutoffs, process changes, and recycling of cooling waters. Water use was reduced by about 50 per cent, from 1.99 to 1.05 million cubic metres per year. A $1.8-million capital saving resulted from a reduction in the size of the treatment plant needed. Annual savings comprise $313 740 in water and sewer costs, $50 000 in pre-treatment costs, and $195 000 in energy costs or a total of $569 000. The one-time program cost was $550 000.

- The Gillette Company began a water conservation program in 1973 at its plant in South Boston, Massachusetts, and has since expanded the program to all of its plants worldwide. The Safety Razor Division reduced its water use by 70 per cent, saving enough water to provide for 10 000 homes. The division installed cooling towers for plastic moulding machines, and now recirculates cooling water and reuses washing water. Total water use was cut from 2.75 million to 0.59 million cubic metres per year. The $1.025 million program cost has resulted in $771 000 annual savings in water and sewer charges.

- Since 1970 Howard Johnson's frozen food processing facility in Brockton, Massachusetts, has reduced water use from 240 000 to 28 000 cubic metres per year. The company introduced a leak detection and repair program, converted to a 4-day, 40-hour work week, installed a new cooling system, installed a compressor water recirculation system, began recirculating refrigerated water for process and comfort cooling, and enacted tighter controls on equipment operating time. The $30 000 cost resulted in $93 000 annual savings.

- A Digital semiconductor plant in Hudson, Massachusetts, instituted water conservation in 1982. The drainage system in the product rinsing area was retrofitted to reuse water. Conductivity meters signal valves to divert water, depending on its quality. Only lower quality water is diverted to the plant's wastewater treatment system. Annual savings of $341 000 have been achieved from a $20 000 investment. Annual savings include,
  - $22 750 in water fees, a saving increased to $91 000 by 1984 rate hikes
  - $22 750 in sewer charges
  - $61 000 in energy costs for pumping and water heating, and
  - $97 142 in on-site chemical treatment costs.

- The Augat electronics equipment plant in Attleboro, Massachusetts, installed flow restrictors and temperature control valves, changed wet processes, and installed a custom-designed heat recovery chiller to eliminate the need for cooling water for a solvent recovery still. The total program cost was $28 000. Water use has decreased from 62 000 to 10 000 cubic metres a year, and the wastewater treatment plant now runs only every third workday. Total annual savings equal $36 000.

Water Pricing

Early in the 1980s, the U.S. Office of Water Research and Technology tested the economics of municipal water conservation for both the United States as a whole and for specific cities.[1] The benefit-cost ratios over a wide set of circumstances were extremely favourable (nearly 10:1 for the nation). No comparable national review has been carried out in Canada, though some regional studies do exist. However, given common approaches, high rates of use, and the admitted wastefulness of many common practices,[2] it is most unlikely that general results in the two countries would differ.

Despite the common impression, water as a commodity is no different from any other natural resource. Appendix A presents overwhelming evidence that higher prices for water do lead to reductions in use, and that water is more valuable (i.e., users are willing to pay more) in some uses than in others. Although the response to a given price increase varies with a number of factors, pricing policies are useful instruments for managing water demand by making water users who use more water pay more.

Existing Pricing Systems

Municipal Sector -- Traditional municipal water rate structures follow one of three patterns:

- a flat rate (one charge regardless of use or discharge)
- uniform rates (the price of each litre of water is the same regardless of quantity used or discharged)
- declining block rates (the price per litre declines with increasing use so that the greater the use, the lower the average price).

The first rate structure provides no incentive to conserve; the marginal cost to the user is zero. In the latter two cases, some user incentive to conserve water exists as the price rises with increased consumption. However, neither adequately points up the value of conserving nor does either reflect increasing costs per litre.

Fortin and Tate report that 30 per cent of Canadian municipalities use flat rates for water.[3] Most others use some combination of flat rates and uniform or declining rates, although the volume of water charged at a flat rate is typically large enough that only large industries pay per unit of water used. Therefore, most Canadian municipalities are providing water at an effective marginal price of zero -- even though many of them face increasing costs for supply.[4]

Agricultural Irrigation -- Water for irrigation has typically been provided at much below cost.[5] Water agreements signed between the farmer and the agency providing the irrigation service base the charge for water on irrigated area rather than volume used, providing no incentive to conserve.[6] Metering water and basing prices on the amount of water diverted would reduce wastage and encourage farmers to adopt more of the water-saving practices discussed in chapter 2.

Industrial and Other Large Users -- Most municipalities charge industrial users for the amount of water used at a declining block rate. Some municipalities, such as Winnipeg, also charge industries for the amount and quality of water discharged into municipal sewers. However, self-supplied industrial users are seldom charged. Jurisdiction over direct water withdrawals lies with provincial (and territorial) governments. In the provinces, users apply for a permit that allows unlimited withdrawal from and discharge into surface or groundwaters and various provincial statutes and common law are used to resolve disputes between users. No cost is associated with the amount of water used. In the Northwest Territories and Yukon, under the Northern Inland Water Act, licences also set limits on quantities that can be withdrawn or discharged, but no charges are made. Authorities need to investigate how water users might be charged for the amount they withdraw directly from, and the quantity and quality they discharge into, surface and groundwater.

Alternative Rate Structures

Because water has different values for different uses, consumers tend to reduce their use of water as its cost approaches its value. Hence, the price structure is as important as the price itself. Among the price structures that have been identified and tried are the following:

- **uniform rates**, wherein the consumer is charged for the metered amount of water at the same per-unit rate no matter how much is used (i.e., the marginal rate is constant)
- **declining block rates**, wherein progressively lower per-unit rates are charged as the metered quantities increase (a decreasing marginal rate)
- **increasing block rates**, wherein progressively higher per-unit rates are charged as the metered quantities increase (an increasing marginal rate)
- **seasonal pricing**, wherein a higher per-unit rate is charged for water during the summer months when usage traditionally increases
- **excess use pricing**, wherein a special surcharge is applied if use exceeds a specified metered quantity
- **wastewater charge**, wherein the charge for wastewater discharge is tied to the quantity produced
- **sewer surcharge**, wherein a flat charge for sewage treatment is billed as a separate item on each water bill
- **marginal cost pricing**, wherein customers are charged at a rate that reflects the cost of expansion of the water supply and/or wastewater treatment systems.

Most analysts favour a system of water pricing in which prices track costs of water supply. The system that does this most accurately is known as marginal cost pricing. For the common situation in which water supply is increasing in cost, the appropriate rate structure would be increasing block rates. In most applications of this price structure the rate per unit of water increases as the volume of use increases, and the increases occur at specific points so that the rate structure exhibits a step-like pattern. Theoretical studies suggest that reductions of 50 per cent in water consumption could result from increasing block rates.[7]

The first major utility in the United States to adopt increasing block rates was the Washington Suburban Sanitary Commission in Maryland in the mid-1970s. Its system applies to all users, and incorporates 100 increments of use. Each increment is set at about 38-litre intervals. It also includes a capacity charge determined by the size of the pipe to the home or establishment. Other communities have followed with similar (though generally simpler) schemes. Fortin and Tate found only two Canadian municipalities with increasing block rates, both on the Prairies where costs of water supply are higher than elsewhere in Canada.[8] The Kitchener-Waterloo-Cambridge and the Durham regions in Ontario considered such systems, but decided not to adopt them.[9]

In Maryland reductions of only 18 per cent were observed (probably because the need for lawn and garden watering is low) and lower income consumers ended up paying less. Increasing block rates were adopted in Maryland following the recommendations of a citizens' advisory committee that gathered evidence and held public hearings. Authorities that have bypassed these steps have run into political opposition -- mainly from industrial and commercial users and people with large lots. In some cases, the opposition has been strong enough to force recall of the plan and to cause election defeats for councillors who supported the higher rates. In the Waterloo region, a modest plan to replace the current declining block rate with a more uniform one was halted because of industry's view that it would be unfairly penalized (a complaint that is justified only to the extent that industrial demand tends to be uniform over the year).

Another option for water pricing involves "lifeline rates" for residential consumers. Under this option, each consumer is allowed a certain volume of water -- presumably set to reflect typical household needs -- at a special low rate. The only large city to adopt this approach is Los Angeles where the first 900 cubic feet (roughly 25 000 litres) per unit-month is sold at a special low rate. Needless to say, if the lifeline rate is not set below cost, there is nothing to distinguish it from any initial block rate for water sold at a fixed price.

A further option that is increasingly being adopted is a "hookup charge" to the water and sewer system. This charge accurately reflects the marginal costs that the new connection imposes on the system. These costs may be two or three times as high per litre as average cost. This system has the advantage of varying according to the nature and size of the connecting unit, and even the location in the city or the height to which the water has to be pumped.

Peaking Rates

Given that water supply utilities face capacity limitations more often than absolute shortages, and that 50 per cent to 75 per cent of water utility investment goes to meet peak loads, it is surprising that so little attention has been devoted to economic means for cutting the peak. The main problem is seasonal loads, though daily peaks are a problem in a few areas. As a result of grass and garden watering, summer use is usually substantially above winter use (about 90 per cent higher in the United States) and reaches a peak when water supplies tend to be at their lowest. Instead of implementing peak pricing, authorities have introduced information programs and regulations designed to divert use to off-peak periods.

A variety of peak pricing systems are conceivable. Peak load pricing is one option, but, because it is more complex to apply with water than with electricity, and because the important peaks are seasonal not daily, a simpler option has been sought. The most common method involves a charge for excess use imposed on consumers whose summer use is more than some fixed percentage above their average monthly use. Such consumers pay a substantial surcharge per litre. Charge systems for excess use have the advantages of being easy for the public to understand and of offering a feeling of equity. They have the disadvantage of bluntness, however, -- the peak of residential use may not coincide with system peaks.

Like increasing block pricing systems, excess charge systems vary widely. Utilities in California impose surcharges ranging from twice to 20 times normal rates for the first block of excess use. These moderate to severe surcharges are reported to have cut overall water use 12.5 per cent to 30 per cent (with the larger figures in western states) and to have cut the ratio of maximum to average daily demand from 1.6 to 1.4.

Studies done for the Regional Municipality of Waterloo, Ontario, suggested that a surcharge come into effect for all customers when the ratio of summer to winter use exceeded 1.25.[10] If total system revenues were held constant, 80 per cent of customers would receive lower bills, 13 per cent slightly higher bills, and 7 per cent increases of more than 10 per cent. Most water users foresaw only minor implementation problems (e.g., allowing for new firms), but opponents were strong enough to block the proposal. The region also rejected the idea of a surcharge on large industrial sewage flows with excess oxygen demand or suspended solids. A revised plan is being prepared in which the surcharge would be applied on the wholesale rate between the regional municipality and the three major cities within the region. Research is needed on how to overcome the sociopolitical barriers to any excess charge system.

<u>Metering of Water Use</u>

Any system for charging per unit of consumption requires measurement, and metering permits greater control of the water system (see "Supply System Management" below).

In Canada, water is metered in about two-thirds of municipalities, including most of the larger ones, but in some cases the metering only applies to industrial and large commercial consumers. In the United States the use of water meters began early in some dry areas. Los Angeles installed its first meters in 1902 and completed its system in the late 1920s. Metering has spread rapidly over the last 20 years. A few states require all new users to be metered, and about half a dozen have total coverage, except for government buildings and services, parks and hydrant users. Nevertheless, many major cities, such as New York and Washington, D.C., remain largely unmetered.

In the municipal sector the installation of meters without any price increases has caused permanent reductions in water use of 10 per cent to 40 per cent. Not surprisingly, the biggest decreases come in summer use. Commonly reported volume reductions are 20 per cent indoors and 30 per cent outdoors, and peak-day reductions of 20 per cent to 40 per cent. Per capita use of water fell by 23 per cent when the Durham region of Ontario installed meters and added a surcharge for sewers (previously paid for through property tax). The bulk of the reduction occurred within two years of meter installation.[11] These reductions in water use are impressive considering how small the absolute increases were in typical annual water bills -- for example, from $93 to $160 between 1976 and 1981. Comparable results are obtained regardless of whether metered and unmetered cities are compared, or individual cities are studied before and after meters are installed. Edmonton, which meters all residential users, consumes half as much water as Calgary, which is only partially metered.[12] Those parts of Calgary that are metered, however, show rates of use similar to those in Edmonton.

In the late 1970s meters were said to be cost effective if water cost more than 21¢/1000 litres and the meter could be installed for less than $500. A 1986 report from New York State states that meters will be cost effective at anything under $650 per meter. The same report said that a meter (device and installation) costs $400 at a residence and $2000 at a large apartment house. A 1984 California report states that the cost of providing metered water to a house at the time of construction is only $80. Many regions in Ontario and some cities in other provinces are now moving to water meters with remote reading capabilities to eliminate the need for someone to enter the house to check the dial.

Metering of water for industry has been common for some time. What is new is the metering of the return flow to the sewer system. In a few cases the rate varies not only with the quantity but also with the quality of the return flow.[13] Case studies show that such charges commonly result in cuts of one-third to two-thirds in the volume of discharge from such widely varying industries as steel, food processing, and electronics.

Installation of meters does not solve all measurement problems. For accurate results, meters have to be sized and matched to the user. In addition, after 8 to 10 years, meters tend to wear out, which results in under-reporting of water use. This not only reduces the efficiency of water management but also reduces returns to the supplying agency. Under-reporting also occurs at low flow rates (less than about 3 litres per minute in typical residential meters), with the same results. According to authorities in California, a meter maintenance program is almost always cost effective. In cities that have instituted programs of meter replacement, the payback period simply from the elimination of under-reporting has been less than a year.

Supply System Management

Other actions, besides installing meters and establishing a pricing system, can be taken by water supply utilities to cope with growing demands and capital shortages. Two offer substantial savings: reduction of pressure in the mains and elimination of leaks.

Pressure Reduction

Pressure reduction reduces both water usage and leakage, and cuts down on maintenance costs for the system. The reduction has to be consistent with firefighting requirements, but in general pressure in municipal areas need be no higher than 345 to 420 kPa (50 to 60 psi) in the mains and 275 kPa (40 psi) inside a house. Many systems operate at pressures twice this high. Pressure can be reduced relatively cheaply by installing special valves in the mains. In one system where typical pressures were above 500 kPa, uniform reduction to 345 kPa would, based on a mathematical calculation, have cut use by 16 per cent to 24 per cent and peak demands by 27 per cent; about half this amount is more likely in practice.

Leakage
The extent of leakage in U.S. water systems seems unrelated to the age of the system. Systems experience leakage of from 12 per cent to 40 per cent.[14] Some states have active technical and financial assistance programs to aid municipalities in leak detection and repair, and many water utilities there, and some in Canada, have ongoing leak detection and repair programs.

With modern sonar equipment and flow measure techniques, leak detection crews can survey 2 to 3 km of main per day, much faster than formerly. However, repairing underground leaks can be costly, and may not always be worthwhile. Several years ago Pitometer Associates told the Regional Municipality of Waterloo, Ontario, that, "based...on 80 years of experience," not much can be done with water systems leaking less than 15 per cent.[15] On the other hand, California officials argue that it is generally more cost effective to repair leakage than to expand the system down to leakage levels of 1 per cent to 2 per cent. A side benefit is reduced property damage; as water leaks undermine roads and structures. The type of leak detector selected should be based on preliminary evaluation of losses.[16]

Other Measures
Utilities can reduce water losses in at least two other ways: corrosion control and valve "exercising." The former is closely related to the leak reduction program, and the latter ensures that valves are operational and efficient. Both are low in cost and should be part of normal preventative maintenance programs.

Regulation of Water Use and Discharge

Plumbing and Building Codes
Since the early 1970s, when California set the pace, the use of plumbing codes to conserve water has become common in the United States. Although objections are still raised -- e.g., the codes are intended for safety, not for efficiency; codes become maximum, not minimum, standards -- the gains from water conservation are so substantial, and the fixtures involved are so often bought by contractors rather than by the ultimate users, that the arguments have had rather less weight than comparable arguments about using building codes to attain energy efficiency. As of the mid 1980s, about one-third of the states had plumbing codes that set standards for the water efficiency of certain fixtures, backed by protocols for measuring efficiency. In Canada, plumbing codes do not include efficiency provisions, and provinces do not allow selective codes that apply to one region or municipality. Building and plumbing codes have been brought under provincial jurisdiction for the specific purpose of eliminating variations from one municipality to another. The only discussions on record among a municipality, plumbing manufacturers, a standards writing body, and a provincial government, about standard protocols for defining water-efficient fixtures and adding efficiency provisions to the plumbing code, occurred in 1980-81 in Kitchener-Waterloo. However, these discussions did not lead to any standards or code changes.[17]

The use of by-laws to enforce water conservation by means of plumbing codes is also common in the United States. A well documented example is that of Fairfax County, Virginia, where by-laws governing flow rates and water usage for new construction and repairs caused a 6 per cent reduction in demand and a nearly 15 per cent reduction in treatment and distribution requirements, as well as a reduction in peak demands.[18]

California officials calculate that with a plumbing code that only specifies the lowest cost approaches, and less than state-of-the-art fixtures, inside water use by typical families in new residential buildings would be cut by 30 per cent to 55 per cent (and by 50 per cent for hot water). For retrofits, the savings would be somewhat lower, 19 per cent to 44 per cent. In either case, payback occurs within a year and cost effectiveness is very high.[19]

Fairfax County (Va., USA) Plumbing Code

Water closets, tank type: 3.5 U.S. gallons per flush
Water closets, flushometer type: 3.0 U.S. gallons per flush
Urinals, tank type: 3.0 U.S. gallons per flush
Urinals, flushometer type: 3.0 U.S. gallons per flush
Shower heads: 3.0 U.S. gallons per minute
Lavatory, sink faucets: 4.0 U.S. gallons per minute
Lavatories for public use: faucets of lavatories located in restrooms intended for public use shall be of the metering, or self-closing type.

In commercial institutions using comparable techniques (with appropriate variations, such as self-closing valves) savings of up to 40 per cent would be possible. The results in commercial establishments vary depending upon the business -- highest for hotels, motels, and dormitories where usage is similar to the residential sector; 20 per cent to 25 per cent for car washes, beauty salons, and retail establishments. The potential in apartment buildings is high, as indicated by metered rates of use ranging from 200 to more than 1000 litres per suite-day. Appropriate retrofitting can pay for itself within a year, but, in contrast to many energy conservation techniques, regular servicing of water-conserving devices will be required. Application of the code also reduces sewage flows by 10 per cent or so in typical communities. Box 1 indicates some measured savings based on case studies in areas where plumbing codes have been enacted or made a part of the building code.

About half a dozen types of plumbing code are in use. The National Standard Plumbing Code, used by many government agencies in the United States, is the "leader in progressive water conservation standards."[20] The more advanced codes provide not only the standard but also the protocol for measuring water use.

In Canada, there is an immediate need to include water efficiency in plumbing and building codes.

Minimum Standards

Instead of regulating water appliance and fixture efficiency under a plumbing code, a water authority may set minimum standards for new appliances or fixtures manufactured or sold within its jurisdiction. These minimum standards must be practical and attainable, and standard protocols for measuring water consumption must be agreed upon. Experience with appliance and heating/cooling equipment standards in the United States indicates that a system of national (or even continental) standards is by far the most manageable arrangement. Recent United States legislation sets energy efficiency standards for 1990; these were negotiated by government, industry, and special interest groups. The feasibility of a Canadian national minimum water efficiency standards program should be investigated.

Conservation Requirements in Water Permits

A number of American states have begun to limit new permits to drill for, take, or otherwise use water to applicants who can demonstrate that they do not neglect low-cost conservation measures. Similar requirements have been applied to requests from one level of government to another for assistance with municipal construction or with expansion of the supply system. Only California requires that each water utility considering expansion develop a long-range conservation plan.

Making conservation requirements a condition for granting other forms of permits -- e.g., at the time of property transfer or with a request for a zoning change -- has been discussed but not

Box 1. Selected Examples of Water Savings through Improved Plumbing Codes

- Boston's Prudential Center complex realized savings of 9000 cubic metres of water and 227 000 kilograms of steam a year from a 1973 program to retrofit toilets and sinks.

- Pennsylvania State University installed low-flow showerheads in dormitories at a cost of (U.S.)$15 000. The university has since saved over (U.S.)$100 000 per year in water and energy costs.

- At Gettysburg (Pennsylvania) State College, a faucet and shower retrofit program, with an initial investment of (U.S.)$5000, resulted in a first-year reduction of 32 per cent of total water use and an annual saving of (U.S.)$13 550.

- The Park Plaza Hotel in Boston achieved first-year savings of (U.S.)$30 000 to (U.S.)$50 000 by retrofitting rooms with 9.5 litres-per-minute showerheads. The cost of the program was recovered in 30 days.

- Iyanough Hills Motor Lodge, also in Massachusetts, reported 35 per cent savings in fuel and water costs from installing low-flow showerheads, toilet tank inserts, and faucet aerators in rooms. No guest complaints resulted from the changes.

- In East Brunswick Township, New Jersey, 564 packets of water-saving devices were purchased and distributed at municipal expense. Two-thirds of the contacted households installed at least one device. An average home saved 23 cubic metres of water per year at a cost to the township of 12¢ per 1000 litres saved (in 1980 dollars). Projecting these results to the entire town of 37 000 suggests a potential savings of 160 000 cubic metres per year, or 43B cubic metres per day. This figure, not counting production for outdoor use, is 3.4 per cent of daily production and could support 400 to 450 new homes.

- Amherst, Massachusetts, in a state-funded pilot program, offered low-flow showerheads to a group of home owners. Those homes decreased use by 16.4 per cent. An apartment complex in the town installed low-flow showerheads and reduced water pressure, resulting in a 33 per cent drop in total water use.

- In another state-funded demonstration project in Massachusetts, the town of North Reading provided low-flow showerheads, toilet flushdams, and faucet aerators to 180 homes. Average water use in the households decreased by 15 per cent. Expanding the program to the entire town was estimated to cost (U.S.)$18 per household; the value of the saved water alone would recover the costs within 31 months.

Source: New York State Senate Research Service, Water Conservation: The Hidden Supply (Albany, N.Y., 1986).

implemented. This approach was not politically acceptable for energy conservation, and this experience may have made legislators cautious.

In Canada, the only areas where permits or licences are used to regulate water withdrawals are in the Yukon and Northwest Territories under the Northern Inland Water

Act. Under the act, water boards grant licences covering withdrawals and discharge quantity and quality (concentration and pollutant loadings). The water boards are beginning to use licences to encourage the use of the most water-efficient technologies and practices, and to treat use of assimilative capacity of water as a "demand."[21] Other jurisdictions should study the potential for comprehensive demand management using an instrument such as the Northern Inland Water Act.

By-Laws
Municipalities commonly use by-laws as a way of restricting water use, particularly during dry summers. Such by-laws can affect a wide range of water uses from the glass of water offered on the restaurant table to irrigation. Perhaps the single most common use of by-laws is to restrict lawn and garden watering by day on an odd/even basis. (These restrictions can backfire: people may water on "their" days, even if the water is not required. In some cases, water use has gone up after passage of the "restrictive" by-law.) By-laws have also been used to prohibit hosing of sidewalks, air conditioners that have high flow rates (per tonne of cooling capacity), and even certain industrial and agricultural practices.

Pollution Controls
The legislation of pollution controls on municipal and industrial discharges, through the granting of licences, or the setting of minimum standards, has an indirect impact on water demand. In addition to reducing the amount of contamination, such controls are also an incentive to reduce water use through more efficient practices and processes. In Sweden, strict effluent controls resulted in the pulp and paper industry cutting its water use in half over a 10-year period.[22] In the United States, water use in industry dropped dramatically with the passage of the Clean Water Act. In Ontario, new municipal effluent standards will force municipalities to reconsider expanding sewage treatment facilities without first trying to reduce water demand.[23]

Under the Northern Inland Water Act, Territorial Water Boards have the power to license the loading and concentration of pollutants being discharged into rivers and streams. Licences can be used to limit the degradation of water and indirectly to encourage more efficient use of water.[24]

Canada should document the reduction in water use associated with effluent controls in the United States and other countries. There is also a need to assess the ability of legislation, such as the Fisheries Act, the Northern Inland Water Act, and the proposed Environmental Control Act, as well as the U.S. Clean Water Act, to encourage efficient use of water.

Financial Incentives
Direct financial incentives for water conservation are uncommon. California used to offer tax credits on the purchase of water-efficient irrigation equipment and conservation systems, including both rainwater and graywater (all household waste water except toilet) cisterns and more conventional water-conserving devices and fixtures. South Carolina also offers tax credits. Financial incentives have also taken the form of retrofit programs, direct rebates to builders or contractors who install water-efficient fixtures, and government-to-government grants.

Retrofit Programs
A form of financial incentive common in watershort areas of the United States involves the free distribution of water-conserving kits to residences. Some utilities have gone further and also offer free installation of the devices, which, of course, increases the cost but also their acceptance. Surveys indicate that where installation was left to the householder a maximum of 60 per cent of recipients installed the kits. Higher incomes and greater water use boosted the rate of installation. At Californian water rates, the kits paid for themselves in about a year of use. Follow-up surveys suggest that 60 per cent to 90 per cent of the devices were still in place five years after installation, with the lower figures applying to toilets and the higher to showerheads.

The most extensively documented retrofit program in Canada occurred in a subdivision of 650 homes in Kitchener, Ontario. The program was undertaken by the University of Waterloo with labour hired through a federal employment program. The program offered both retrofit devices for bathroom fixtures and installation. The range of savings was wide (negative in 9 per cent of the homes) but averaged 13 per cent of total household water use. Given the $15 cost of devices and installation, the payback period was eight months. Similar results were attained in a smaller test in apartment buildings.

Although the Kitchener program was considered successful, Pawley mentions a number of problems.[25] The savings were not visible and householders tended to remove the devices if they did not work properly. Also, some householders referred all future plumbing problems to the municipality, whether or not related to the retrofit devices. Howard-Ferreira and Robinson had from the first maintained that retrofit programs such as the Kitchener one needed a strong public education program and an information program about which devices work and how they work.[26] As a result of such problems, Kitchener did not adopt a full retrofit program, although it maintained free distribution of the conservation devices at municipal offices and a registry to permit follow-up.

All evidence indicates that retrofit programs work best if installation is provided. In this way the best device can be selected for the fixture, and proper installation is assured. Research should be undertaken to determine how to avoid the problems with installation that were identified in the Waterloo test.

Rebates and Direct Incentives

The regional municipality of Waterloo in Ontario offers a $75 rebate to any plumbing contractor who installs water-conserving fixtures in new or renovated residential units.[27] The $75 figure was set so as to provide a direct incentive beyond the added cost of the fixtures ($20 to $43 per household), which cost the same as conventional ones to install. Savings to the householder are $30-$60 a year and to the region $58 a year.[28] This program was not successful until a catalogue of CSA-approved fixtures made selection convenient. Rebates are now paid for over 200 units per year. In developing the program, a number of options, including direct payments to the homeowner and reductions in the lot levy (which is intended to cover costs of servicing new lots), were considered but rejected in favour of working directly with the contractors.

But contractors are still cautious about new water-efficient techniques and equipment. Most (even those who promote conserving fixtures in their sales efforts) do not take advantage of the rebates, despite substantial savings for owners of single family homes, and the satisfactory performance of the fixtures.[29]

Increased awareness among building contractors has successfully overcome similar caution with respect to energy conservation. Research is needed to determine the extent to which similar information programs could be used to teach plumbing contractors about the advantages of water conservation.

Intergovernment Programs

In the United States, financial incentives take the form of government-to-government assistance with, say, meter installation or leak detection and repair (in some cases equipment rather than money is loaned). According to a report from New York, "Several states offer grants, loans or technical assistance to local suppliers (local water authorities) to help conserve water."[30] Other states bias their existing system for awarding grants for water development projects by giving bonus points to authorities that incorporate conservation in their programs. Such intergovernmental programs are not common in Canada.

Information Programs

Information programs are the most common methods employed for reducing water use. According to surveys, consumers expect governments to focus on information programs to a much greater degree than financial assistance and conservation pricing. The public's concerns about water conservation go well beyond simply saving money. Programs that focus on economic benefits will have a smaller impact than those that make the case for conservation on broader grounds.[31]

In some areas, reduced water usage may be attributable to the existence of successful information programs. Yet, surprisingly little is known about the effectiveness of specific types of program. Effectiveness also depends on (a) the extent of water problems, and (b) supporting measures (e.g., water pricing).

Public Education

Public education approaches have included bill stuffers, parades, sophisticated motivational advertising, and telephone hot lines. One of the most imaginative has been the introduction of a water-use index in the Kitchener-Waterloo area of Ontario.[32] The index is published daily during the summer and citizens are expected to conserve water depending on its level. The value of the index is set according to the capacity of the area's water system and the water-using habits of the population. It has a value of 100 at the average daily demand from the previous year and a value of zero at what is considered to be maximum safe delivery capacity. (This form of index has the advantage that the zero setting can be adjusted as necessary.)

The impact of an imaginative education campaign may be seen through a comparison of two U.S. cities: Tucson, which has actively promoted conservation through educational programs, and Phoenix, which has not. Current reports indicate that per capita daily consumption in the former is less than half that in the latter. Success in this case was partly a result of attention being focused on summer use, with encouragement not to water lawns, wash cars, or fill swimming pools during peak periods.

Education about appropriate lawn and garden care -- generally involving less water than most people believe necessary -- has been effective, as have efforts to encourage the planting of drought-resistant and local species. Some cities crack down on fire hydrant use for summer cooling or install sprays that offer children the same pleasure with a fraction of the water used by an open hydrant. Intensive education programs using a variety of media, can also be used to shift the time of use away from the system peak.

Education programs for employees are essential to industrial and commercial water conservation: in the absence of commitment from management and education for staff, conservation becomes uncertain. A side benefit of employee education programs is that they reinforce the idea of conservation at home.

Information Distribution

The most common way to make users aware of water conservation is a billing format in which householder (or establishment) consumption is shown and compared with the previous year and with some assumed "standard" level of use. Another approach involves tags affixed by meter readers to outside taps indicating how much water will come from opening the tap only one-quarter or one-half.

Although analytic studies are lacking, it is generally agreed that information on the water-use characteristics of plumbing fixtures will have an influence on purchasers, and that means plumbers. This is the approach that has been followed in Kitchener-Waterloo where the regional municipality now publishes, and annually updates, a "Water-Efficient Fixtures Catalogue." Because of its limited distribution, however, this catalogue has had no effect on manufacturers. In fact, according to one analyst, Canadian manufacturers of plumbing equipment resist notions of efficiency because they prefer to market largely on the basis of style, not function.[33] Another possible approach is to use a labelling program for water-using appliances, similar to the Energuide labelling program. Washing machines and dishwashers could have labels affixed that show water as well as energy use.

Water-Use Audits

The first step in any water demand management program for apartment houses,[34] commercial buildings, and industrial establishments is an audit to document where, when, and how water is used. Considerable effort has gone into developing simple audits in the form of checklists for the common kinds of commercial, institutional, and industrial establishments.[35] For more complex operations, more sophisticated audits become necessary.

School Programs
A variety of school programs, including extended study curricula, have been developed around the issue of water (not exclusively demand) management. One of the most innovative education kits on water conservation was developed by the National Survival Institute for use in Calgary schools. Lesson plans and information for grades 4, 5, 6, and 9 were developed, and a computerized simulation game designed for use with the grade 9 kit. The game sets up the player as a municipal water manager who must respond to water crises and make decisions with respect to new development and water supplies, with quotas of money and sources of supply. There are plans to develop similar kits for cities elsewhere in Canada. There is a need to expand this approach and perhaps extend it outside the school system into municipal training programs.

Training Programs
We found no Canadian examples of training programs for commercial and industrial sector building and plant managers, nor for municipal water system planners and generators. This important area should be studied further.

Recirculation and Process Change
Although recirculation is used to some extent in industry and in thermal power plants, few demand management initiatives specifically encourage it. The only program designed to encourage industrial water efficiency is in Israel, where minimum water-use standards per tonne of product are set for each industry and are gradually increased as more efficient technology is developed. This program has resulted in a 70 per cent reduction in industrial water use in 20 years.[36]

Effluent standards and other forms of pollution control indirectly encourage industries to reuse water and to use more efficient processes. Environmental regulations appear to be the main force leading to cuts of 45 per cent in water withdrawals by the pulp and paper industry in Sweden and in California.[37] In the two territories, licences could be used to ensure that industries use water as efficiently as possible.

Water recirculation in other sectors is rare. Costs to restore municipal wastewater to potable quality are high -- at least $1.00 per 1000 litres, and even more using current technology. Denver, Colorado, has an experimental program aiming for restoring wastewater to potable water quality by 2000, but has not overcome the problem that many heavy metals and chemicals are not removed by conventional treatment. New treatment techniques using ultra-filtration may make reuse more feasible (see chapter 2). There is a need for incentives that encourage recirculation in all sectors.

Research and Development
Support for R&D programs is essential if demand management is to be widely used. The development of new products and processes in energy conservation and renewable energy was accelerated through programs run by the National Research Council and government departments. Although support for research on how to lessen demand for energy never matched that for research on how to increase the supply, significant research programs were carried out and the results transferred to Canadian industry and energy users. We would expect a similar pattern in water research. The interdepartmental approach adopted in the Panel on Energy Research and Development may also be applicable to water.

In Canada support for research on how to reduce demand for water has traditionally been weak, and no specific programs have been implemented. Only about 2 per cent of all water research funds in 1983 were spent on water conservation projects, and half of this was in the agricultural sector.[38]

Mitchell and McBean cite demand management research as a top priority.[39]

We need research and data collection on all types (e.g., analytical, technical, and socioeconomic) of water demand management and in all sectors. We also need federal and provincial programs to support water demand management. Few models exist in other countries, but Mitchell and McBean have suggested several strategies for water research that should be further developed.[40]

The previous chapter of this report considered management of the demand for water in terms of policy options. These policy options are rarely applied one at a time. More commonly, several changes are made at once during a period in which consciousness of the need for such policies is spreading. This chapter considers management of water demand from a regional point of view. How have the policy options been combined into programs in Canada and the United States?

Canada

The importance of demand management was not widely appreciated in Canada until the subject was addressed by the Inquiry on Federal Water Policy in 1985. Although the inquiry made several recommendations about municipal water pricing, it was silent on how comprehensive sectoral or regional programs to manage demand for water might be executed. The only really comprehensive one in Canada has been running for the past 10 years in the Regional Municipality of Waterloo, Ontario, although some municipal governments apply summer restrictions in dry weather.

According to Robinson's analysis of the Waterloo water program, the region has legal responsibility for water supply, whereas individual municipalities retain responsibility for distribution.[1] Rural areas have adequate groundwater supplies to last until after the turn of the century, but during hot dry weather the growing urban areas approach the limits of their groundwater capacity. Realizing it would be expensive to increase supply, regional councillors initiated, in the mid-1970s, a water conservation program that focused on public education and water-efficient plumbing fixtures.

The University of Waterloo was asked to help advise the Regional Municipality and set up some of the programs. The aspects of the program that deal with management of water demand have received considerable impetus from the faculty of the Department of Man-Environment Studies (now Environment and Resource Studies) at the university, "who were able to introduce new ideas to their less enthusiastic municipal engineering colleagues."[2] Appendix B provides a chronological outline of the program. To further their cooperation, university staff proposed a unique arrangement to the regional municipality: a Municipal Working Group on Water Conservation Alternatives was created and brought together representatives from each jurisiction within the municipality. This body obtained funds from each jurisdiction, reviewed program proposals, and supported research into water conservation. Within a few years, the working group had become influential enough (and water had risen high enough on the political agenda) to be renamed the Regional Advisory Committee on Water Conservation and made a permanent responsibility of the engineering department.

Among other things, the committee conducted a pilot retrofit program, distributed free water-conserving devices, offered rebates to contractors installing water-efficient fixtures, and conducted a public education campaign. A by-law requiring the use of water-efficient fixtures was not possible because responsibility for the plumbing code lies with the province, which was reluctant to permit municipal variations. Local opposition also blocked proposed changes to pricing practices.

Conflicting trends make it difficult to determine whether or not the program was successful.[3] A survey carried out as part of a "Master Water Supply Study" found that the public does not consider water conservation a pressing issue. Recent developments in the municipality suggest that, even after 10 years of managing the demand for water, and with a single agency responsible for water supply and sewage disposal in place, the municipality still sees demand management as an interim measure.

The view is not reasonable. If the cost of all the new supply and treatment schemes now being considered under the Master Water Supply Study are to be recovered, water users in the region will see a fivefold increase in their water costs.[4] It is estimated that a doubling of current water prices will lead to a drop in water use. Therefore, the region will not be able to pay for the schemes by passing the costs on to consumers. A combination of demand management and supply augmentation would be a far more reasonable approach. Unfortunately, the view that demand management is an interim measure is still held in hundreds of other communities. Municipalities urgently need planning tools that show how to integrate the effect of cost increases into water supply and disposal plans.

Because the data available on the efforts of the Regional Municipality of Waterloo to manage the demand for water are so extensive, the authors recommend they be further analysed.

United States

In the United States, climatic conditions vary widely and water, being a local, state, or regional issue, is controlled by many jurisdictions. Therefore, the number of attempts to manage water demand has been high, and more is known there about managing the supply of, and demand for, water than in most other parts of the world. With few exceptions, the attempts at management have been straightforward and their results remain unintegrated and only poorly documented.

Federal programs for water demand management are rare in the United States due to constitutional division of powers and strong regional interests in water. However, the federal government supports and builds water supply projects and provides matching funds for sewage control plants. It has undertaken a number of forecasts of water demand, but attempts to control this demand have been left to state and municipal authorities.

However, in one way, the federal government has played a major role in demand management: as indicated in chapter 3, passage of the Clean Water Act was intended to reduce the damage from uncontrolled water discharges, mainly from industry, but has had the side effect of forcing firms to completely re-evaluate how they use water. In many instances, they began reusing water to reduce the amount of pollutants discharged, thereby greatly reducing the volume of water withdrawn or discharged.

Studies have assessed the extent to which states are involved in water demand management.[5] The results of the Blackwelder and Carlson study appear as appendix C. Although the study was conducted more than 5 years ago, the survey is still representative of the extent of state efforts.[6] California operates by far the most extensive state program -- it is the only state with an Office of Water Conservation (staff of 20) -- followed by a group including Arizona, Florida, Massachusetts, New Jersey, North Carolina and Oklahama, with the other states falling well behind. Almost all states make some effort to educate the public, most tie in responsibility for conservation planning with that for water supply, many have programs for retrofitting state buildings (especially dormitories), and many provide assistance with leak detection and repair. However, the attitude in state water supply utilities and agencies is that water conservation is a stopgap measure that at most will achieve 10 per cent savings and will raise rates. Typically, these agencies appropriate little or no money for conservation.

The programs of two states with relatively strong programs -- California in the west and Massachusetts in the east -- will be surveyed here. They are similar in that both are industrial states with growing populations and declining surface and groundwater availability. They differ in size and in the amount of water used for agriculture and for residential outside uses (3 per cent in Massachusetts; 47 per cent in California).

California

From the time of European settlement, water has been critical to California's economic development, and for that reason has been a central concern of government. The state developed an extensive system of reservoirs and canals, managed by a Department of Water Resources, but over the past 20 years it has become apparent that the system was not merely vulnerable to periods of severe drought but also that physical and economic limits to expansion were in sight. Local water utilities started examining water use in the early 1970s; in 1976 the first major state-wide conservation study was published; and by 1983 the state water plan indicated that growth in water use should be cut by one-third through conservation in municipal and agricultural uses -- mainly the former.

California has begun to implement this plan. Since 1928, water conservation had been identified as a goal in the state constitution. Over time, the courts interpreted this to mean that all water use was subject to this provision, and that it referred to both <u>reasonable</u> and <u>beneficial</u> use, where the former implies efficiency and the latter social utility. Not surprisingly, a large body of case law now exists that makes almost all uses of water subject to a permit system. The state water code has been amended to ensure that those who conserve water are not penalized by older "use it or lose it" provisions in permits. Groundwater pumping rules are also designed to encourage conservation, but these rules have not yet gained widespread public support.

In 1976 California became the first state to adopt a plumbing code intended to save water. This code is backed by American National Standards Institute (ANSI) national performance standards, is part of the state building code and therefore applies to all new housing, and is supported by provisions of the State Energy Commission. California also provides grants on a benefit-cost basis to small and medium-sized water utilities for audits and leak detection programs: utilities are expected to maintain programs once the grants cease. The state also has a program aimed at helping growers use water efficiently and for several years provided tax credits for the purchase of more efficient irrigation equipment. Similar tax credits were available until recently for water-efficient toilets and showerheads, rainwater and graywater cisterns, flow-reducing devices, and industrial equipment.

In support of the foregoing measures, California has also set up the best public education program about water anywhere in the world. It includes school programs, speakers, radio and TV spots, and technical and general information brochures. Technical assistance on water conservation is offered to state agencies, municipalities, water utilities, and even to large private users. The most notable parts of the program relate to landscaping (providing detailed ways to reduce water use by up to 70 per cent through species selection and optimal watering) and household use (free distribution of water-saving devices for toilets and showers). In the first year a pilot program demonstrated that savings of three times the cost could be achieved. The program was eventually extended across the state using mass mailings, school programs, and public information programs. In areas where the program has continued, the retention rate for toilet retrofits is over 65 per cent, and for showerhead retrofits it is nearly 90 per cent. California's education program, like its plumbing code, has been widely copied.

Massachusetts

The water demand management program in Massachusetts was set up only five years ago, as it has only recently become evident that even in the northeast water quantity and quality are serious problems. To get the program off the ground, the state initially provided funding and technical assistance for municipal demonstration programs involving rate structures, water-saving devices, pressure reduction, and use of graywater, that led to significant savings for many communities and the cancellation of what would have been expensive supply augmentation plans.

The program now established is simpler than that of California. It depends more on education and information and leaves most of the action to individual firms and municipalities. Perhaps the state's most important contribution is giving strong reinforcement to all water conservation efforts by commendations and publication of results. It is remarkable how many case studies of water conservation by industries and businesses come from firms located in Massachusetts. It is unclear whether this reflects better management of firms or better publicity for results.

Under the program, Massachusetts requires metering; it has adopted a plumbing code applicable to all new buildings; state buildings have been retrofitted with water-conserving appliances; and 50/50 matching funds are available for leak detection. The state also monitors rate structures and manages groundwater withdrawals.

The state's efforts have been supported by a number of nonprofit groups, notably Resource Management Associates, whose activities have included developing and promoting water conservation techniques for municipal, industrial, and commercial users.

New York

The State of New York all but ignored water conservation until it suffered the second of two droughts within five years in 1981; now most of its policies focus on measures to alleviate conditions during droughts. The state also regulates water supply companies and utilities and requires water permits for almost every step related to drinking or irrigation water and for drilling of water wells. The state does not gather its own data about how water is used, but it maintains access to a national database developed by the United States Geological Survey, which details water use in seven sectors by county and by river basin.

The state government has offered only rhetorical leadership for conservation planning. On the other hand, some local and regional bodies have already moved toward water demand management. Notably, the City of New York is being urged to include demand management as one of three parts of its water program (the other two are increasing supply and evaluating trends). Among the recommended actions are metering, conservation pricing, leak detection and prevention, education campaigns, plumbing retrofits, and recycling and dual water systems. Suburban areas are adopting similar programs but their goals appear to be very modest.

The New York State Senate Research Service has published a report documenting current water conservation activities and their potential.[7]

Other States

A few other states have initiated programs with interesting elements. Connecticut allows private water companies that provide management services to small water users to exempt their fees from the rate-making process. Connecticut also requires applicants for water-use permits to outline proposed conservation measures and long-range conservation plans. Several states offer water supply utilities and certain users technical help in detecting leaks. Pennsylvania and a few other states couple this assistance with funds or equipment. Pennsylvania, Delaware, and some other states also require that applicants for permits or well drilling indicate what they have done and will do in order to conserve water. Most states, however, merely require that the use be beneficial and in the public interest. Oklahoma has made waste reduction and water conservation prerequisites for state funding for sewage and water supply projects. North Carolina ranks funding applications according to a point system in which extra points are assigned for specified water conservation activities. Many states now require metering, at least for new consumers or larger systems. New Jersey is the only state that requires that all residential water bills have a standard format so that consumers can easily determine usage and the effectiveness of their conservation efforts. Arizona is notable for the extensiveness of its groundwater management laws and programs. They affect all wells and all users: agricultural users have to develop conservation plans; and new development requires proof of a 100-year supply. South Carolina mandates the use of trickle and drip irrigation systems and micro-sprinklers. Wyoming has a recycling program for water in areas where oil drilling is occurring. Florida and other states with large irrigation requirements have established water control districts governed by special rules. Finally, Nebraska recently published a study that outlines options for reducing water demand, particularly in irrigated agriculture.[8]

Data on Canadian Water Use

Environment Canada collects data about how water is used and publishes them in the Canada Water Yearbook and elsewhere.[1] These publications report how much water is used by industry (manufacturing, mineral extraction, and thermal power), by agriculture, and by municipalities in each province. The municipal water demand statistics are based on periodic surveys by Environment Canada (stored on the department's MUNDAT database). The information is reported by province and by type of water distribution system (utility or wholesale/retail trade). Ontario, Quebec, Alberta, and British Columbia have the largest municipal water use.[2] The distribution of municipal water use among the sectors is estimated as follows:

- Residential 44%
- Commercial/Public 26%
- Industrial 17%
- Leakage 13%

Residential: The water used in the residential sector is almost never measured (and the result never published) independently of overall municipal uses.

Commercial/Public: The only source of data on the commercial sector's demand for water is in those municipalities that meter water use and differentiate between classes of customer.

Industrial: How water is used in the industrial sector is well documented. The Department of Environment surveys industrial water use every few years and publishes the results.[3] For each province and for each Standard Industrial Classification (SIC) group in "manufacturing and mineral extraction industries," it collects the following data:

- number of plants and number of employees
- total water intake, recirculation, gross use, consumption, and total discharge
- water intake by source: fresh/brackish, public/self supplied, surface/ground/tidal
- type of intake treatment: filtration, disinfection, slime control, screening, hardness control, none
- intake by purpose (end use): processing, cooling/heating, sanitary
- distribution by month
- water discharge by point of discharge: public, freshwater, tidewater, ground, reuse
- water discharge by type of treatment: primary, secondary, tertiary, none
- water recirculation by purpose: processing, cooling
- water costs for acquisition, intake treatment, recirculation, discharge treatment.

In the industrial sector, four manufacturing and two mineral extraction groups dominate water use: food and beverage, paper and allied, primary metals, chemical and chemical products, metal mines, and mineral fuels. Only three of these groups -- paper and allied, metal mines, and mineral fuels -- currently recirculate significant amounts of water, and none of them uses much water treatment beyond primary. Most water is used for processing and cooling, the importance of each varying from one major SIC group to another. Of the four manufacturing groups, only food and beverage shows significant monthly variations in water use, peaking in the summer at about 1.3 times winter use.

Three provinces -- Ontario, Quebec, and British Columbia -- dominate water use in industry.

Agricultural: Water use for irrigation and livestock watering is not surveyed on a regular basis in Canada. Environment Canada has carried out some national studies and regional assessments associated with river basin studies. The Canada Water Yearbook gives water use for stockwatering and irrigation for each province.[4] Alberta and, to a lesser extent, Manitoba and Saskatchewan account for 95 per cent of all irrigation demand. Demand for watering livestock is spread among Ontario, Quebec, the Prairie Provinces, and British Columbia.

Power Generation: The industrial surveys carried out by Environment Canada, include surveys of public and private electrical utilities. Water use in each province is proportional to the amount of power generated thermally, with Ontario and Alberta dominating the national totals. No recirculation is used at power plants in Ontario, and the average recirculation rate in Alberta is 2.8.

Recommended Improvements in Data Collection

Except for the industrial sector, current water-use statistics show the total water supplied by municipalities rather than giving a breakdown by type of user. Residential, commercial, and institutional water use are not known because municipal water supply and wastewater collection is surveyed as a whole.

If the demand for water is to be managed more widely, data must be gathered on water use by sector and, where possible, by major end use. This will require changes in current data collection programs in the municipal and agricultural sectors. For each end use, surveys should record the following data:

- amount of water used
- degree and type of degradation
- size of end use (e.g., population, industrial output, floor area, irrigated area).

Surveys should record water use by the following types of industry, residence, and building, or agricultural activity:

- water-intensive SIC groups (industrial sector)
- homes with yards and those without yards (residential sector)
- institutions, water-using services (e.g., laundries), and general commercial (commercial sector)
- irrigation and different types of livestock (agricultural sector).

Appendix D identifies some specific end-use data collection initiatives that would support management of the demand for water.

Changes in water use can be achieved through demand modification or structural changes. The results of water conservation experiments and programs must be properly documented and set in context. We suggest the following guidelines:

- Results should be presented as percentage savings and the discontinued technology or practice should be identified.
- It should be clear whether the percentage savings apply to all water use, water use for a given end use, or water use by a single fixture.
- Municipal data should distinguish residential, commercial, industrial, and other urban water use.
- It is important to describe all measures taken to increase efficiency in water use and when testing impact to avoid double counting of the result.
- The extent to which a mix of different types of water-using fixtures, practices, and processes may be in use at the same time should be taken into account.
- The water-use patterns of homeowners, commercial users, and industries in terms of daily usage of a fixture, appliance, or practice, should be documented.
- Prior water use should not be exaggerated.

Monitoring and audit programs must also be designed with the documentation requirements of demand managers in view. More detailed suggestions are given in appendix D.

Research should lead to a plan for gradual implementation of water-demand surveys, field measurements, and monitoring activities over the next few years.

A Preliminary End-Use Analysis of Canadian Water Demand

Appendix D describes the current methods employed to analyse water demand and develops a preliminary end-use model that uses water-use coefficients to disaggregate 1981 Canadian water demand by sector, subsector, and end use. Table 2 shows the sectoral breakdown for gross water use provided by the model.

The following observations were made from the preliminary end-use analysis:

° The industrial sector is by far the largest water user in terms of both intake and degradation. Recirculation rates are generally low in industries that use a lot of water and the level of discharge treatment is seldom above primary.
  - The food and beverage industry withdraws significant quantities of water from public sources (and discharges to them) and uses only a small degree of recirculation for processing and cooling.
  - The pulp and paper industry has the highest gross use but also a high recirculation rate. Degradation is still high, however, because of low treatment levels.
  - The chemical and primary metals industries use a lot of water for

Table 2. Canadian Gross Water Use, by Sector

Sector	Gross Water Use (m^3 millions)
Industrial:	
Public*	965
Self Supplied	11 218
Subtotal	12 184
Agricultural:	3 064
Residential	
Public*	1 802
Self Supplied	200
Subtotal	2 002
Commercial*:	658
Power Generation:	17 273
Municipal Demand:	
Delivered	3 425
Unaccounted For	605
Intake	4 030

* Included in municipal demand

heating and cooling, do not do much recirculation, nor much waste treatment.

- A generally low level of recirculation of cooling water is found in all industries.

° In the agricultural sector, the most significant widespread water use is livestock watering.

° In the residential sector, both potable and non-potable (sanitary) end uses are equally significant. The largest single uses are in toilets and showers. The residential sector accounts for less than half of municipal water demand.

° The commercial sector is not a large water user. On average, it uses less than one-half of what the residential sector uses. In some municipalities this could still be significant, however.

° Although water use by the power generation sector is high, most of the withdrawals are from large water bodies such as the Great Lakes and the only contamination is a small rise in temperature.

Managing the demand for water is a new concept in Canada, and it will take time for it to become commonplace in all sectors and all regions of the country. Jurisdictional and other barriers currently limit the extent to which the demand for water can be managed. At this time, ways must be found to apply this concept to Canada's worst problems and her greatest opportunities. We call these "priority sectors and end uses" and suggest some programs to manage the demand for water that might be carried out by governments.

An Initial Set of Priorities

To identify sectors and end uses where water supply is becoming a problem we used the following five basic criteria:

- volume of water use
- evident conservation opportunity
- practicality of control and monitoring
- water system costs
- conflicting demands for water.

Cost effectiveness was excluded as a criterion, not because it is unimportant, but because the purpose of the initial set of criteria was to identify sectors for which cost-effective water demand management options appear to be needed.

Identifying Priority Sectors, Subsectors, and End-Uses

The above criteria were applied to the end uses in appendix D and the data in chapters 3 and 4 to identify sectors and end uses for priority attention.

Industry: In industry, the following subsectors deserve priority attention for demand management:

- food and beverage because of their large water withdrawals and discharges from and to municipal systems, and low recirculation rates
- paper and allied because of their large use of water for processing, and their significant degradation of water flows
- chemicals because of their large use of water for heating and cooling, and their significant discharge of toxic substances
- metal mines because of locational conflicts.

In general recirculation and reuse of water in Canadian industry is low compared with other countries.

Agriculture: Canadian agriculture uses little water in total, but both irrigated farms and feedlots significantly degrade the water they do use. Per unit of production, irrigated farms are the largest consumers of water, but are important only in Alberta and Saskatchewan.

Residential and Commercial Sectors: In the residential and commercial sectors, priority end uses in terms of the proportion of water use are toilet flushing, washing (shower and laundry), and landscape management (lawn and sprinklers). None of these end uses is large compared with industrial end uses, but the gains from simple conservation measures are readily attainable. For individual households, dollar savings are small at best, but for water-intensive commercial establishments and public institutions they can amount to many thousands of dollars per year. Further, these sectors make up much of the load in municipalities where costs are, in many cases, increasing.

Municipal Use: Municipal water agencies should look closely at "unaccounted for" water, particularly if it seems due to leakage. They should also look closely at municipal services such as street cleaning in the summer.

Jurisdictional Questions

Unfortunately the jurisdiction that is most interested in managing demand for water does not always have legal authority to do so. We know from experience with energy conservation that the failure to address jurisdictional differences will hinder the implementation of potentially important and cost-effective conservation measures.

The most important jurisdictional issues that need to be considered are as follows:

- federal jurisdiction over water that is split among departments
- unclear (federal/provincial) jurisdiction over land-based activities that consume water or affect water quality
- the difficulty of setting national standards for measuring (and possibly regulating) water consumption when the need to measure and regulate consumption may only be regional
- provincial jurisdiction over plumbing and building codes when the need for change is local and the pressure for change is federal.

Jurisdictional Problems with Water-Efficient Fixtures

The greatest interest in water-efficient fixtures comes from municipalities and regions facing increasing costs for new water supplies. However, according to most constitutional experts, it is provincial governments that have the authority to set standards that would limit sales of toilets, showerheads and faucets, to those meeting certain minimum water-use standards, and to establish province-wide building and plumbing codes.

When the regional municipality of Kitchener-Waterloo investigated the possibility of establishing its own minimum standards for water-using fixtures through a local variation of the building code, the province refused permission on grounds that this would lead to a plethora of inconsistent codes across the province. We suggest that a building or plumbing code with specific water-use maxima could be established by the province, and still allow stricter standards to be set, perhaps up to some limit, by individual municipalities. In addition, the federal government could produce a model national code covering water use as it does for energy use in buildings.

For consistency in manufacturing and installation, standard methods for measuring water efficiency and minimum efficiency standards should be national in scope. A framework for the development of the former already exists in the Canadian Standards Association's Steering Committee on Plumbing Products and Materials. This committee has representation from industry, government, and consumers and considers standard protocols for measurement. However, no framework yet exists to set national minimum efficiency levels for water-using products. Although these could be achieved by inter-provincial agreement, the federal government is understandably reluctant to step into an area that has been a provincial concern. An intermediate option would be for the federal government to develop a labelling system indicating the water use of selected fixtures as it has for the energy use of major household appliances. Even here it is not clear which level of government can enforce (as opposed to proclaim) such labelling regulations.

Jurisdiction over Land-based Activities that Use Water

The question of jurisdiction over land-based activities that affect water quantity and quality has caused problems within federal departments, among federal departments, and between federal and provincial governments. Until recently, the Environmental Conservation Service within Environment Canada was responsible for assessing in-stream quantity and quality, and the Environmental Protection Service was responsible for protecting these waters from land-based activities. Land-based activities also come under provincial jurisdiction. Where federal responsibility does apply, the most powerful legal instrument, the Fisheries Act, is currently available only to the Department of Fisheries and Oceans, and not to the Department of Environment.

Fortunately, jurisdictional questions regarding effluent discharges from land-based activities are being worked out. Some provinces grant licences and set maximum discharges for municipalities and selected industries. Federal/provincial agreements on collection of data about water resources and quality are also being drawn up. Further practical steps toward joint management of water withdrawals and discharges from land-based activities would be to extend these arrangements to cover provincial licences or agreements on water withdrawals and to set up other joint data collection programs on water intake, consumption, and discharge by end use, subsector, and sector.

Barriers to Water Demand Management

Over the past 15 years, it has become clear that gains in energy efficiency are limited by economic forces and, even more, by institutional barriers. Similar barriers appear to block water efficiency, specifically, barriers related to inappropriate economic signals, market failure, and the nature of the organizations engaged in water supply management.

Most barriers stem from a perception that water use can and should grow with per capita income. Similar views were expressed about energy use in the 1970s. This view of water consumption is changing. However, senior personnel in many water supply agencies still doubt that conservation can reduce demand by more than 20 per cent on a permanent basis. In 1978 the American Waterworks Association reported that "Although conservation of water is a stopgap solution rather than a permanent one, it is, of course, a worthwhile effort."[1] This attitude is little different from that taken today by the Regional Municipality of Waterloo, Ontario.

Economic Barriers

Although the situation varies across sectors and regions, water tends to be underpriced; so consumers undervalue both the water they use and the opportunities for conservation. Water prices are typically below opportunity costs, even where those costs reflect no more than supply and distribution costs and alternative uses for the water. Exactly the same is true for sewerage rates and disposal costs. Moreover, the underpricing is worse in periods of peak demand, when capacity is heavily stressed. Consequently, there is little incentive to shift use to off-peak periods.

A second economic barrier to managing demand for water is the general failure to charge self-supplied users for water-use rights. There is good reason to treat water like oil, so that firms and individuals wishing to use, draw, or drill for water pay a fee for the initial right of access and in addition a royalty keyed to consumption. The theory of water rents is well-developed, but specific applications are not. Possibly water users who already draw water from wells or surface waters would be exempt, but new supplies should be subject to rents.

Research is needed to adapt the various theories of water-use value so that governments can charge a rent for water, including self-supplied water.

Market Failures

Little research has focused directly on market failures in water use. Research is needed to identify market failures that limit the effectiveness of conservation efforts. Based on experience with energy conservation, the following appear to be among the important barriers to efficiency.

- Water users generally lack adequate information on conservation opportunities, have not investigated the costs and benefits of alternative products and practices, and perceive risks from technical change as greater than they actually are.
- Water users, particularly individual householders and municipalities, may be unable to respond appropriately to market signals because they lack access to adequate capital at affordable rates; thus municipalities may know that leakage is high, but still find it easier to pay the high annual costs for pumping than to obtain the capital for repairs.
- When making decisions about investing in water-saving products or practices municipalities tend to use investment criteria (payback terms, rates of return) that are more restrictive than the criteria applied to other decisions. This is also likely to be the case in the industrial and commercial sectors. As a result, even if water prices were set according to marginal principles, investment in demand management would be less than optimal.

- For most users water supply is not a significant cost and will not be even with appropriate pricing. Because of this, even when water conservation is demonstrably cost effective, users may not bother to take any action. Building renovators and industrial process engineers may also overlook opportunities to increase water-use efficiency.

- The costs of water conservation investments are often divorced from the benefits, which means that appropriate price signals do not generate an appropriate response. For example, landlords tend to pass water costs on to tenants, and, from the tenant's point of view, a short-term lease discourages investment.[2] Another example occurs in government; building managers lack incentives to request the capital to retrofit for lower water use because higher water costs are automatically included in the annual budget and any savings are simply deducted from that budget.

Organizational Barriers

Agencies devoted to water management have hitherto focused almost exclusively on delivery and treatment of adequate supplies and collection and treatment of wastewater. These agencies are geared to engineering solutions. In some cases, this approach is enshrined in their formal mandates, and the requirement to manage water demand is not.

This situation is beginning to change, however. Recently the mandate of some water supply utilities has been expanded to include management of demand. Even so, many utilities are reluctant to take on such different work, and their extreme caution can limit their effectiveness in this new area. They may also fear that a shift toward management of demand would threaten their financial solvency, at least in the absence of marginal cost pricing.

The keys to effective programs by water supply agencies are as follows:

- strong commitment by management, including a water-conserving program within the utility's own operations
- good relationships between the utility and its customers
- a public that believes that managing the demand for water is in its own interests and that the measures applied are fair.

The keys to effective programs in industries and businesses are essentially the same except that an additional relationship must be considered, that between employer and employees.

Another problem is that provincial governments (and to a smaller degree the federal government) have been willing to fund construction projects to augment supply capacity but have not been willing to provide funding for projects that might reduce the need for those supplies. Ironically, concern about drinking water quality has contributed to this short-sighted approach.

Researchers should look at new ways of designing and managing water supply agencies so that they favour the most efficient and lowest-cost water system. Before we can judge the difference this could make, we need to know the extent to which current legislation and other regulations and incentives now favour supply augmentation over managing demand.

An Initial Water Demand Management Program

The following collection of programs to manage the demand for water could form the basis of a Water Demand Management Strategy for Canada. It covers those areas that appear to offer considerable scope for cost-effective water conservation.

The suggested programs are given on a sector by sector basis, except for government facilities, which are considered separately from the rest of the commercial sector.

All Sectors

Examples of cross-sectoral programs are pricing, licensing and permits, financial support for innovation, data gathering, and research programs.

Research Programs: More attention must be paid to water conservation and demand management research. The summary of research needs in chapter 7 should form the basis for all federal and provincial research programs.

Pricing Information and Support Program: There is no shortage of information on which to build marginally-based water pricing systems, nor is there much doubt that such systems would improve the efficiency with which water is used. A federal and/or provincial water pricing program is needed, not to legislate the optimum pricing system for each water utility, but to identify the options in various situations and to help utilities adopt the systems they choose. The program's literature should describe different pricing systems (including ways of charging self-supplied water users and of reducing usage during periods of peak demand) and case studies of utilities that have changed pricing systems. A follow-up program should offer financial assistance during the changeover and training of municipal water planners and operators.

Model Licensing Program: This program would review existing licensing arrangements, such as those defined under the Northern Inland Water Act, and develop one or more "ideal" models for the guidance of provincial and municipal governments.

Venture Capital Program: A venture capital program is needed to offer low-interest funding to manufacturers of water-conserving products and water-efficient processes. The capital would be specifically earmarked for commercialization and demonstration of these products and processes.

A Data Collection Program: Knowing the ultimate uses of water is the basic requirement for analytical work in managing the demand for water. Canada should initiate a major program for collecting both physical and economic information on water use. However, first, federal/provincial research should define the kinds of data required. For example, we need to know what proportions of municipal water are used by the residential and commercial sectors. In the industrial sector, data should be collected on type of process and equipment used. A model is suggested in appendix D.

A Conservation Industry Capability Program: To support all the foregoing activities, the water conservation industry, made up of manufacturers and consulting firms that promote the use of water-efficient products, practices, and processes, should form an association, modelled on the Conservation and Renewable Energy Industry Council (CREIC).

Residential and Commercial Sectors

A National Standards and Information Program: A minimal program should have two components: (a) national protocols for measuring water use by fixtures and appliances under specified conditions in a precise way; (b) mechanisms for publicizing the water use of fixtures and appliances tested under those protocols (e.g., standardized labels or an easily updated catalogue). All protocols should be developed under the aegis of existing bodies such as the steering committees for the Canadian Standards Association. Such a program would increase the effectiveness of all other programs in these sectors.

A Model Building Code: A number of building codes and plumbing codes designed for water efficiency are in use in the United States. A Canadian program should evaluate existing codes, select those most appropriate for Canada, and promote their adoption. At a minimum, federal programs, including the R-2000 home insulation program, should be expanded to include water-conserving appliances, and training associated with the R-2000 home insulation program should include a component on water conservation. Or governments could require the use of water-efficient equipment in buildings being constructed with federal and provincial support.

Minimum Efficiency Standards: This program would set out the maximum amount of water all major water-using fixtures and appliances should release or use. Such regulations would require clear legal authority and a commitment to enforcement. The best way to organize this program would be through federal-provincial agreement.

A Financial Assistance Program: Such a program could provide the commercial sector and home builders with financial assistance, in the form of direct grants or low-interest loans, for the installation of water-efficient fixtures and appliances. Experience in Waterloo, Ontario suggests that this would be effective. Another approach would be for provinces to offer a tax credit for construction projects that incorporate water-efficient fixtures and appliances. Financial assistance programs might well be held in reserve pending evaluation of information programs and minimum standards.

A Water Audit Program: This program should either teach the commercial sector how to measure water use in buildings under specified conditions or do it for them. In either event, the program should also recommend retrofit options.

Information and Training Programs: These fall into two groups: (a) training programs aimed at builders, building managers, and landlords; and (b) education programs aimed at students, householders, and tenants. The training programs should focus on teaching those who will design, construct, and manage buildings about water-conserving equipment and practices. They should also enourage them to mount sales promotions based on a product's superior water-efficiency. For education programs, excellent materials are available for every sector. A special effort should be made to reach people in the market for buying, building, or upgrading a home. School programs could be based on the innovative program developed by the National Survival Institute and concentrate on educating students both as potential water users and water managers.

Government Buildings

It is not because they use water differently that we consider government buildings separately from other buildings in the commercial sector but because particular budgetary adjustments must precede efficiency improvements. Governments thus require their own programs, for which the Federal Energy Management Program (FEMP) provides a model. First, each major water-using agency must decide on its own water-conservation plan. Although implementation would be decentralized, a central office should ensure that the plans are developed and monitor progress within the government.

A program for government buildings should include:

- setting targets for water savings compared with some base year
- training programs for government building managers
- establishing model building and plumbing codes for government buildings, and possibly for quarters to be rented by government
- establishing procurement criteria for water-efficient fixtures and appliances
- performing audits of existing buildings and operations where operating agencies do not have the capacity to undertake them themselves.

The budget process should be redesigned to encourage water-conserving retrofits: funds saved through water conservation should stay in the budget to support other activities. The establishment of a specific capital fund would probably become necessary for retrofits of government facilities. In the interim, a simple option would be to allow an agency to borrow against anticipated expenditures for water to pay for cost-effective retrofits.

On some military bases, government agencies become, in effect, water utilities and should decide how best to manage the local demand for water, by studying programs designed for utilities in other sectors. Government agencies should experiment with innovative options, such as re-use of residential and municipal wastewater.

Agricultural Sector
Certainly more appropriate pricing practices should be adopted. A technology transfer program would help farmers to adapt to higher water prices, by explaining how to minimize use of water in production and how to use detailed weather information so as to avoid unnecessary irrigation. A technology transfer program in agriculture could reach farmers through extension services, schools, journals, and radio.

A financial assistance program would focus on farmers moving out of irrigated farming or coping with new wastewater disposal regulations. Because low water prices are so deeply built into the agricultural economy, this program may have to incorporate direct grants rather than loans.

A federal government/agriculture task force might be set up to focus attention on this area.

Electric Power Sector
Because of the structure of electrical utilities in Canada, and the high degree of competence in existing staffs, no specific programs are necessary to encourage greater water-use efficiency in the electric power sector.

Industrial Sector
Water is used for so many specific tasks in industry that programs should focus on broad opportunities to stimulate conservation.

A Compendium of Water-Efficient Products and Practices: Cases of water conservation in industry should be published in an annual compendium of new products and practices. Particular attention should be paid to new ideas for saving energy and water at the same time, and for recycling water.

Expanded Energy Task Force Mandate: In order to focus more attention on conservation in industry, the mandates of the federal government/industry task forces on energy conservation might be extended to include water.

A Water Bus Program: Small buses equipped to perform simple water audits could offer small and medium-sized industries information about technology and financing. Following the approach taken with the highly successful Energy Bus Program, these buses could also demonstrate equipment, such as sonar leak detectors.

A Financial Assistance Program: If changes in pricing practices are announced well in advance, financial assistance should not be needed by new plants. It is unlikely that many existing firms will have high enough water bills, even with revised pricing, to support a specialized industry offering retrofit services on a shared savings basis. Nevertheless it will not be easy for them to adjust efficiently to higher prices. Financial assistance, probably in the form of low-interest or guaranteed loans, could help firms faced with higher water prices to switch to manufacturing processes that use less water or that degrade water less. Any such funding should be available for a limited time. Financial assistance for industries might be held in reserve until the effects of other programs are known.

Accelerated Depreciation Allowance: Water conservation investments should be deemed eligible for accelerated depreciation allowances. Such allowances call attention to the need for investment in the selected sectors.

Municipal Sector
Very few of the benefits of the programs described above for the residential, commercial, government, and industrial sectors will be realized unless municipal agencies responsible for water supply and sewage disposal are involved.

Water Demand Management Manual: Such a manual should instruct municipal water agencies on how to manage the demand for water as an alternative to increasing supply. It would provide models to analyse demand, details of available water-efficient products and practices, alternative pricing arrangements, and selected programs for managing demand. It would provide the tools to develop least-cost solutions to water demand requirements.

Water Demand Management Training Program: Existing training programs for municipal water supply and waste treatment staff should be modified to include training on least-cost solutions and the use of demand management options.

The research, development, and data needs identified in the preceding chapters should form the basis of a Water Demand Management Research Program. We make suggestions in three categories: analytical (the analysis, planning, and management of water demand), technical (the development of more water-efficient products and processes), and socioeconomic (the removal of economic, market failure, and organizational barriers).

Analytical

1. The water end-use framework developed in this report and used for a preliminary analysis of Canadian water demand should be further developed, calibrated, and tested. The Water Availability and Demand Evaluation System (WADES) model developed in the United States for municipal end-use analysis should also be studied further to determine its applicability in Canada (see appendix D).

2. Programs to collect data on water use on a wider scale should be initiated. Data should be available by end use, subsector, and type of water-using product, practice, and process.

3. Current levels of market penetration of each type of water-using product, practice, and process should be determined.

4. Models that (a) include water that is degraded as part of demand and (b) can cope with water recycled from one end use or subsector to another should be developed.

5. By metering a cross section of residences across the country, typical daily per capita water consumption and water contamination figures for water-using fixtures and appliances should be determined.

6. Water-use audits should be carried out to determine how water-use patterns differ between types of households (particularly those with and without yards) and to determine the market penetration of water-efficient products and appliances.

7. Typical daily patterns of water use and water contamination for each end use and type of equipment in commercial and institutional buildings should be determined using existing privately collected data, metering, monitoring, and water-use audits.

8. A database of water use in commercial and institutional buildings should be developed.

9. Market penetration rates for water-efficient products and appliances in the residential and commercial sectors should be determined.

10. Models should be developed to estimate monthly deviations from a base load water use in each sector.

11. Water consumption, gross use, recirculation rate, source of intake, point of discharge, degree of contamination, and treatment should be determined (if possible per tonne of product produced) for each end use and type of process and equipment in major water-using industries. This could be achieved by expanding the Environment Canada industrial water-use survey and carrying out local monitoring where necessary.

12. Regional average water-use coefficients for irrigation should be determined by type of crop and type of equipment.

13. Estimates of leakage and infiltration in municipal systems should be improved.

14. Models should be developed to break municipal demand down into its residential, commercial, and industrial components.

15. The federal and provincial governments need to agree on a common set of

categories for data on the demand for water, and cooperate in developing a workable data collection program over the next few years.

Technical

1. Water-efficient faucets, shower heads, and sanitary equipment for the residential, commercial, and institutional sectors are already available. No further research is needed but the products require extensive demonstration.

2. Research to improve the water and energy efficiency of residential and commercial washing machines and dishwashers should be stepped up and integrated.

3. Standard methods of measuring the water efficiency of all residential and commercial water-using fixtures and appliances should be developed through an existing standards writing body.

4. Residential-scale products that enable consumers to reduce overwatering of lawns and gardens (e.g., timers) should be developed and demonstrated. New "soaker hose" watering systems, for residential and commercial use should be further developed.

5. More water-tolerant varieties of irrigated crops need to be developed, and many of the new products for managing water use for irrigation need to be demonstrated.

6. More research on large-scale membrane separation and integrated waste treatment equipment is needed so that it becomes more cost effective to recirculate water in industry and reduce discharges of pollutants.

7. There is a need for wider demonstration of the economic value and technical feasibility of recirculating cooling water, particularly in industries or commercial establishments that use municipal water supplies.

8. Research is needed to redesign machine tools and equipment that use water for washing and/or cooling so that they use water more efficiently and can reuse the water after filtering and cooling.

9. Improved control systems -- including metering, automatic timers and shutoffs, flow and temperature optimization, pressure control, and automatic recirculation/discharge control -- are needed to help plant and building managers use water more efficiently.

10. New low-cost methods to detect and repair leaks and infiltration in water and sewage systems are badly needed.

11. In industries where water-efficient processes have not been developed, there is a need for process design research. This is most urgent in subsectors such as the food and beverage industry where a large proportion of water is drawn from municipal sources.

12. Techniques widely used in the United States to improve water efficiency in irrigated agriculture, such as the use of lasers to level fields, water reuse pumps, local weather information services, and computer-controlled distribution, need to be demonstrated in Canada.

Socioeconomic

1. Price elasticities over a wide range of prices for each major end use and sector in Canada need to be determined, so that more elastic uses, and those where efficiency gains have been demonstrated, can be addressed selectively in demand management programs.

2. Alternative pricing arrangements for municipal water consumption, peak demand, and excess use need to be more completely documented, so that each municipality can determine the most appropriate pricing policy.

3. New pricing strategies for irrigation water based on consumption and excess

use are needed to replace the current fixed charge approach.

4. Alternative pricing strategies for self-supplied water users should be developed. They should treat water in the same way as other natural resources such as oil and timber, and define use as both consumption and quality degradation (i.e., the amount used is proportional to intake quantity and quality minus discharge quantity and quality).

5. Socioeconomic studies are needed to examine why the market fails to favour water efficiency, and determine why water pricing reform and other ways of reducing demand for this resource have run into problems.

6. Model plumbing codes covering the efficiency of all water-using equipment should be developed for residential and commercial buildings.

7. The feasibility of a Canadian program to set minimum water-efficiency standards for appliances and fixtures should be investigated.

8. Research is needed to document the reduction in water use associated with the imposition of effluent standards or the granting of water withdrawal or discharge licences, based on experience in the Northwest Territories and in Sweden, Israel, and the United States.

9. Research is needed on ways to ensure that programs to retrofit with water-efficient products are acceptable, effective, and result in permanent acceptance of the product by the user.

10. Research is needed to determine whether methods used to train building contractors in energy conservation techniques can be used to train them in water conservation techniques.

11. A method is needed to determine appropriate rebates for water-efficient products installed in a retrofit or new building program.

12. Research is needed on how to encourage water reuse and recirculation in the industrial sector.

13. Research is needed on how to structure water agencies so that they have built-in incentives to select the most efficient and lowest cost water system.

NOTES

1. Introduction

1. Donald M. Tate, Alternative Futures of Canadian Water Use -- 1981-2011, Inquiry on Federal Water Policy (Hull: Inland Waters Directorate, Environment Canada, May 1985).

2. We do not attempt to deal with either crisis management of water in reaction to drought, nor with the possibility of a water quality (as opposed to quantity) crisis precipitated by an accident or sabotage.

2. Efficient Water-Using Technology

1. Examples of efficient showerheads and faucets are described in Examples of State-of-the-Art Water-Efficient Technologies, a report to the Science Council of Canada prepared by the Water Program of Rocky Mountain Institute, unpublished, 24 pp.

2. Ibid.

3. Examples of very high efficiency toilets are described in Examples of State-of-the-Art Water-Efficient Technologies, op. cit. (note 1).

4. Canadian Standards Association, C360-M1980 -- Test Method for Measuring Energy Consumption and Capacity of Automatic Household Clothes Washers (Rexdale: Canadian Standards Association, May 1980), and Canadian Standards Association, C373-M1980 -- Energy Consumption Test Methods for Household Dishwashers (Rexdale: Canadian Standards Association, 1980).

5. Energuide Directory, CLOTHES WASHERS, January 1985 (Ottawa: Consumer and Corporate Affairs, 1985), and Energuide Directory, DISHWASHERS, January 1985 (Ottawa: Consumer and Corporate Affairs, 1985).

6. Details of a typical soaker hose are given in Examples of State-of-the-Art Water-Efficient Technologies, op. cit. (note 1).

7. Paul D. Sinisgalli and James L. McNutt, "Industrial Use of Reverse Osmosis," Management and Operations--AWWA Journal (May 1986).

8. Details of a typical integrated treatment unit are given in Examples of State-of-the-Art Water-Efficient Technologies, op. cit. (note 1).

9. Environment Canada, Canada Water Yearbook 1985, Water Use Edition (Ottawa: Canadian Government Publishing Centre, 1986).

10. Sandra Postel, Water: Rethinking Management in an Age of Scarcity, Worldwatch Paper 61 (Washington, D.C.: Worldwatch Institute, 1984).

11. Ibid.

12. A more detailed review of irrigation practices may be found in James E. Robinson and Mary Anderson, The Role of Water Demand Management in a Federal Water Policy, Inquiry on Federal Water Policy (June 1985).

13. The Commonwealth of Massachusetts, Special Legislative Commission on Water Supply, Water Conservation: Money in the Bank (Boston: June 1983).

3. Tools for Managing Water Demand

1. U.S. Department of the Interior, Office of Water Research and Technology, An Evaluation Framework for Assessing Variations in the Costs and Benefits of Municipal Water Conservation, prepared by Intasa, Inc. (Menlo Park, CA: December 1981).

2. Peter Rogers, "Water -- Not as Cheap as You Think," Technology Review (November/December 1986).

3. Michel Fortin and Donald Tate, Water Rate Setting Practices in Canada, Draft Report for Environment Canada, 1985.

4. A.P. Grima, "Empirical Basis for Municipal Water Rates Modification," Canadian Water Resources Journal 9, 3 (1984).

5. Bruce Mitchell, "The Value of Water as a Commodity," Canadian Water Resources Journal 9, 2 (1984).

6. Robinson and Anderson, op. cit. (note 12, ch. 2).

7. Where sewerage charges are keyed into water use rather than being paid through property taxes, the effect of the rising rate is magnified. About 60 per cent of Ontario municipalities impose sewerage charges, but they are uncommon elsewhere in Canada.

8. Fortin and Tate, op. cit. (note 3).

9. The Durham proposal emphasized that all use, not only the last block, should be priced at the cost of additional supply. This would have resulted in commodity charges rising to $1.47 (1975$) from then rates of 5.9¢ to 8.5¢ per 1000 litres; at the same time, fixed service charges or lot levies would have been eliminated or reduced. R.M. Louden, "Region of Durham Experiences in Pricing and Water Conservation," Canadian Water Resources Journal 9, 4 (1984).

10. James Edward Robinson, Integrating Demand Management of Urban Regional Water Systems: A Canadian Case Study and Implications (Ann Arbour: University of Michigan, 1986).

11. Louden, loc. cit. (note 9).

12. According to studies reviewed by Mitchell, op. cit. (note 5).

13. This system is used in Winnipeg. It was developed in Germany for management of the Rhine.

14. System leakage is typically reported as "unaccounted for" in water-use tables. This category also includes under-reporting, hydrant use, firefighting, and unmetered uses. Except where the last category is large, leakage can be assumed to account for anything over about a few percentage points in the category.

15. Ben Benninger and James E. Robinson, Leak Detection in Municipal Water Supply Systems (Waterloo: Man-Environment Studies, University of Waterloo, 1981).

16. Paul W. Kroushl, "Demand Reduction: Water Conservation Through Leak Detection," Canadian Water Resources Journal 9, 3 (1984).

17. J.E. Robinson, personal communication, February 1987.

18. Fred P. Griffith, "Peak Use Charge: An Equitable Approach to Charging for and/or Reducing Summer Peak Use," Canadian Water Resources Journal 9, 3 (1984).

19. Sandra Howard-Ferreira and James E. Robinson, Community Retrofit Programmes to Reduce Residential Water Consumption (Waterloo: Department of Man-Environment Studies, University of Waterloo, June 1980). Howard-Ferreira and Robinson calculated discounted (5 per cent) dollar savings for typical families in central Ontario as $146 to $280 for the toilet and $250 to $500 for the shower.

20. Brent Blackwelder and Peter Carlson, Survey of the Water Conservation Programs in Fifty States -- Model Water Conservation Program for the Nation, United States Department of the Interior, Bureau of Reclamation (Washington, D.C.: Environmental Policy Institute, August 1982).

21. Brian Wilson, personal communication, 1987.

22. Postel, op. cit. (note 10, ch. 2).

23. Robinson, op. cit. (note 17).

24. Wilson, op. cit. (note 21).

25. J.D. Pawley, "Water Demand Management -- A Case Study," The Canadian Public Works Conference, Ottawa, 12 May 1986.

26. Howard-Ferreira and Robinson, op. cit. (note 19).

27. Pawley, op. cit. (note 25); Benedict A. Benninger, Evaluating Water-Efficient Plumbing Fixture Use, (Waterloo: University of Waterloo, 1986). The definitions of water-efficient fixtures were as follows: toilet flush 13 litres per flush maximum; showerheads 14 litres per minute at pressure of 345 kPa; faucet taps 11 litres per minute at the same pressure.

28. Eight per cent discount rate, Benninger, op. cit. (note 27).

29. Fewer than one-quarter of the residents with water-efficient fixtures were aware of the special nature of the fixtures (ibid).

30. Barrett Russell, William S. Nechamen, and Jerry Sandau, Water Conservation: The Hidden Supply (New York: New York State Senate Research Service Task Force on Critical Problems, September 1986).

31. Raymond De Young and James E. Robinson, "Some Perspectives on Managing Water Demand: Public and Expert Views," Canadian Water Resources Journal, 9, 4 (1984).

32. Pawley. op. cit. (note 25).

33. Benninger, op. cit. (note 27).

34. Detailed water audits have not been done in other types of residences.

35. See the list of hotels, motels, and other businesses in Massachusetts prepared by Resource Management Associates, Inc., Water Use Management for Dollars and Sense -- The Time is Now!, Greater Boston Chamber of Commerce (Boston: Resource Management Associates, Inc., 1982).

36. Postel, op. cit. (note 10, ch. 2).

37. Ibid.

38. Bruce Mitchell and Edward McBean, Water Resources Research in Canada: Issues and Opportunities, Inquiry on Federal Water Policy (Waterloo: University of Waterloo, 1985).

39. Ibid.

40. Ibid.

4. Regional and Sectoral Demand Management Programs

1. James Edward Robinson, Integrating Demand Management of Urban Regional Water Systems: A Canadian Case Study and Implications (University of Michigan, 1986). This PhD thesis analyses each of the phases of the Waterloo program in detail, and many of its observations, analyses, and conclusions have been used in this report.

2. Pawley, op. cit. (note 25, ch. 3).

3. Ibid.

4. J.E. Robinson, op. cit. (note 17, ch. 3).

5. For example, Blackwelder and Carlson, op. cit. (note 20, ch. 3); Stephen W. Sawyer, "State Water Conservation Strategies and Activities," Water Resource Bulletin 20 (October 1984): 681, and Russell, Nechman, and Sandau, op. cit. (note 30, ch. 3).

6. Brent Blackwelder, personal communication, 1987.

7. Russell, Nechamen, and Sandau, op. cit. (note 30, ch. 3).

8. Nebraska, Governor Robert Kerry and the members of the Nebraska Legislature, Water Use Efficiency Report (Lincoln, NE: Natural Resources Commission, 1985).

5. Canadian Demand for Water

1. Environment Canada, op. cit. (note 9, ch. 2); and Paul J. Hess, Ground Water Use in Canada, 1981 (Ottawa: Environment Canada, Inland Waters Directorate, National Hydrology Research Institute, 1986); Donald M. Tate and David N. Scharf, Water Use in Canadian Industry 1981 (Ottawa: Environment Canada, Inland Waters Directorate, Water Planning and Management Branch, 1985). The latter is the latest in a series of reports on industrial water use. Previous issues were published in 1972 and 1976.

2. Environment Canada, op. cit. (note 9, ch. 2).

3. E.g., Tate and Scharf, op. cit. (note 1).

4. Environment Canada, op. cit. (note 9, ch. 2).

6. A Water Demand Strategy for Canada

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2. Renters can be curiously unaware of their water use. In a survey in Massachusetts, 50 per cent of businesses indicated that they used no water because they used rented space.

APPENDICES

A.1 THE CURRENT SITUATION

Although seldom used to manage demand for water, pricing is gaining recognition as means of inducing water conservation. Water, unlike other natural resources, has typically been treated as a free good. If any charges have been levied for use, they have related only to recovery of the costs for supply, distribution, and (possibly) treatment. A review of Canadian and U.S. water rate structures indicates that in many cases (particularly for irrigation water) even these latter costs are not fully recovered.

Water has historically been considered to be outside the normal market. Millerd advanced the following reasons:[1]

- Water is regarded as a necessity, not subject to conventional economic analyses like other commodities.
- Water supply decisions are dominated by public health and engineering concerns.
- Water is regarded as abundant and easily accessible so there is little need to limit demand.
- Political considerations and local regulation exert continuing pressure to keep rates low.

Economic theory suggests that the underpricing of water delivery and treatment will have adverse effects, among them the following:

- Users will have inadequate incentive to improve efficiency or reduce use, both of which will lead to overuse.
- Overuse will lead to water systems that are overbuilt and unnecessarily costly.
- Reduced quality in discharged water will lead to negative impacts on third parties.
- An implicit transfer of income will occur between sectors without any political decision for such a transfer.

Policies that would increase the cost of water to most users are gaining support for several reasons. People are starting to recognize that the adverse effects predicted by economic theory occur throughout society. At the same time attitudes have changed toward appropriate use of natural resources. Water shortages, notably in the United States, where attitudes and approaches are similar to those in Canada, have raised questions about the adequacy of future supplies. Concerns about the quality of drinking water and water in general have led to requirements for more thorough treatment with attendant higher costs. The public is becoming more aware of pollution, about which more is known: for example, the increased detection of trace toxics. All of these trends are occurring at a time of budget restraint when the idea of managing demand for water instead of investing in new supplies is bound to attract attention. In the United States, the water supply industry is the most capital-intensive industry per dollar of revenue and is in third place (behind electricity and petroleum) in total capital expenditures.[2] For all these reasons, there is growing agreement that we must begin to charge a price for water that reflects its value and actual costs.

A.2 THE VALUE OF WATER

By establishing a framework for assigning value to water, it will become possible to give it a price and subject its use to allocation and efficiency criteria normally applied to other commodities.[3] This will lead to changes in water-use patterns, because price increases encourage consumers to use water more efficiently and to curtail less important uses of water.

Conventional valuation may not provide a complete basis for managing the demand for water as it does not and, in principle, cannot capture all aspects of value.[4] Ethical components are not necessarily consistent with efficiency maximization, and this means that some preferences -- for example, the desire to preserve some wild lands -- will not be properly accounted for in the valuation.

Some alternative approaches to valuation of water are therefore necessary.

A.2.1 Approaches

Mitchell presents three procedures that provide a framework for placing a value on water:[5]

- **Next Best Alternative:** A value can be assigned to water in terms of the cost of the next best alternative. This approach reflects the cost of obtaining and delivering alternative supplies.

- **Value-Added:** The value of water can be established with reference to the value added to the manufacturer's products or consumer's satisfaction. Using this procedure, Mitchell calculates that in 1980, about $11 billion was added to the value of recreation in Canada due to water-based activities.[6] This concept also applies in the case of water uses that deplete or degrade the water supply for "downstream" users. The economic analysis of the upstream action could incorporate appropriate compensation.

- **Intrinsic Value:** An intrinsic value could be assigned to water before it is developed, as is done with other natural resources. The cost to the user would include this intrinsic value of water plus the costs of supply, treatment, and distribution. As Mitchell points out, the only way to calculate the in-source value of water is through bargaining among interested parties. For example, in South Dakota a water price at source was established between the state and a private corporation, which resulted in a 50-year agreement to supply water from the Missouri River to Wyoming via a 445-kilometre pipeline.

A.2.2 An Estimate of Value

Using the "next best alternative" approach, Muller has estimated that the socioeconomic value of water to Canadians in 1984 was between $7.5 and 23 billion.[7] He assessed the average net willingness of consumers to pay for a number of major withdrawal and in-stream uses of water. Table A.1 shows estimates, each of which is derived from consideration of demand elasticities: price, cost, and quantity of water devoted to each use; alternative sources of supply; and technologies that could be employed to reduce water use once prices reached a certain level. On an annual basis, in-stream uses were judged to be two to seven times as valuable as withdrawal uses. Although Muller cautions that his results show average, not marginal, values of water and that they depend on comparison with specific alternatives, nevertheless, they lead him to conclude, "Any cost-benefit analysis of water development projects must, accordingly, pay careful attention to the recreational and non-participatory values which might be destroyed by diversion or pollution."[8]

A.3 RELATIONSHIPS BETWEEN PRICE AND WATER DEMAND

A.3.1 The Nature of Demand

Empirical evidence produces demand curves -- the mathematical relationship between price and use -- that are non-linear and imply high elasticity at low prices and low elasticity at high prices. When water is cheap, it is used frivolously. This behaviour ceases as prices rise and less important uses are dropped or cut back. On the other hand, there are certain uses for which water is essential and that are not easily cut back even at high prices.

Research has shown that certain end uses are particularly sensitive to price increases. This suggests that the value of water to the consumer varies among end uses, and/or technical alternatives exist that are not being employed because of the current low price of water.

Given that certain end uses are more sensitive than others, sectoral demand curves (i.e., curves that integrate all or a number of end uses in a given sector) should exhibit "kinks." These sharp changes separate zones of low value (and generally high volume) uses with high elasticity from zones of higher value (and generally lower volume) uses with low elasticity. Virtually all researchers have concluded that certain trends in elasticity are evident and provide useful insights into the expected effective-

Table A.1. Selected Estimates of the Economic Value of Water, Canada

Use	Average Net Willingness-to-pay Low	Average Net Willingness-to-pay High	Total Net Willingness-to-pay Low	Total Net Willingness-to-pay High
	($ per megalitre)		(millions of $ per year)[a]	
Withdrawal				
Municipal	100	2 430	288	6 968
Irrigation	0	36	0	109
Thermal power	9	9	169	169
Industrial				
Paper	87	87	251	251
Chemical	76	76	217	217
Primary	16	43	44	118
Petroleum	19	19	10	10
Food and Beverages	30	124	13	53
Subtotal			536	650
Total			993	7 896
Instream				
Hydroelectricity			4 226	6 553
Waste assimilation[b]	1	4	645	2 272
Recreational fishing[c]	20	74	1 677	6 309
Seaway navigation			0	0
Freshwater fishery			0	0
Total			6 549	15 134
Grand total			7 541	23 030

Source: R. Andrew Muller "The Value of Water in Canada" Canadian Water Resources Journal 10, 4 (1985).

a 1984 prices.
b Average willingness-to-pay in Canadian dollars per kilogram of Biological Oxygen Demand (BOD) removed.
c Average willingness-to-pay in Canadian dollars per fishing day.

ness of pricing in managing the demand for water. Estimates of price elasticities under varying conditions in Canada should be a high priority research area -- not so much to be able to predict future consumption (the most common use of elasticity information) as to identify the forces that can make water use more price elastic.

A.3.2 Agricultural Irrigation Water Demand
Muller calculated the value of irrigation water based on an estimation of the marginal product of irrigation water -- the difference between farm incomes on the same land with and without irrigation. Muller found no Canadian studies of this difference. However, based on U.S. estimates of a marginal product of up to Cdn$69 per million litres for the U.S. Ogalla high plains, he estimated the product for Canada at up to Cdn$36 per million litres. This figure contrasts sharply with the average capital cost of over Cdn$100 per million litres per year to deliver irrigation water in Alberta.[9] The supply of irrigation water in Canada is generously subsidized.

When water is priced below cost, the farmer has an inadequate incentive to consider alternative crops or cropping methods or even to adopt more efficient irrigation practices. Higher water prices could result in major shifts in western Canadian agriculture, chiefly in a return of hundreds of hectares to dryland farming.

Figure A.1 presents the estimated demand curve for irrigation water in Manitoba farms and is representative for western Canada. There are marked kinks in the demand curve. The elastic portion of the demand curve, marked A, shows that even small price increases in this region of the curve will reduce the quantity demanded significantly. Large quantities of irrigation water are used on low-value crops that modest price increases would render no longer profitable to irrigate.[10]

A.3.3 Residential Water Demand
Residential uses of water, including both single and multiple family dwellings and both indoor and outdoor end uses, constitute a major portion of municipal water demand. Household water demand is significantly responsive to price. For example, outdoor water uses in the United States (which represent half of the total residential use in drier regions) are highest for high income earners. This is perhaps why higher income groups are able to adopt lower water-use options most rapidly.

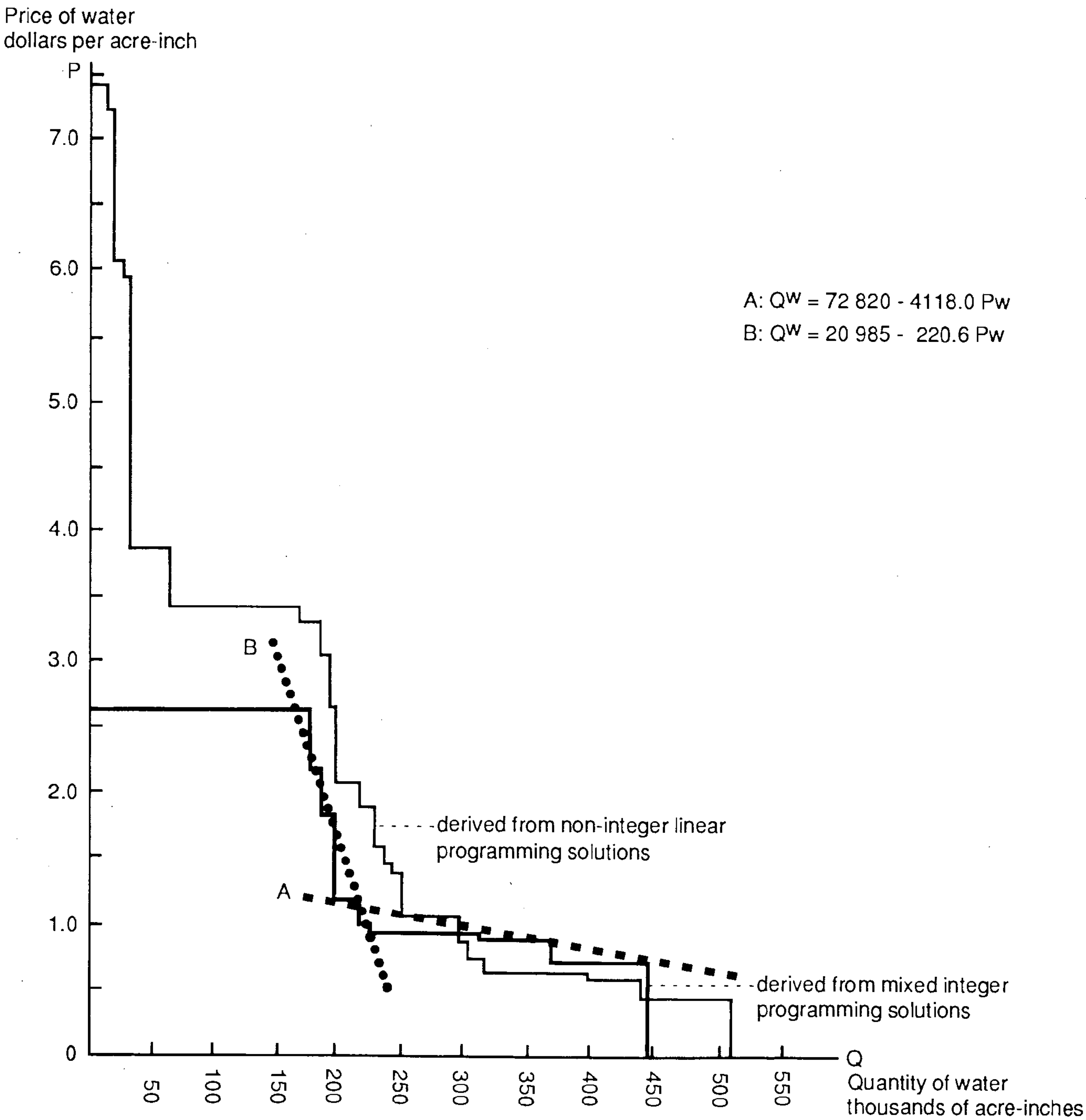
On the other hand, demand for water for some uses does not change even with higher prices, but nor do these uses grow with growth in income.

A number of estimates of price elasticity for residential water use have been published.[11] Typical figures reported are in the range of -0.24 to -0.40, except for lawn watering in the west where the figure exceeds -0.70.[12] In general, it is easier to cut back on outdoor uses -- principally lawn and garden watering, pool filling, and car washing. In the early years of attention to energy conservation, similarly low figures were reported, but as more and more options for conserving energy became available and as time was allowed for adjustments to the new prices and the new attitude, elasticities rose and in some cases exceeded -1.0. The ability of users to reduce demand in response to a change in price grows with time because more efficient technology becomes available.

Figure A.2 presents a simplified double kinked demand curve reflecting the conditions noted above. When water takes a very small proportion of disposable income, price increases are not enough to encourage conservation. At higher prices, several end uses are easily reduced (e.g., lawn watering) and use declines sharply. At still higher prices, there are fewer ways to conserve, particularly immediately after a price increase. As the demand for water-efficient products increases, more options become available.

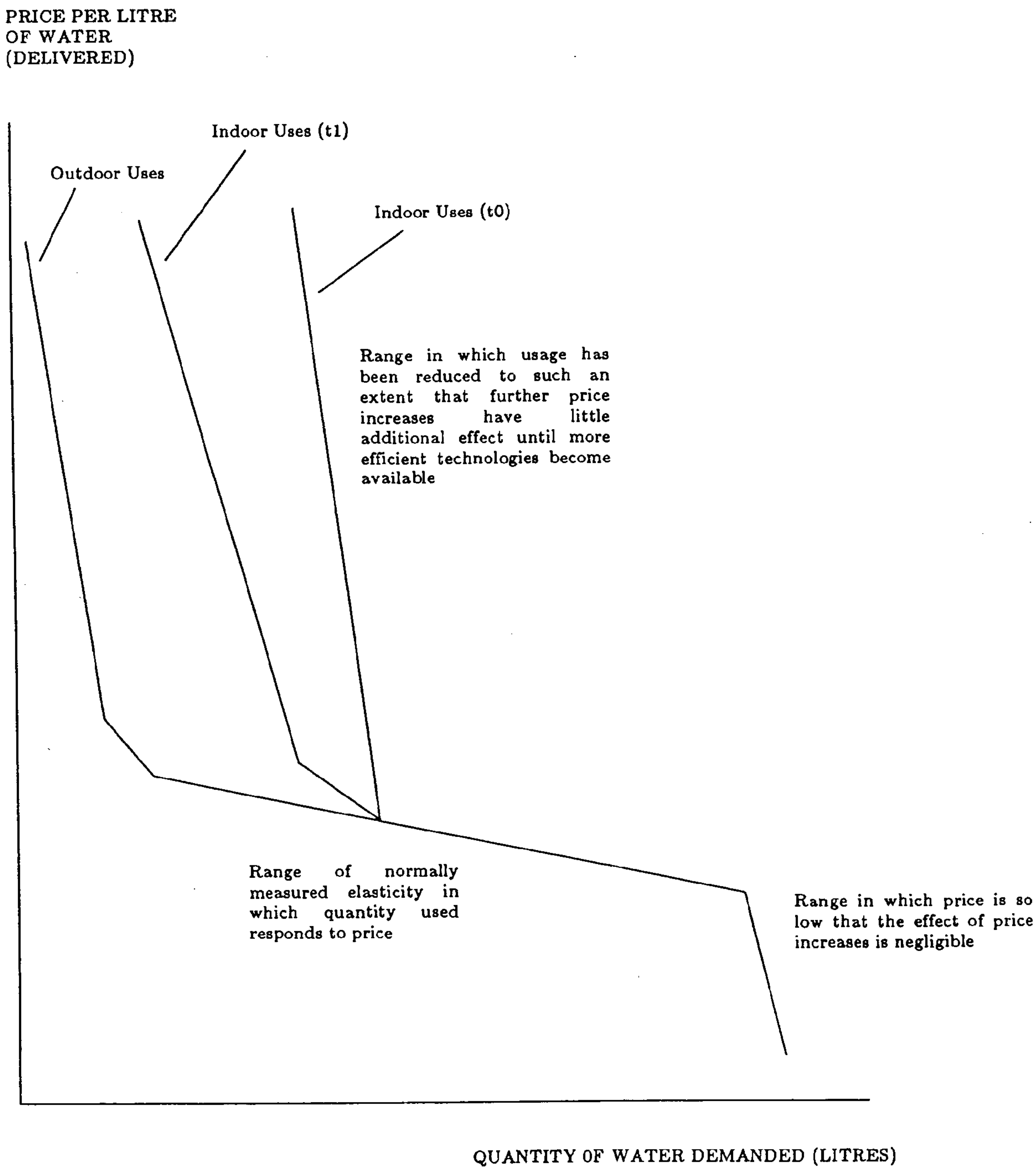
A.3.4 Cooling Water Demand (Industry and Thermal Power)
Industry uses water for two main purposes: for cooling and in production processes. Thermal electrical generation uses water almost exclusively for cooling. The upper

Figure A.1 "Stepped" Aggregate Demand Curve for Irrigation Water (Manitoba Farms)



Source: W.J. Craddock, "Linear Programming Models for Determining Irrigation Demand for Water," Canadian Journal of Agricultural Economics, 19 (November 1971).

Figure A.2 Conceptual Demand Curves for Water in the Residential Sector



Note: t0 refers to initial period and t1 to a period with more technical options price that either will pay for cooling water is determined largely by the cost of recirculating cooling water within the plant. Citing the case of U.S. electrical utilities, Rogers suggests that:[13]

- at 1¢ or less per 1000 gallons (Cdn$3.50 per thousand cubic metres) of water, a typical utility would employ "once-through" cooling, at a rate of 50 gallons (190 litres) of water per kilowatt-hour
- at 5¢ cents per 1000 gallons (Cdn$17.50 per 1000 cubic metres) of water, a typical utility would build a cooling tower that would consume 0.8 gallons (3 litres) of water per kilowatt-hour
- at 18¢ cents per 1000 gallons (Cdn$63 per 1000 cubic metres) of water, a typical utility would use a dry cooling tower.

The price of electricity would rise slightly as water prices increased and as cooling methods changed. A demand curve for water in the thermal power sector would also be kinked, perhaps twice. Although specific costs are not available for industrial users of cooling water, general conditions and thus the shape of the demand curve should be similar to that for electrical utilities.

A.4 COST OF WATER SUPPLY

Generally the costs of water are highest in the municipal sector, both because of the need for treatment to potable quality and the need for an extensive distribution network. Thus, although costs for water for each sector need investigation, that for municipal supplies gives an indication of the upper limit.

Grima reviewed past studies and made his own analysis of water costs for 43 municipalities in Ontario.[14] Grima found that municipal water supply costs were affected by operating cost and debt servicing on capital. About half of the communities he investigated were facing increasing costs for water supply. Economies of scale in supplying water seemed to be exhausted beyond population levels of 18 000. However, whether costs are increasing or declining, there is little correlation between costs and rates charged to customers. In Grima's words, "The evidence in this study strongly suggests that there were important random or political or haphazard inputs into the decisions to price urban water services."[15] The major problem is underpricing of water, particularly for larger users, so that small users and those paying only fixed charges subsidize others. In addition, as predicted by theory, there is considerable over-investment in supply facilities.

Notes to Appendix A

1. Frank W. Millerd, "The Role of Pricing in Managing the Oemand for Water," Canadian Water Resources Journal 9, 3 (1984).

2. Peter Rogers, "Water -- Not as Cheap as You Think," Technology Review (November/ Oecember 1986).

3. Bruce, Mitchell, "The Value of Water as a Commodity," Canadian Water Resources Journal 9, 2 (1984).

4. Oavid S. Brookside, Larry S. Eubanks, and Cindy F. Sort, "Existence Values and Normative Economics: Implications for Valuing Water Resources," Water Resources Research 11, 22 (October 1986).

5. Bruce Mitchell, op. cit. (note 3).

6. Ibid.

7. R. Andrew Muller, "The Value of Water in Canada," Canadian Water Resources Journal 10, 4 (1985).

8. Ibid.

9. Ibid.

10. Bruce Mitchell, op. cit. (note 3).

11. Frank W. Millerd, op. cit. (note 1); J. Ernest Flack, Urban Water Conservation: Increasing Efficiency-in-Use Residential Water Demand (New York: American Society of Civil Engineers, 1982), 111.

12. W. Douglas Morgan, "An Economist's View of Demand Projections Considering Conservation," Water Resources Bulletin 16, 5 (October 1980).

13. Peter Rogers, op. cit. (note 2).

14. A.P. Grima, "Empirical Basis for Municipal Water Rates Modification," Canadian Water Resources Journal 9, 3 (1984).

15. Ibid, 37.

B. A HISTORY OF ATTEMPTS TO MANAGE THE DEMAND FOR WATER IN KITCHENER-WATERLOO, ONTARIO[1]

Year(s)	General activity	Participants	Accomplishments
Prior to 1976	Municipal lawn watering regulations -- alternate night sprinkling	Area staff	Some control over peak demands
	Region adopts policy of lawn watering bans when supply not replenished over a 24-hour period	Region staff	Peak demand controlled at cost of public upset over perceived crisis management techniques
1976-77	Water-conserving devices installed in apartment units to test possible savings	Region staff	General test of possible water savings and user satisfaction
	"Water use index" formulated to provide daily advice on water supply situation to public	Region staff	Daily newspaper ads keep public informed. No surprises when lawn watering ban imposed
1978	Water conservation program is initiated at Man-Environment Studies, University of Waterloo	Faculty and students	Identification of research projects Creation of newsletter for stuffing in utility bills
1979	Research on water conservation options	Staff of water conservation program at the University of Waterloo	Objectives established for comprehensive water conservation component of water supply program Further research including pilot tests of retrofit water-conserving devices for homes Identification of need for cooperation among governments before various water conservation options can be implemented

Year(s)	General activity	Participants	Accomplishments
1980	Creation of Municipal Working Group on Water Conservation	University of Waterloo faculty and students, regional staff, and senior politicians	Agreement of local municipalities to cooperate to implement various water conservation actions
1980-1983	Detailed research and development of water conservation options under Municipal Working Group	University of Waterloo faculty and staff, regional staff, and senior politicians	Publication of a series of working papers on water conservation options Publication of a twice yearly newsletter Approval-in-principle from regional council of a rebate for installation of water-conserving devices in new homes Approval-in-principle for the introduction of an excess use charge by City of Kitchener city council
1983	Municipal Working Group on Water Conservation disbanded. Advisory Committee on Water Conservation appointed by Regional Council	Region and local staff. University of Waterloo faculty retained as consultants	Public education activities
1984	Major conference: Managing the Municipal Demand for Municipal and Industrial Water	University of Waterloo faculty in cooperation with the Canadian Water Resources Association and Grand River Authority	Elevated awareness of water managers regarding demand management Created recognition for water conservation activities in the Regional Municipality of Waterloo Provided for a plan for future endeavours
1985	Continued program	Regional Advisory Committee on Water Conservation, regional staff, and public relations consultant	Publication of a catalogue of water-efficient fixtures Implementation of a rebate program for new and renovated living units

Year(s)	General activity	Participants	Accomplishments
1985 (cont'd)			Evaluation of an apartment retrofitting program
			Evaluation of rebate program

Note to Appendix B

1. J.D. Pawley, "Water Demand Management -- A Case Study," The Canadian Public Works Conference, Ottawa, 12 May 1986.

C. A SURVEY OF WATER CONSERVATION PROGRAMS IN THE UNITED STATES[1]

Methodology

The Environmental Policy Institute asked each of the 50 states for information on their water conservation programs and ones they were studying. States that did not respond to the written survey were phoned. Figure 1 groups responses into 13 categories. The question posed in each category was as follows:

1. Public Education: Does the state have a program educating the public about the wise use of water?

2. Plumbing Code: Does the state plumbing code require low-water-use fixtures in new construction or reconstruction?

3. Retrofitting: Does the state have any program to retrofit existing dwellings, homes, and buildings with low-flow fixtures for toilets, faucets, and showers?

4. Metering: Does the state require all municipalities to meter their water?

5. Leak Detection: Does the state have any requirement for detecting and repairing leaks or require municipalities to have one?

6. Rate Structure: Does the state require pricing structures to encourage wise use of water or require sound billing practices by municipalities?

7. Contingency Planning: Does the state have any requirement or plan for dealing with droughts?

8. Reuse and Recycling: Does the state encourage or even allow recycling and reuse of water or waterless toilets?

9. Outdoor Use: Does the state have any requirement on outdoor use or require municipalities to regulate outdoor use?

10. Groundwater Management: Does the state have regulations on the use of groundwater to encourage wise use?

11. Industrial Use: Does the state have any program to encourage or require efficient use of water by industry?

12. Agricultural Use: Does the state have any program to encourage or require efficient use of water in agriculture?

13. Government Buildings and Grant Requirements: Does the state require water conservation in state buildings or does it require, where appropriate, water conservation measures in state grants or loans?

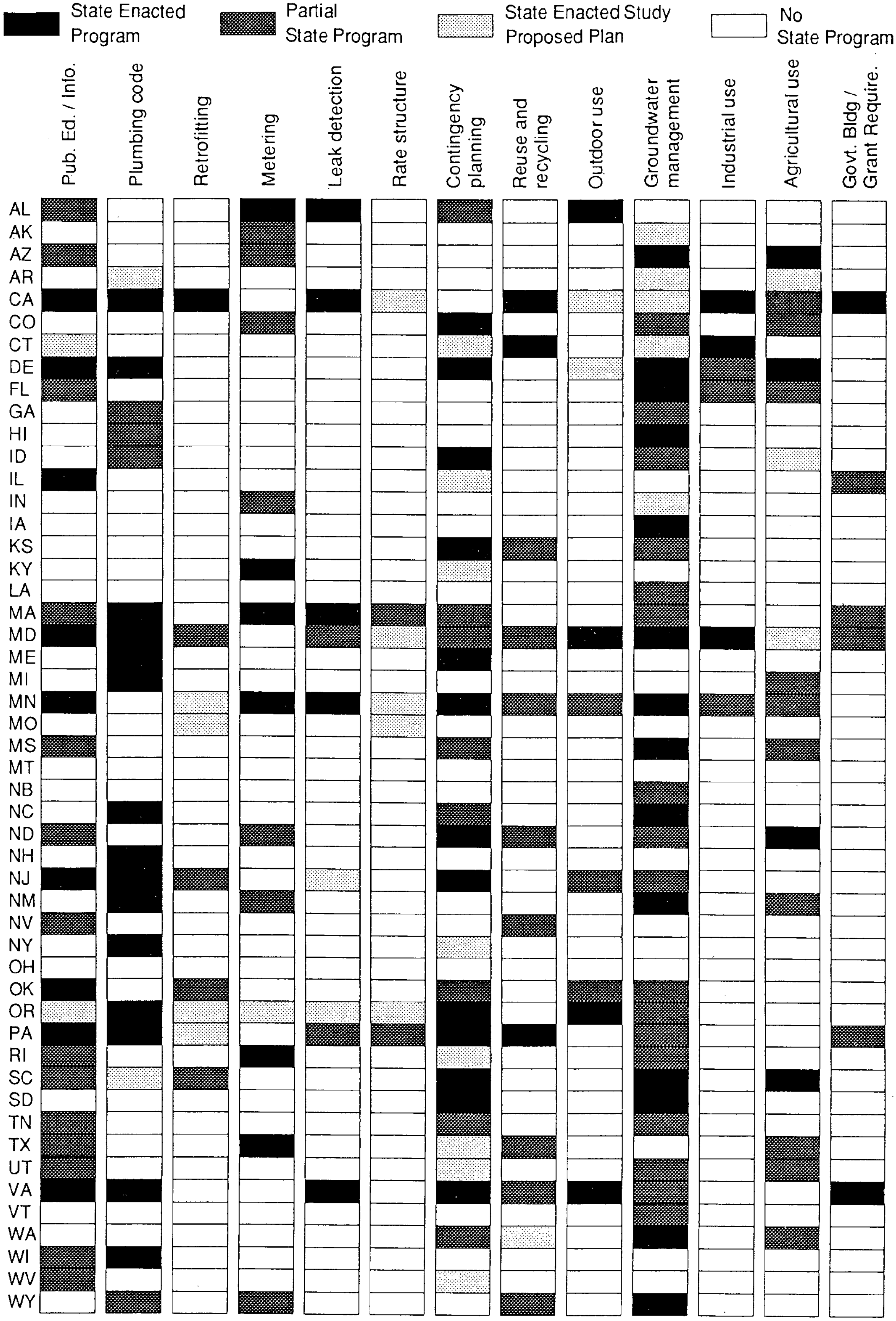
Conclusions of the Survey

1. California stands out as having the most significant and far-reaching water conservation program in the nation. The state has prepared a wealth of material on the potential of water conservation measures in all sectors.

2. The states of Massachusetts, Minnesota, and Maryland have also taken some significant initiatives in water conservation.

3. A wide range of actions remains to be taken. Only two states have programs to insure that state government buildings use water efficiently. Only one state has a comprehensive program to retrofit existing buildings with water-saving fixtures. Only five states are working on the leakage problem. Only three have programs to encourage more efficient water use by industry.

4. The category in which there was the most action was groundwater management. Thirty-five states have some groundwater management or regulation. Undoubtedly in many states the groundwater code was drafted to protect existing users without water conservation as an objective; however, this management is essential to insure wise use of water.


State Enacted Program
Partial State Program
State Enacted Study Proposed Plan
No State Program
Pub. Ed. / Info.
Plumbing code
Retrofitting
Metering
Leak detection
Rate structure
Contingency planning
Reuse and recycling
Outdoor use
Groundwater management
Industrial use
Agricultural use
Govt. Bldg / Grant Require.
AL
AK
AZ
AR
CA
CO
CT
DE
FL
GA
HI
ID
IL
IN
IA
KS
KY
LA
MA
MD
ME
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MS
MT
NB
NC
ND
NH
NJ
NM
NV
NY
OH
OK
OR
PA
RI
SC
SD
TN
TX
UT
VA
VT
WA
WI
WV
WY

5. The category in which there was the least effort statewide was in reform of rate structures. One reason is that regulation of rate structures is often left up to local public service commissions or public utilities commissions.

Note to Appendix C

1. Brent Blackwelder and Peter Carlson, Survey of the Water Conservation Programs in Fifty States -- Model Water Conservation Program for the Nation, United States Department of the Interior, Bureau of Reclamation (Washington, D.C.: Environmental Policy Institute, 1982).

More widespread management of water demand in Canada will require analytical techniques that are able to disaggregate demand to the end-use level. For this we will need better water demand data.

D.1 OVERVIEW OF CURRENT TECHNIQUES

The conventional method of forecasting demand for water is to look separately at industrial, agricultural, municipal, and power generation demands and estimate future demand in each by assuming a fixed relationship between water demand and economic and demographic factors. This method has several major shortcomings:

- It cannot address structural changes in lifestyle, water-use efficiency, industrial processes, or other variables that might change the basic relationships between demand and economic or demographic activity.
- It cannot describe specific end uses of water in sufficient detail for management of demand to be addressed as an alternative, or an addition, to supply augmentation.

Tate has analysed structural changes in industrial water demand, but only to the point of slight disaggregation at the manufacturing group level.[1]

It is now generally accepted by energy analysts, utilities, and government that end use energy analysis methods are superior to any other method for forecasting future energy demand and for efficiently managing current energy demand.[2] This section suggests ways in which the end-use approach can be applied to water demand analysis.

D.2 FACTORS AFFECTING WATER DEMAND

The amount of water used for a specific task depends on the following:

- the task to be carried out (e.g., washing, flushing, cooling, irrigation)
- the efficiency with which water is used to carry out the task
- the size of the task (e.g., tonnes of product produced, square metres of building floor area) or the number of people for whom the task is carried out.

The demand for water is usually classified by sector, as follows:

- industrial
- agricultural
- municipal
- power generation.

Municipal demand is a combination of demands from the individual residential, commercial, and industrial sectors served by municipal water and sewer systems plus allowance for leakage and infiltration.

Industrial Water Demand is determined mostly by the type and size of economic activity in each manufacturing or other industrial group, and by the efficiency with which water is used within plants (including the extent of recycling, reuse, treatment, and so on). The degree to which more efficient practices and equipment are used is, in turn, determined by water supply and disposal prices, by the availability and cost of water-efficient equipment and processes, and by regulations governing amount of withdrawal and quality of disposal.

Agricultural Water Demand is usually defined as demand for irrigation water and water for livestock, which has to be supplied and disposed of, excluding precipitation and natural run-off. It is determined by the hectares under irrigation and number of livestock, as well as by the efficiency with which the water is used (the percentage that is lost to evaporation and leakage). The number of hectares under irrigation is sensitive to the price charged for water whereas the number of livestock is determined more by other costs such as feed.

Residential Water Demand may be divided into two broad components: indoor and outdoor. Indoor residential water demand is determined mostly by the size and lifestyle of the population in terms of number of water-using appliances and the efficiency of water-using appliances. Outdoor water use is determined mostly by lot size and climate. Both indoor and outdoor use are strongly linked to the price of water, the relative cost of water-efficient equipment, and the income of the population.

Commercial Water Demand is determined by the size of the commercial sector as measured by floor space or number of services, and the efficiency of water-using equipment. The degree to which water efficient equipment is used depends mostly on water price and the availability and relative cost of the equipment.

Power Generation Water Demand is determined by the amount of electricity generated by thermal power plants, by the type of thermal power (nuclear versus other), and by the degree of recirculation of cooling water within these plants. The degree of recirculation (using cooling towers) is directly related to the cost and availability of water.

Municipal Water Demand, as defined above, is the sum of the publicly serviced residential, commercial, and industrial sectors. Additional factors affecting municipal demand are the degrees of leakage from distribution systems and infiltration into sewage collection systems. The degree of leakage and infiltration are usually determined by the size and age of the distribution and collection systems, the "value" of water in terms of the cost of new treatment and disposal facilities, and the regulations governing water and sewage treatment.

Demand for water in each of the above sectors varies with the time of day, day of the week, and time of year. Water supply must be able to meet both total and peak demand, as must the infrastructure built to treat, distribute, and collect water. Average and peak demand will also vary from one end use to another.

In practice, water demand also depends on attitudes towards conservation, the availability of good information, and several other factors. There are many examples of water users ignoring cost-effective opportunities to reduce demand.

D.3 SOME MODELS CURRENTLY AVAILABLE FOR THE ANALYSIS AND FORECASTING OF WATER DEMAND

Most models currently used to analyse water demand are of the input-output type:

water use = water-use coefficient x economic
or demographic activity

The analysis is conventionally carried out by calculating water-use coefficients from water-use surveys and economic/demographic statistics for the four usual divisions: industrial, agricultural, power generation, and municipal. These coefficients can be modified to make allowance for structural or technological changes (e.g., changes in water-use practices, efficiency, lifestyle). For example, Sonnen and Evenson introduced numerical conservation targets to improve the ability to predict water use.[3] Future demand is then estimated using the coefficients and future assumptions of economic and demographic growth rates. This approach was used by Tate to analyse several economic and demographic scenarios and forecast Canadian water demand to the year 2011.[4]

An alternative approach uses a simulation model to analyse water supply and demand in a selected river basin. The Water Use Analysis Model (WUAM) is an example.[5] WUAM allows the user to match supply and demand at each "node" in the selected river basin. Estimates of future demand are calculated from scenarios of economic and demographic growth, and from user-specified price/demand and industrial process water efficiency relationships. The model was primarily developed to analyse the impact of energy resource development, particularly in parts of western Canada with limited water supplies. For example, WUAM has been used to analyse water supply and demand in the Saskatchewan-Nelson river basin under a number of energy development scenarios.

The first model to attempt to use individual water coefficients for each end use is the Water Availability and Demand Evaluation System (WADES) currently being developed and tested by the Energy Systems Research Group (ESRG) in the United States. The model disaggregates each municipal sector (residential, commercial, industrial) by end use. Scenarios for future water demand can therefore be based on the penetration of actual water-using technologies and practices into that end use. More accurate predictions of scenario results can be made and targeted demand management initiatives become more practical.

The WADES model may be used in the following ways:

- as an information system to describe past patterns of use
- as a long-range forecasting model
- as a policy assessment tool by which supply and demand strategies can be evaluated
- as a planning tool to study the effects of short-term actions on water quantity.

The model is currently being used to study water supply and demand management options in the Boston area, where both water supplies and distribution/collection infrastructures are becoming limited.[6]

Another type of model that can be used to analyse water supply and demand is the Socio-Economic Resource Framework (SERF), developed by Statistics Canada and now operational at the University of Waterloo. SERF uses general systems theory to estimate resource supply and demands based on historical trends and projected economic, demographic, and resource coefficients supplied by system users. SERF currently calculates water demand from a simple per capita water-use coefficient and then estimates the value of capital stock needed for water and sewage distribution, collection, and treatment. The model can be adapted to disaggregate demands for resources according to end use. The current version of SERF, however, can only disaggregate energy demand from residential appliances.

D.4 A CONCEPTUAL FRAMEWORK FOR END-USE WATER DEMAND ANALYSIS

Although there are several models in use for predicting water demand on the basis of gross demographic and economic parameters, most are limited in their ability to analyse specific end uses of water. With the exception of WADES, it is not possible to analyse the effect, for example, of programs to retrofit commercial and institutional buildings with water-efficient fixtures. No water demand model currently in use is able to address degradation of water as a demand.

The challenge for a water demand manager, therefore, is to develop a framework that allows analysis of each end use -- similar to the framework used by energy end-use managers. Such a framework would need the following attributes:

- It must treat each end use separately, and allow differences between the amount of water needed (the water service) and the amount of water actually used to be taken into account:

  water use = service requirement/end-use efficiency

- It must relate consumption, gross use, and degree of recirculation for each end use to appropriate demographic or economic statistics:

  Consumption (m^3) = consumption coefficient (m^3/unit) x number of demographic or economic units

  Gross use (m^3) = gross use coefficient (m^3/unit) x number of demographic or economic units

  Intake (m^3) = gross use (m^3)/ recirculation rate

- It must allow for different intake sources and discharge points.

- It must contain some quantitative measures to indicate the degree of contamination and treatment associated with each end use.

- It must disaggregate sectors and subsectors sufficiently to identify major water users and end uses.

- It must be able to handle average and peak water demands.

Inputs to such a model for each end use, sector (industrial, agricultural, commercial, residential, and power generation), and subsector would be as follows:

- Average and peak consumption coefficients
- Average and peak gross use coefficients
- Demographic or economic units appropriate to the end use
- Recirculation rate
- Intake source distribution (reuse,[7] public, ground, surface)
- Discharge source distribution (reuse, public, ground, surface)
- Type of contamination (temperature, biological, nutrient, solids, toxics)
- Type of intake treatment (none, filtration, sterilization, other)
- Type of recirculation treatment (none, primary, secondary, tertiary)
- Type of discharge treatment (none, primary, secondary, tertiary)

Other inputs would include municipal supply leakage and wastewater infiltration coefficients for the area in which the model is used.

Average and peak outputs from the model for each end use, subsector, and sector would be as follows:

- Gross use
- Consumption
- Recirculation
- Total intake
- Intake from reuse, public, ground, and surface sources
- Gross discharge
- Total discharge
- Discharge to reuse, public, ground, and surface points
- Quality index (total discharge x treatment factor[8])

Sectors, subsectors, and end uses in such a framework should be chosen so that major end uses, and both water-intensive and non-water-intensive subsectors can be analysed separately.

The industrial sector should include the four major water-using manufacturing groups (food/beverage, paper/allied, primary metals, and chemicals) and three mineral extraction groups. At least three industrial end uses should be included: processing, heating/cooling, and other.

In the agricultural sector, irrigated and non-irrigated farms should be separated and coefficients per hectare and per head of livestock used respectively.

In the residential sector, yard-access houses (e.g., single houses, row houses) should be distinguished from households lacking access to a yard (e.g., apartments). Residential end uses should as a minimum include potable, sanitary (toilet), and yard.

In the commercial sector, institutions that use a lot of water (e.g., laundries), and water-intensive services (e.g., car washing) should be separated from other commercial users.

The electric power sector may be assumed to use water only for cooling.

Aggregated municipal demand is calculated from total publicly served residential, industrial, and commercial demand plus leakage and infiltration.

D.5 USES OF AN END-USE WATER DEMAND MODEL

An end-use water demand model built from the framework described above would be an improvement over the traditional input/output or simulation models currently in use.

- It could be used to describe historical and current water demand in a disaggregated fashion so that each water-using technology, process, and practice can be associated with a water-use coefficient. This would indicate more precisely where most water was being used, and what the expected reduction in demand associated with the development and penetration of each new generation of water-using technology or process might be.

- It could be used for long-range demand/supply analyses with greater accuracy than a more aggregated model.

- It could be used to assess demand management strategies aimed at specific end uses. This makes it possible to compare the cost effectiveness of demand management and supply augmentation.

- It could be used to determine where supply curtailment will cause the least economic and social impact in case of water emergencies.

- It could be used to improve the accuracy, usefulness, and capacity of integrated resource models such as SERF.

D.6 RESEARCH NEEDS

The concept of end-use analysis applied to water demand is in its early stages. The framework described above is, so far as we know, the first to comprehensively integrate end-use coefficients for consumption and gross use, recirculation, intake and discharge source, and water quality considerations into a single model at the subsector level. More research is needed to develop such a concept into an end-use model. Part of this research should include comparison with, and possible integration into, other water and general resource models such as SERF, WUAM, and WADES.

The most appropriate scale for testing and calibration of an end-use model would be at the regional level in an area where sufficient data are available covering a period during which water prices changed, and there was identifiable penetration of water-efficient technologies and appliances. The long-run objective of the research would be to identify water-use coefficients associated with each level of efficiency for each end use and sector.

Additional research would be required to determine the current degree of penetration of each "generation" of efficient technology or practice in each end use, so that the effect of demand managment on each end use can be addressed in forecasting.

Two other major areas where model design research is required are the concept of water degradation as a "demand," and the reuse of water from one end use to another. Given that effluent regulations often result in process change or increased recirculation, an end-use model must be able to provide a measure of the quality of a discharge as well as its quantity.

D.7 WATER-USE COEFFICIENTS AND DATA NEEDS

Water-use coefficients are not routinely calculated by any water agency in Canada or the United States. Coefficients generally come from one of four sources:

- case studies of single water users or small groups of users
- surveys of water users in which the total amount used and the percentage of water used for each end use is reported
- measurements of the efficiency of a specific water-using practice or technology
- calculations from aggregate water use (volume) and statistical or demographic measures.

Most water-use coefficients are reported for average gross use with current technology. In some cases, peak gross use coefficients or average recirculation rates are reported as well. Water-use coefficients for more efficient technologies are generally expressed in terms of the savings that can be achieved over conventional technologies.

Residential Sector: Most residential water-use coefficients are reported on a per capita or per household basis. Table D.1 gives average residential water use in several countries. Other estimates for all end uses include 140 litres per capita per day for a typical European household and 225 litres per capita per day for a typical U.S. household.[9] No Canadian residential water-use information is available because all data are reported as total municipal use per capita. Some Canadian data are available

Table D.1. Average Residential Water Use by End-use in Several Countries

		Litres per capita per day (percentage)				
Country	Total use	Toilet	Bath/shower	Laundry	Kitchen	Yard/other
United States[1]	295	70(24)	60(21)	45(15)	45(15)	75(25)
Sweden[1]	215	40(19)	70(32)	30(14)	50(23)	25(12)
Netherlands[1]	104	39(37)	27(26)	17(16)	17(16)	4(4)
United States[2]	245	95(38)	75(31)	50(20)	15(6)	11(5)
Several North American cities[3]	225	90(40)	66(30)	33(15)	31(14)	5(2)
Massachusetts[4]	212	84(40)	73(35)	29(14)	22(10)	4(1)

Sources:
1 Modelling Water Demands, ed. J. Kindler and C.S. Russel, (Toronto: Academic Press, 1984).
2 Sandra Postel, Water: Rethinking Management in an Age of Scarcity, Worldwatch Paper 61, (Washington, D.C.: Worldwatch Institute, 1984).
3 Environment Canada, Water Conservation Alternatives for the North (Ottawa: Environmental Protection Service Report EPS 3-WP-80-2, February 1980).
4 Resource Management Associates, Water Use Management for Dollars and Sense: The Time is Now (Boston: Greater Boston Chamber of Commerce, 1982).

on water use in apartment buildings. Barclay reports a breakdown by end use as follows: toilet, 40 per cent; bath/shower, 40 per cent; and other, 20 per cent.[10]

In terms of water consumption and discharge versus gross water use, it is usually assumed that only yard water is consumed in the sense of disappearing from the municipal system. All remaining water ends up in municipal sewers (or septic fields) whereas yard water evaporates or is absorbed by plant material.

A high daily summer maximum occurs around 1800 hours. Two peaks are usually found on a typical winter day -- one around 0900 and another around 1800. Robinson reports that in Kitchener/Waterloo average summer water use is 1.25 to 2.5 times average winter use, depending on the extent of summer water use for pools and lawn watering.[11] This range makes it difficult to estimate typical Canadian values for residential end-use coefficients for average or peak gross use, let alone coefficients for different parts of the country and different types of household. Assuming that water-using practices and technologies in Canadian households are more like those in the United States than any other country (except those for yard use), the following coefficients might apply to an average Canadian residential area:

	litres per capita per day	(percentage)
Potable uses		
Bath/shower	65	(29)
Laundry	40	(18)
Kitchen	30	(13)
Subtotal	135	(60)
Sanitary uses (toilet)	80	(35)
Yard/other outside uses	10	(5)
Total	225	

The most important data needs in the residential sector are therefore good Canadian estimates of water use per capita for each end use and water-using appliance. Typical data collection and analysis projects could include:

° Metering of water use by toilets, showers, dishwashers, clothes washers, outside faucets, and so on in a cross-section of households over a period of one year in different parts of the country.

° Water-use audits of large residential areas to determine usage patterns, such as the number of times particular appliances are used or lawns watered.

° Development of typical daily or monthly water consumption data for different models of toilets or appliances.

° Better documentation of the average degradation of water associated with each end use and technology.

The overall objective would be to build a picture of residential water use starting with end-use appliances or practices and calculating water-use coefficients on the basis of the timing and rate of use of each appliance or practice in each type of household.

Commercial Sector: Water-use coefficients in the commercial sector, when reported at all, are given most frequently on a per employee or a per municipal population basis. Neither measure is really useful. (The former assumes that labour productivity is uniform and the latter assumes that water use in commercial establishments is directly related to local population size.) A more appropriate basis for the calculation of commercial water-use coefficients is floor area in the case of offices, warehouses, and institutions, or constant dollars of commercial activity in the case of retail stores, hotel/motels, and restaurants.

Very few reports of water-use coefficients in the commercial sector exist. Tables D.2 and D.3 provide total use coefficients from two U.S. sources. Table D.4 provides total use coefficients for a Toronto office building. No commercial end-use coefficient data appear to exist. It is therefore impossible to provide any generalized estimates for end-use water coefficients for the commercial sector.

Water-intensive end uses and subsectors need to be identified and intensive metering carried out to develop a database of water use for commercial and institutional establishments. The approach taken to assemble commercial energy-use data could be followed. Several energy service companies and government agencies are developing databases from energy audits of commercial buildings. Individual measurements of fuel use are made, and compared with monthly utility bills. Energy end-use coefficients are calculated from these data for each building using a model such as SUMAC, which identifies monthly deviations from a "base load" and assigns them to seasonal uses such as air conditioning and space heating.

Typical data collection and analysis projects needed for the commercial/institutional sector are as follows:

° Documentation of water-use data collected by institutions and individual private and government facilities.

° Metering of water use by end use in a wide variety of commercial and institutional buildings, especially in water-intensive subsectors such as retail

Table D.2. Water Use in Selected Commercial Subsectors

Type of facility	Water use	Source
Offices	20-25 L per employee per day	2
Offices	40-55 L per employee per day	1
Shops	20-25 L per employee per day	2
Shops	200 L per day per metre frontage	1
Other businesses		
With dirty conditions	50-100 L per employee per day	2
Bakery	50-450 L per employee per day	2
Butcher	100-400 L per employee per day	2
Hairdresser	100-300 L per employee per day	2
Garage	35 L per car per day	2
Garage	40 L per car per day	1
Laundry	40-80 L per kg of clothes	2
Laundry	950-1900 L per machine per day	1
Hotels		
Room without bath	50-100 L per room per day	2
Room with bath	100-150 L per room per day	2
Motel (without kitchen)	380-570 L per unit per day	1
Restaurants	25-20 L per customer	1

Sources: Modelling Water Demands, ed. J. Kindler and C.S. Russel, (Toronto: Academic Press, 1984).

Table D.3. Water Use in Selected Retail Stores

Function	Mean water use, litres per m^2 per day
Health food	1.19
Men's clothing	0.91
Women's clothing	1.05
Hosiery	5.15
Shoes	1.12
Wigs	3.46
Uniforms	3.35
Carpets	0.98
Cutlery	1.04
Appliances	0.72
Music	1.55
Sporting goods	0.44
Books	0.48
Jewelery	2.06
Toys	0.86
Cameras and photography	1.99
Gifts and stationery	0.88
Fabric	0.73
Art supplies	0.73
Cosmetics	2.68
Art gallery	0.31
Bath goods	0.6B
Gourmet food	1.62
Opticians	1.57
Average	1.17

Source: Richard H. McCuen, Roger C. Sutherland, and Jae R. Kim, "Forecasting Urban Water Use: Commercial Establishments," Management--AWWA Journal (May 1975).

Table D.4. Water Consumption in a Toronto Office Building

	Years					
	1981	1982	1983	1984	1985	Mean
Litres per square metre per year	1495	1442	1301	1721	1818	1560

Source: Reported by Jack Smits, Manufacturers Real Estate, at Second Annual Energy Management Conference and Exhibition, 12-14 May 1986, Constellation Hotel, Toronto, Ontario.

(laundry, food stores), restaurants, and hospitals.

- Water-use audits of a wide variety of commercial establishments and the development of algorithms relating different end uses to deviations from a base load.

- Documentation of quality degradation associated with each commercial end use.

Industrial Sector: Tate has developed intake, gross use, and consumption coefficients for several manufacturing and mineral extraction industries and estimated the changes in these coefficients due to changes in production, water-using technologies and water-use practices for 1966-76.[12] Tate's coefficients are expressed as intake and gross use per employee and per dollar of output. Gross-use coefficients per dollar of output for 1976 are shown in table D.5. There is considerable variation in the coefficients among different regions of the country. Although much of this variation stems from scale and type of process, economic factors also have an influence. Coefficients per tonne of output show less variation and would not be subject to inflation.

New data collection initiatives in the industrial sector should therefore focus on individual end uses in water-intensive industries, such as food/beverage, paper/allied, chemicals, iron/steel and mineral processing. The water use per tonne (or dollar) of output associated with each unit operation and process should be determined, as should the recirculation rate (both practised and maximum potential) and variations on a daily and seasonal basis. Much of this information might be available from individual plants that document water flows at different stages in the plant. Other data would have to be measured on site. Because much of the potential for water efficiency in industry lies in changes in practice rather than individual pieces of equipment, these measurements would also permit demand managers to estimate savings associated with industrial incentive programs.

For the industrial sector, the source of water intake and wastewater flows are of particular importance. Although it may be assumed that most residential and commercial water is supplied from municipal distribution systems and discharged untreated into the municipal sewer, most water-intensive industries are self-supplied and handle

Table D.5. Industrial Gross Water-Use Coefficients for Canada (1976)

Industry	Million cubic metres of gross water use per $million output
Food and beverage	0.048
Rubber and plastics	0.113
Textiles	0.076
Wood	0.182
Paper and allied	2.045
Primary metals	0.709
Iron and steel	1.849
Metal fabricating	0.003
Transportation equipment	0.126
Non-metallic mineral products	0.165
Petroleum and coal products	0.573
Chemical and chemical products	1.194
Metal mines	1.080
Mineral fuels	0.087
Non-metal mines	0.421

Source: D.M. Tate, "Structural Change Implications for Industrial Water Use," Water Resources Research 22 (October 1986).

their own disposal. Reported data provide information on sources, discharge, and degree of treatment for the industry as a whole, rather than by end use. Future industrial water-use surveys should differentiate between end uses to a greater extent to allow development of a complete picture of an end use, from source to discharge.

Agriculture: Water-use coefficients for irrigation are usually expressed in terms of water use per hectare per year for each crop type. The coefficient will of course depend on the climate (temperature and precipitation) and the type of irrigation practice or equipment used. As with the industrial sector, most coefficients are calculated from amount of water used and area under irrigation. Few attempts have been made to estimate actual crop requirements per hectare and the percentage of requirements supplied by irrigation. In 1980 it was estimated that 630 000 hectares of farmland in Canada were being irrigated, using 2700 million cubic metres of water per year.[13] At least half of this is either lost by evaporation or consumed by the crop. Average Canadian irrigation water-use coefficients are therefore about 4300 cubic metres per hectare per year (withdrawal/gross use) and 2000 cubic metres per hectare per year (consumption). No coefficients for individual crops are available.

Estimates of water-use coefficients for livestock watering are available for several types of livestock, as shown in table D.6. It is assumed that, in feedlot or barn conditions (no natural watering), these coefficients apply in most regions of the country and that most of this water is consumed.

Table D.6. Water-Use Coefficients for Livestock

Type of livestock	Litres per head per day
Milk cows	154
Steers	51
Bulls	97
Calves	25
Other cattle	64
Pigs	9
Sheep	3
Horses	68
Hens/chickens	0.3
Other poultry	0.5

Source: Environment Canada, Canada Water Yearbook 1985 Water Use Edition (Ottawa: Canadian Goverment Publishing Centre, 1986).

New data collection initiatives in the agricultural sector should focus on developing regional average irrigation coefficients for various crops so that water demand can be calculated from the crop area irrigated. Coefficients for each crop should reflect the type of irrigation practice and technology and any seasonal variations.

Power Generation Sector: It can be assumed that water is used only for cooling in the power generation sector and that most of the water is returned to surface or groundwater sources. Gross use water-use coefficients for Canadian public and private electric power utilities range between 0.13 and 0.21 thousand cubic metres per GWh (million Kilowatt hours). Recirculation rates are zero in all provinces except Alberta, where the average rate is 2.8.[14]

Municipal "Sector": As stated earlier, the municipal sector is not a true sector but an aggregate of residential, commercial, and small industrial demands. Although it is common to think of municipal demand as mostly residential, and therefore express municipal water-use "coefficients" on a per capita basis, it is estimated that at least 19 per cent of municipal water in Canada is used by industry and 31 per cent by commercial, public service, and other users.[15] It is more realistic, therefore, to calculate municipal water demand from individual sectoral coefficients in each region or community plus allowances for municipal use, leakage, and infiltration. Water and wastewater source and discharge information should be documented at the municipal level.

Table D.7 provides a range of municipal water-use coefficients and estimates of leakage and infiltation.

Data collection in the municipal sector should concentrate on better estimates of leakage and infiltration and on algorithms for calculating municipal demand for water quantity and quality from sectoral coefficients and other data.

Table D.7. Municipal Water-Use Coefficients

Region	Water use (litres per capita per day)	Leakage or municipal use (unaccounted for)
Boston[1]		26%
Kitchener[2]	485	
Ontario municipalities (less than 10 000 pop.[3])	290	15 to 25%
United States[4]		up to 50%
United States[5]		4 to 75%

Source:
[1] Paul D. Raskin, James Goldstein, and Michael Lazarus, Closing the Gap: Preliminary Assessment of a Conservation Scenario for Meeting the Long Term Water Needs of the MWRA Communities, (Boston: Energy Systems Research Group, Inc., 1986).
[2] J.D. Pawley "Water Demand Management -- A Case Study" Canadian Public Works Conference, Ottawa, 12 May 1986.
[3] J.W. MacLaren, Municipal Waterworks and Wastewater Systems (Toronto: Inquiry on Federal Water Policy, 1985).
[4] J. Kindler and C.S. Russel, eds., Modelling Water Demands, (Toronto: Academic Press, 1984).
[5] John Regnier, Edgar H. Waldrup, and John A. Garrett, "Reducing the Cost of Water," Management and Operations--AWWA Journal (June 1986).

Summary: The priority areas for data gathering include:

- water end-use coefficients and recirculation rates associated with specific industrial processes in each manufacturing group on a per tonne or per dollar of output basis
- water end-use coefficients associated with various commercial establishments on a per square metre of floor space or dollar of service value basis for different end-use efficiency levels and practices
- the current degree of penetration of water-efficient equipment and practices -- especially in the industrial and commercial sector
- load factors (peak versus average) for water use in each end use and sector
- improved estimates of leakage and infiltration in municipal systems, and algorithms for calculating municipal water use from sectoral coefficients
- the degree of contamination associated with each end use in each sector
- algorithms for determining end-use coefficients from monthly water audit data.

D.8 A PRELIMINARY END-USE MODEL

Despite the general lack of data, an attempt was made to fit some of the water-use coefficients described above into an end-use model so that a preliminary analysis could be made.

A Lotus 1-2-3 spreadsheet[16] was developed based on the conceptual end-use framework described in this section for Canadian water use in 1981.

The first six pages of the spreadsheet printout show the inputs for the five sectors and their subsectors and end uses. The next four pages show the water-use outputs calculated from the inputs, along with subsector and sector totals. The last page summarizes municipal inputs and outputs.

D.9 MODEL INPUTS

The following inputs were used in the model:

Industrial Sector: Because no water-use coefficients per tonne of production are available (and Statistics Canada does not publish annual output in tonnes anyway), water-use coefficients per dollar of output were used. Coefficients for the major water-using industries were developed from those shown in table D.5 for gross use and consumption and for processing and heating/cooling end uses. Coefficients for 1981 were assumed to be 60 per cent lower than those for 1976 to allow for inflation.[17] Consumption and recirculation rates for each end use were estimated from 1981 industrial water-use survey data.[18] Industrial output data for 1981 for each industrial group were taken from Statistics Canada publications.[19] Appropriate types of pollutants were associated with each industry; water source, discharge point, and treatment information was taken from the Canada Water Year Book.[20]

Commercial/Institutional Sector: Commercial water-use coefficients were developed from data on water use per unit area presented in tables D.3 and D.4., which range from about 0.3 to 1.5 cubic metres per square metre of floor area. A value of 1.0 cubic metre per square metre was assumed for non-water-intensive buildings such as offices and retail stores. It was assumed that institutional and water-intensive commercial establishments were three times more water intensive than other commercial establishments. For lack of a better estimate, it was assumed that in all institutions and non-water-intensive commercial establishments 67 per cent of water uses are sanitary and 33 per cent potable. In water-intensive establishments a breakdown of 50 per cent each for washing and sanitary uses was assumed. Floor areas for each subsector were estimated from a report on energy use in the commercial sector prepared for the Ontario Ministry of Energy,[21] assuming that national floor area is approximately three times Ontario floor area. It was assumed that all commercial sector water is received from and discharged to public (municipal) services and that there is no recirculation, consumption, or water treatment. Commercial sector waste discharge was assumed to be contaminated only with biological and nutrient pollutants.

Residential Sector: Average residential coefficients for each end use suggested in Section D.4 above were used, together with population statistics from Statistics Canada.[22] It was assumed that 90 per cent of residential water is received from public (municipal) sources (with the rest from wells),[23] that all but yard use is discharged to public sewers; and that there is no recirculation or waste treatment. Residential sector water discharge was assumed to be contaminated with biological and nutrient pollutants only. Population breakdown between yard-access and non-yard-access subsectors was assumed at 60 per cent/40 per cent.[24]

Agricultural Sector: Irrigation and livestock coefficients and 1981 area-under-irrigation statistics were taken from the Canada Water Yearbook and 1981 livestock statistics were from Statistics Canada.[25] It was assumed that all irrigation water is derived from surface waters and all livestock water from groundwater. It was also assumed that there is no recirculation, and that contamination is due to nutrients and solids in the case of irrigation, and biological pollutants and nutrients in the case of livestock. Consumption rates were taken from the Canada Water Yearbook,[26] and it was assumed that all discharges were 50 per cent to groundwater and 50 per cent to surface water.

Power Generation Sector: The average water-use coefficient for power generation cooling and thermal power generation statistics for 1981 were taken from the Canada Water Yearbook. It was assumed that the average recirculation rate is 1.1 and that all water is contaminated only with heat. Source of water, point of discharge, and treatment information was taken from the Canada Water Yearbook.

Municipal "Sector": Percentage unaccounted municipal use and infiltration were both set at 15 per cent based on available information, and source, discharge, and treatment information was taken from the Canada Water Yearbook.

D.10 COMPARISON WITH AGGREGATE DATA

The sector totals calculated by the model were compared with 1981 water-use data reported in the Canada Water Yearbook.

Most sector totals appear to agree quite well with survey data. Discrepancies between predicted and surveyed municipal aggregate demand are probably due to the lack of good coefficients for the commercial sector. The order of magnitude for the commercial sector does appear to be right, however. Industrial water demand discrepancies are likely a result of structural changes in demand between 1976 and 1981. (The odd negative discharge for some industrial end uses in the model is because it was assumed that all consumption takes place during processing.)

Table D.8. Canada's Annual Water Intake

Sector or group	End-Use Model	Canada Water Yearbook
	(Millions of cubic metres)	
Industrial		
Public[a]	65	11
Self-supplied	11 218	9 774
Total	12 184	10 585
Agricultural	3 064	3 125
Residential		
Public[a]	1 802	---
Self-supplied	200	347
Total	2 002	---
Commercial[a]	658	---
Power generation	17 273	18 166
Municipal demand (intake)	4 030	5 074

[a] Included in municipal demand.

Notes to Appendix D

1. D.M. Tate, "Structural Change Implications for Industrial Water Use," Water Resources Research 22, 11, (October 1986).

2. William R. Huss, "What Makes a Good Load Forecast?" Public Utilities Fortnightly (28 November 1985).

3. Michael B. Sonnen and Donald E. Evenson, "Demand Projections Considering Conservation," Water Resources Bulletin 15, 2 (April 1979).

4. Donald M. Tate, Alternative Futures of Canadian Water Use -- 1981-2011 prepared for Inquiry on Federal Water Policy (Hull: Inland Water Directorate, Environment Canada, May 1985).

5. D.J. Norrie et al., Regional Modeling of Water Supply and Demand -- A Tool for Interagency Cooperative Planning, 1986. WAUM was developed jointly by Environment Canada, Energy, Mines and Resources Canada, and Acres International.

6. Paul D. Raskin, James Goldstein, and Michael Lazarus, Closing the Gap: Preliminary Assessment of a Conservation Scenario for Meeting the Long Term Water Needs of the MWRA Communities (Boston: Energy Systems Research Group, Inc., October 1986).

7. Reuse is use of water from another end use and recirculation is reuse of water within the same end use.

8. Treatment factor might be a simple measure of degree of water treatment, for example, 0(none), 1(primary), 2(secondary), 3(tertiary).

9. T. Konen, Performance Requirements and Test Procedures for Water Closets, presented at the National Water Conservation Conference on Publicly Supplied Potable Water, Denver, 1981.

10. David S. Barclay, "Retrofitting Apartment Buildings to Reduce Costs and Water Demand," Canadian Water Resources Journal 9, 3 (1984).

11. J.E. Robinson, personal communication, February 1987.

12. D.M. Tate, op. cit. (note 1).

13. Environment Canada, Canada Water Yearbook 1985, Water Use Edition (Ottawa: Canadian Government Publishing Centre, 1986).

14. Ibid.

15. Ibid.

16. A photocopy of the spreadsheet is available from the publications office, Science Council of Canada.

17. Statistics Canada, The Consumer Price Index, Publication 62-001 (Ottawa).

18. Environment Canada, Water Use in Canadian Industry 1981, Donald M. Tate and David N. Scharf (Ottawa: Environment Canada, 1985).

19. Statistics Canada, Publication 26-213, The Crude Petroleum and Natural Gas Industry; 26-223, Metal Mines; 26-224, Non-metal Mines; and 31-209, Manufacturing Industries of Canada (Ottawa).

20. Environment Canada, Canada Water Yearbook 1985, op. cit. (note 13).

21. Marbek Resource Consultants Ltd., Calibration of the Ministry of Energy Commercial Energy Demand Model Final Report, Ontario Ministry of Energy, (Ottawa: Marbek Resource Consultants Ltd., 1986).

22. Statistics Canada, Publication 92-901, Age, Sex and Marital Status (Ottawa, 1981).

23. Environment Canada, Canada Water Yearbook 1985, op. cit. (note 13).

24. Canada Mortgage and Housing Corporation, Canadian Housing Statistics 1983 (Ottawa, 1984).

25. Environment Canada, Canada Water Yearbook 1985, op. cit. (note 13).

26. Ibid.

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