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Buried Treasure: The Economics of Leak Detection and Water Loss Prevention in Ontario

Steven Renzetti
Environmental Sustainability Research Centre and Department of Economics, Brock University
Diane Dupont
Environmental Sustainability Research Centre and Department of Economics, Brock University

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Steven Renzetti [a], Diane P. Dupont [a]

[a] Environmental Sustainability Research Centre and Department of Economics, Brock University, St. Catharines, Ontario, Canada, L2S 3A1

Abstract

On average approximately 13% of the water that is withdrawn by Canadian municipal water suppliers is lost before it reaches final users. This is an important topic for several reasons: water losses cost money, losses force water agencies to draw more water from lakes and streams thereby putting more stress on aquatic ecosystems, leaks reduce system reliability, leaks may contribute to future pipe failures, and leaks may allow contaminants to enter water systems thereby reducing water quality and threatening the health of water users.

Some benefits of leak detection fall outside water agencies' accounting purview (e.g. reduced health risks to households connected to public water supply systems) and, as a result, may not be considered adequately in water agency decision-making. Because of the regulatory environment in which Canadian water agencies operate, some of these benefits-especially those external to the agency or those that may accrue to the agency in future time periods- may not be fully counted when agencies decide on leak detection efforts. Our analysis suggests potential reforms to promote increased efforts for leak detection: adoption of a Canada-wide goal of universal water metering; development of full-cost accounting and, pricing for water supplies; and co-operation amongst the provinces to promulgate standards for leak detection efforts and provide incentives to promote improved efficiency and rational investment decision-making.

Keywords

Water supply; leakage; cost benefit analysis

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1.0 Introduction

Suppose you owned a factory that shipped one hundred truckloads of your product to your customers every day. However, you learn that thirteen of those trucks never make their deliveries because they arrive empty. You would know something was wrong and you almost certainly would take action to remedy the problem. Unfortunately, that's the situation that Canadian municipal water suppliers find themselves in today. On average, approximately 13% of the water that is withdrawn from the environment, chemically treated, pressurized and then distributed is lost[1]. To be sure, Canada tends to fare better than many other jurisdictions where loss rates of 20%-30% are common.

It may be difficult to generate interest in a loss that is usually invisible and one that has become part of the standard operating procedures of almost all water agencies. However, in this time of concern over declining government budgets, the environmental impacts of our actions and concerns for risks to our health, the foregone opportunities and very real costs associated with losses from municipal water systems dictate that we examine the issue.

This is an important topic for several reasons:

- Water losses represent a lost opportunity. According to the latest estimates from Environment Canada, one in every six cubic metres of water supplied by municipal water agencies in Canada never reaches a customer. If all of this water were recovered, it could supply all of the needs for a city of over three million people.
- Water losses cost money. They represent over a billion dollars in potential revenue lost annually across Canada by municipal governments.
- Losses from water supply systems force water agencies to draw more water from lakes and streams thereby putting more stress on aquatic ecosystems.
- Leaks reduce the reliability of the water supply network. This may lead households and businesses to locate elsewhere, find alternative sources of potable water and otherwise find costly ways to protect themselves from the risks of unreliable water supplies. The American Society of Civil Engineers (2011) estimates that the costs to U.S. households and businesses of this reduced reliability of urban water systems is a staggering $75 billion annually.
- If undetected, leaks in water pipes may contribute to future pipe failures. In the city of Toronto alone, there are roughly 1,400 water main breaks a year and the vast majority occur in the winter—up to 70 a week (Hough, 2010).
- Leaks in water pipes may allow contaminants to enter water systems thereby reducing water quality and threatening the health of water users.

This issue has received extensive analysis from engineering researchers (e.g., Somani, 2008; El-Diraby, Karney & Colombo, 2009). In addition a number of municipal water agencies and engineering companies are investigating new approaches and technologies to leak detection. As

[1] We are using the term "leak" in accordance with the AWWA's category of "Real Losses" corresponding to "Leakage on Transmission and Distribution Mains". These do not include losses due to illegal connections or billing errors (AWWA, 2012).

economists, our contribution to this topic is to examine the decision-making that lies behind leak detection efforts. Specifically, we want to consider whether there is evidence that the socially efficient level of resources is being allocated to the leak detection effort. In order to do this, we'll examine what's known regarding the costs and benefits of leak detection and whether decision-makers are using these types of information as they address the challenge of water system leaks. The particular issue we are concerned with arises from the likelihood that some benefits of leak detection fall outside water agencies' accounting purview (e.g. reduced health risks to households connected to public water supply systems) and, as a result, may not be considered adequately in water agency decision-making.

This is a particularly good time for this investigation as Ontario has just passed the *Water Opportunities and Conservation Act*. The stated purpose of the Act is to make Ontario a leader in the development and sale of water conservation and treatment technologies while encouraging sustainable water use through conservation and investments in improved infrastructure and technologies (Ontario Ministry of the Environment, 2011).

2.0 Background

Water losses can occur for a variety of reasons. Some 'losses' are deliberate and are part of the normal operations of any water agency. These arise from necessary system flushing and testing as well as evaporation losses. Other losses, on the other hand, are inadvertent and not part of normal operation procedures. These can occur because of inaccurate meters, leaking pipes and pumps, and pipe breaks. Furthermore, one authoritative source provides the following distinction between apparent and real water losses:

> *Water loss can be either:*
> • *the apparent losses due to meter inaccuracies or unauthorized consumption, or*
> • *real losses due to leakage at water service lines, breaks or leakage on mains and hydrants/laterals or at storage facilities.* (Federation of Canadian Municipalities and National Research Council, 2003, p. ix)

The type of water loss we are concerned about in this report are those arising from leaks in distribution pipes. Leaks in water supply systems are a remarkably common occurrence. Somani (2008) estimates that the average North American water supplier has between 0.5 and 1.4 measurable leaks per mile of pipe. Other jurisdictions do worse with the leak per mile estimate often coming close to 3 leaks per mile. The leaks obviously vary in their size and significance. Nonetheless, when added up, they account for a significant amount of water lost from the system. According to the most recent statistics available from Environment Canada, approximately 13.3% of water on average is lost from distribution systems before reaching consumers across Canada. El-Diraby, Karney and Colombo (2009) provide data showing a great variation in this figure across cities in Ontario with a low of 3.2 % to a high of 30%. These figures represent water lost due to leaks, system flushing, maintenance and other factors. They are based on estimated losses reported by municipal water suppliers across Canada but these estimates have not been independently verified.

We can consider what the figure of 13.3% means. Canadian water agencies supplied approximately 4,741 million cubic metres of water in 2009. Losses of 13.3% translate into 630 million cubic metres of potable water. Based on an average total per capita water use in Canada (186 cubic metres per year), this means that estimated water losses from Canadian supply networks could have supplied the entire annual water needs of a city of approximately 3.4 million people.

Somewhat surprisingly, average estimated losses rose from 12.8% in 2006 to 13.3% in 2009. Environment Canada notes that change could be due to a number of factors, including more accurate measurement, changes in system pressures, or aging infrastructure leading to increases in main breaks and leaks. Another surprise found in the Environment Canada data is that more water is lost through leaks and system maintenance in larger municipalities than in small communities. The percentage in large cities of over 500,000 people (14.9%) is almost twice that of the smallest communities, ie., those with fewer than 1,000 people (7.6%). This difference needs to be interpreted with caution, however, as not all towns and cities provide Environment Canada with data and the response rates vary according to the size of the city with the smallest towns and cities having the lowest response rates.

Finally, across the provinces, the percent of water lost through leaks and system maintenance varies from an estimated low of 7.5% in Newfoundland and Labrador to a high of 22.1% in Quebec. Once again, comparisons across provinces should be made with care as these are self-reported estimates and metering rates differ across provinces (Environment Canada, 2011).
Fortunately, Canada fares relatively well in international comparisons. El-Diraby, Karney and Colombo (2009) cite international surveys indicating that most countries suffer urban water losses in the range of 20-30% with most North American cities having around 20% losses.
There are a variety of methods that water agencies employ to investigate and detect leaking pipes. The obvious challenge is that, unless they have led to a serious pipe failure, the vast majority of leaks occur underground, are difficult to detect and result in relative small water losses. The methods and technologies available to water agencies for detecting and reducing the impact of leaks include the following (Hunaidi, 2000; Federation of Canadian Municipalities and National Research Council, 2003):

- Conventional and smart meters
- Acoustic leak detection technologies
- Valve maintenance
- Pressure management
- Infrastructure repair and renewal
- Zone metering and district metered areas
- Nighttime flow analysis
- Distribution system modeling and monitoring

3.0 The Benefits of Leak Detection

Canadian water agencies are tasked with an important job: providing safe, reliable and affordable water supplies to millions of households and businesses on a daily basis. Despite continuing budgetary pressures and challenging regulatory requirements, these agencies are remarkably successful in accomplishing the task set for them. Every day, most Canadians turn on their taps without giving a second thought to the complex and costly job of supplying water.

One of the parts of the task of providing high quality drinking water is ensuring that system losses are kept to a reasonable limit. As discussed above, water systems lose water for a variety of reasons and water agencies have developed a number of strategies and approaches in their efforts to reduce water losses. Avoiding water losses provides a number of important benefits. Some of these benefits can be measured in a fairly straightforward fashion using currently available data and with current accounting methods. Conversely, some of the benefits listed here may not have received the same amount of analysis in the past and thus require new data and even new measurement methods to be developed. Furthermore, it is important to note that some of the benefits would be seen by the water agency which is investing in water leak detection efforts (although some benefits may be seen 'right away' while others – such as reduced risk of pipe failures in the future – may accrue to the agency over the future) while other benefits would be seen by others in society. After listing the types of benefits, we'll return to this issue of who enjoys the benefits from leak detection and discuss its significance in terms of how much effort is assigned to leak detection. The benefits from leak detection and water loss prevention include the following:

- Reduced water losses from system and the revenue losses they cause
- Reduced demand for energy, labour, chemicals and other scarce inputs needed to purify, pressurize and deliver water
- Reduced CO_2 emissions associated with energy use
- Deferral of water treatment plant and system capacity expansions through water savings
- Reduced traffic congestion, inconvenience and service outages arising from emergency repairs
- Reduced withdrawals of water from rivers and lakes and, thus, increased water for aquatic ecosystems, recreation, etc.
- Reduced risks of contamination of water supplies
- Reduced risk of future pipe and water main breaks

Just as water loss prevention efforts provide benefits to a water agency, its customers and society as a whole, they also require costly resources. These include the costs of actively searching for leaks, costs from pressure regulation efforts (modulating pumping pressures may reduce the risks of pipe breaks and reduce losses from leaks but requires greater planning and effort by the water agency), and construction costs when leaks are found and require repair or replacement. These are out-of-pocket expenses and can be substantial.

It is important to remember that not all of the costs associated with finding and repairing water losses are borne by water agencies. Digging up roadways in order to repair and replace leaking water pipes causes traffic congestion and delays and may reduce economic activity in neighbouring stores and businesses. These costs are borne by local commuters and business owners. More broadly, if a water agency must consume more energy in order to replace the water lost through leaks, then it may be increasing its CO_2 emissions and, as a result, contributing to global climate change. This is a cost borne globally.

The fact that water loss prevention provides benefits but is costly leads naturally to the question: 'what is the appropriate level of resources to devote to water loss prevention?' On the one hand, if leaks are very difficult to find and fix while leading to relatively little water loss, then agencies might reasonably decide that their scarce time and resources were best allocated to some other, more productive, task. On the other hand, if sources of water loss are relatively easy to find and repair while the benefits of doing so are significant, then it should be expected that water agencies would devote adequate resources to accomplishing this task. Like any other commercial decision, the optimal way forward depends on a full accounting and comparison of the relevant costs and benefits.

In order to examine the progress that's being made by water agencies in preventing water losses, it's necessary to first define more carefully what's meant by the costs and benefits of loss prevention and consider how these concepts can be used to identify the socially desirable level of effort for water loss prevention. Next, it's necessary to consider what is known about the magnitudes of the costs and benefits. Finally, we need to examine how water agencies use these types of information in determining the appropriate level of loss prevention efforts.

3.1. Accounting for all of the Costs and Benefits from Water Loss Prevention

As indicated above, a number of diverse benefits follow from detecting leaks in water supply systems. Some of these are enjoyed by the water agency itself (we term these "private benefits") and others are enjoyed by households and businesses other than the water agency (we term these "external benefits"). By the same token, there may be costs incurred in order to detect leaks that are borne only by the water agency ("private costs") and there may be costs borne by others ("external costs").

3.2. Identifying the Socially Optimal level of Leak Detection/Water Loss Prevention

It is critically important to note that the total benefit to society from leak detection is the sum of private and external benefits just as the total cost is the sum of private and external costs. This is important because economic efficiency requires that, when deciding on the appropriate level of resources to devote to leak detection, total social benefits be compared with total social costs. Specifically, efficiency requires that resources be invested in leak detection up to the point where the last dollar has a social cost of one dollar and yields one dollar in social benefits. This is the commonly cited "marginal benefit equals marginal cost" decision rule which underlies much of economic decision-making (including cost benefit analysis). This decision rule was recently emphasized in a National Research Council report that considered sustainable water infrastructure investments (El-Diraby, Karney, & Colombo, 2009)

It is one thing to identify a conceptual decision rule which will, in theory, yield efficient decision making. In order to operationalize such a rule, however, several steps are required. This requires having monitoring and measurement systems in place to provide needed data as well as capacity to do calculations and then see that they support decision-making process.

3.3. Evidence regarding the Benefits of Leak Detection

We will consider first what is known regarding the private benefits that can be expected to accrue to water agencies if they reduce water leaks. We will then turn our attention to what is known regarding the external benefits which households and businesses might enjoy with a reduction in losses from water supply systems.

There are several potential sources of information regarding the private benefits of leak detection. A starting point is to look at water prices since a cubic metre of water lost represents lost revenues. Environment Canada irregularly surveys municipalities in Canada regarding their water and sewerage prices. These prices vary by a number of factors including location, size of city, whether the city meters water use and the type of price structure used. If we average across all of these factors, the price of water typically is approximately \$1.20/ m^3 in Canada (Environment Canada, 2006).

Unfortunately, there's evidence in Canada that water prices do not reflect fully the cost of water supply (Renzetti, 2009). Thus, if water prices are typically lower that the cost of supplying water, using lost revenues due to water leaks will understate the foregone benefits associated with leaks. However, as the recent report from the Expert Panel on Ontario's water system pointed out, there are few reliable estimates of the cost of water supply in Canada (Water Strategy Expert Panel, 2005). Based on recent research carried out at Brock University, we estimate that the marginal cost of supplying water in Ontario ranges from approximately \$3/m^3 for small water agencies to \$0.60 for large municipalities. The mean value of the estimated marginal cost of supply is approximately \$2/m^3.

Based on these data on the price of water and the marginal cost of supplying water in Ontario, every cubic metre of water that is not lost should be expected to provide immediate private benefits to the water agency in the range of \$0.6 to \$3.0 per m^3.

There are additional sources of benefit to the water agency, however, which can be expected to accrue over the longer term. The first additional benefit arises from the observation that if a leak is not detected then there is a chance that it will grow in size and ultimately lead to a complete break in the pipe. These pipe failures are dramatic and costly. They typically result in service interruptions to nearby homes and businesses. They also require immediate remediation leading to costly repairs, road closures and reductions in economic activity for local businesses. The link between the presence of a small leak and the eventual failure of a pipe is a complex one (Kleiner & Rajani, 2001) since a variety of factors can cause pipe breaks. Nonetheless, to the extent that addressing a leak reduces the probability of a future pipe failure some time in the future, this longer-term benefit of leak detection should be estimated and included in the agency's decision-making regarding the efficient level of leak detection effort. Fortunately, as Kleiner and Rajani (2001) indicate, if a water agency invests in the data needed to estimate and maintain statistical models which predict the likelihood of water main breakage, then these longer run benefits arising from leak detection can be approximated and incorporated into the agency's planning.

The second additional benefit arises from the fact that reducing water losses means that the same amount of water leaving the treatment plants can serve a greater number of homes and businesses. In a municipality that is growing rapidly, this added efficiency may mean that planned expansions to treatment plant capacity, length and capacity of the distribution system and pumping capacity may be deferred. While the magnitude of this type of benefit will be specific to each city, it is easy to see that reducing losses by half could lead to a recovery of approximately 5% of the output of water treatment plants and this could correspond to up to two years worth of water demand growth. Deferring capital expenditures of tens or even hundreds of million dollars for two years would provide potentially significant savings to any city.

As indicated above, in addition to the private benefits arising from leak detection, there can be expected to also be external benefits. It should be recognized that, given current accounting and economic valuation methods, the estimation of the magnitude of these external benefits is challenging and not with controversy. Nonetheless, there is good reason to believe they exist and that they merit further analysis. The first of these external benefits relates to the energy savings that result from leak detection. The conventionally measured costs of water supply include the capital, labour, energy, materials and other inputs needed to produce potable drinking water. In many jurisdictions, the energy used by water agencies comes with an additional external cost which is not reflected in the price of energy: its impact on the accumulation of greenhouse gases and the attendant impact on global climate change. The magnitude of this external cost is challenging to estimate and varies according to the relative importance of fossil fuels as the source of water agencies' electricity and other energy consumption. In Ontario, most electricity is produced by nuclear or hydro facilities and, as a result, has relatively smaller carbon footprints compared to other jurisdictions. In the Prairie provinces where a greater proportion of energy needs are met from fossil fuels, the carbon footprint of water supply is greater and, thus, the external cost of water leaks related to their contribution to global climate change is higher. Work done for the European Union suggests that external costs (for quantifiable effects relating to impacts of global warming, public health damages, occupational health impacts, and material damage) from hydropower production range from €0.001 to €0.01 per KWh produced while external costs from coal production are much higher (between €0.02 to €0.15 per KWh). Considering that substantial amounts of electricity are used for producing water, these external costs can be substantial (European Commission, 2003).

To see the significance of these estimates, we can begin by noting that the City of Toronto spent in 2008 approximately $2 million per month on electricity to distribute water throughout the city. Its annual electricity bill in 2008, then, was approximately $24 million. If we employ the European Commission's estimate, then we may assume that the external costs associated with that energy use were approximately $0.0075 per KWh (that is, halfway between €0.001 to €0.01 per KWh once we convert from Euros to Canadian dollars), then the full social costs of the City of Toronto's electricity use to distribute water were approximately $28 million ($24 million private cost and $4 million external cost). Finally, assume that the City of Toronto's water system loses water are at the national average rate of 13.3%. Then, if the City were able to reduce its water loss rate from 13.3% to 6.7%, it would expect to see savings from its reduced electricity consumption alone in the magnitude of approximately $1.5 million annually. Furthermore, the external benefits to society associated with this reduced electricity use would be approximately $0.25 million.

The second external benefit from leak detection relates to the impact of leak detection on the likelihood of future pipe failures. Avoiding the costs of pipe failures certainly provides benefits to water agencies as described above but it also provides benefits to households and businesses. The external costs associated with road works (to repair water system) can be quite significant and thus avoiding these costs can be an important source of benefit. A report from Canada's

National Research Council on a case study of several water supply remediation projects in Winnipeg found that social costs ranged from 28% to 172% of internal project costs (Rahman, Vanier, & Newton, 2005). The report also points out that Canada is not unique in this regard. Many countries experience significant social costs arising from infrastructure repairs. The report cites a British study that concludes the annual cost of traffic delays borne by the public in the United Kingdom due to utility construction is estimated to be in excess of $2.3 billion.

The third external benefit from leak detection relates to the potential health risks arising from leaks in water supply pipes. As the US Environmental Protection Agency (2002) has pointed out, "corrosion can lead to pipe leaks, creating a pathway for pathogen intrusion into the drinking water" (p.17). The EPA report goes on to argue that a potentially significant source of risk occurs when sewage pipes -which the report characterizes "are notorious for leaking" (p. 19) - are in close proximity to leaking water pipes. It is very difficult to link directly observed illnesses to water quality, in general, and the presences of water leaks specifically. In a recent study of the impacts of inadequate investments in water and wastewater infrastructures, the American Association of Civil Engineers (2011) makes the following argument:

> *Water-borne illnesses will exact a price in additional household medical expenditures and labor productivity due to sick time used. The EPA and the Centers for Disease Control and Prevention have tracked the 30-year incidence of water-borne illnesses across the U.S., categorized the type of illnesses, and developed a monetary burden for those cases. That burden is distributed partially to households (29 percent), as out-of-pocket fees for doctor or emergency room visits, and other illness-related expenses leaving less for a household to spend on other purchases, and mainly to employers (71 percent), due to lost labor productivity resulting from absenteeism. The monetary burden from contamination affecting the public-provision systems over the historical interval was $255 billion.* (p.vi)

There is very limited direct evidence on this issue from Canadian sources. A recent Canadian study employs the defensive expenditure approach to obtain the value of reducing health risks that may be present in tap water (Dupont & Jahan, 2012). The authors estimate that Canadians spend approximately $590 million annually on purchases of bottled water and/or home filtration systems as a way of avoiding perceived health risks from drinking tap water. Certainly not all instances of water-borne illnesses can be linked to leaky pipes. There are a variety of ways in which water can become contaminated. Nonetheless, the magnitude of the costs associated with water-borne illnesses indicates the significance of this specific external benefit from addressing water leaks in municipal water systems.

In addition, epidemiology studies (Payment et al., 1997) carried out in Montreal suggested that the water distribution system was at least partially responsible for increased levels of gastrointestinal illnesses. Subsequent analysis of the study's data indicted that people who lived in zones far away from the treatment plant had the highest risk of gastroenteritis (Kirmeyer et al., 2001). This finding may be explained by the occurrences of negative pressures, which, in turn, can rise from leaking pipes. Despite the fact that Montreal employs state-of-the-art treatment processes, the distribution network was found to exhibit low disinfectant residuals, particularly at the ends of the system. Low disinfectant residuals and a vulnerability of the distribution system to pressure transients (possibly arising from leaks) could account for the illnesses observed.

4.0 Discussion

Water losses and the policies and procedures aimed at reducing their impacts need to be assessed within the broader context of water agency operations and the regulations that govern them. A key issue is the regulatory environment in which water agencies operate and make decisions. Currently in Ontario there are no federal or provincial regulations specifying the frequency of pipe inspections or setting out the framework within which decisions are to be made regarding investments in leak detection. In order to promote efficient decision-making, a framework would have to require water agencies to measure all (private and external) costs and benefits of leak detection and to incorporate these data into their investment decisions (Hardeman, 2008). In addition, there are few requirements with respect to cost accounting and pricing. These conditions imply that there is little or no reason to expect that the economically efficient level of leak detection is occurring. This is not because water agencies are uninformed or indifferent to the problems discussed here; far from it. In our view, water agencies across Canada understand fully the costs associated with leaking and unreliable delivery systems. The same agencies, however, lack the regulatory guidance and the political support for the water rate increases that would allow them to confront this challenge.

Many cities in Canada are growing and facing rising water demands. Given the growing competition for water arising from other users (industry, agriculture and even the aquatic ecosystems with their own instream flow requirements), these cities can expect to face resistance from these other users if they seek to meet rising water demands by increasing their withdrawals from local rivers, lakes and aquifers. In the cases of cities located adjacent or proximate to the U.S. border, cities seeking to acquire more water may also face restrictions arising from our obligations under the Boundary Waters Treaty. Addressing water losses then takes on a new urgency, as it may be a cost-effective source of ‘new’ water for growing Canadian cities. Strum and Thorton (2007) argue that water loss control programs are often less expensive than purchasing water or even demand management programs. They report that, for a sample of American water utilities, an average cost of water loss control programs of approximately $430 US$ per ace-foot (or approximately $\$0.35/m^3$). This contrasts to an average wholesale price of water in those jurisdictions over $1000 US$ per ace-foot ($\$0.82/m^3$) and a range of average costs for demand management programs of $350 to $1800 US$ per ace-foot ($\$0.29 – 1.47/m^3$). Thus, water loss prevention can be seen as a potential tool to support growth in Canadian cities by providing reliable water supplies while at the same time reducing the likelihood of the need to raise future property taxes to pay for increases to the capacity of water system as well as costly water main repairs.

This is an ideal time to act. Across Canada, engineering and technology firms are advancing our ability to detect leaks. Budgetary pressures are compelling managers at all levels of government to seek new cost effective ways to deliver the services valued by Canadians. A number of provinces are reexamining their water management frameworks with an eye to enhancing environmental protection while at the same time recognizing water’s contribution to economic prosperity. As an example, Ontario’s *Water Opportunities and Conservation Act* (2010) provides an excellent opportunity to address a number of issues relating to water agency financing, operations and leak detection.

5.0 Conclusions

As any water agency will tell you, water losses through pipe leaks reduce system reliability, threaten water quality, cause enumerable headaches and have very real costs. Engineering researchers have developed sophisticated methods to predict leak and pipe breakage frequencies and to detect leaks.

Our purpose in this report has been to highlight the costs imposed on water supply agencies and the broader community by water losses. Plugging these leaks – while costly and time-consuming – provides benefits economically, environmentally and socially. Because of the regulatory environment in which Canadian water agencies operate, some of these benefits-especially those external to the agency or those that may accrue to the agency in future time periods- may not be fully counted when agencies allocate their limited budgets amongst leak detection efforts and the many other competing needs facing them.

The concerns raised here point to potential areas for future research and also concrete reforms to promote increased efforts for leak detection. These include the following:

- Adoption of a Canada-wide goal of universal water metering
- Development of templates to support full-cost accounting and, pricing for water supplies
- Co-operation amongst the provinces to promulgate regulations that set standards for leak detection efforts and provide incentives to promote improved efficiency and rational investment decision-making.

It is valuable to note that progress has already been made for a number of these ideas. Specifically, a partnership between the Federation of Canadian Municipalities, the National Research Council and Infrastructure Canada that operated from 2001 to 2007 produced the Infraguide program. This developed Best Management Practice guides for a variety of municipal infrastructure topics including leak detection (Federation of Canadian Municipalities and National Research Council, 2003). Working together in the future would continue the work done by that program and other similar efforts to jointly address the challenges posed by municipal water losses.

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