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SURVEY RESULTS FROM VARIOUS CITIES HELP DESCRIBE THE BENEFITS OF IMPLEMENTING A STRUCTURAL WATER MAIN REHABILITATION PROGRAM

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ABSTRACT: The following paper will use results obtained from a study to describe the benefits of implementing a structural water main rehabilitation program. In 2009, a survey was sent to various cities in Canada that have carried out a water main structural rehabilitation program for a number of years. Each municipality was asked to answer a variety of questions including population, number of breaks, number of complaints and operational costs on their water distribution systems. Certain issues such as the number of breaks as the rehabilitation program progressed, in each of the cities, were examined. The results from the survey are shared in this paper to establish the various benefits to each of the participating cities. Benefits pertaining to water and construction cost savings are the main focus of this paper. The purpose of this paper is to raise awareness to the problems, issues and costs associated with old deteriorating water mains along with the technical and economical benefits of implementing a structural water main rehabilitation program.

1. INTRODUCTION

This paper will outline, with the support of actual case study values, the benefits of implementing a structural rehabilitation program for a water distribution system. Construction and repair costs, water, energy and carbon emissions savings are some of the topics that will be discussed.

The origin of water main rehabilitation using trenchless technologies and what prompted municipalities to implement structural rehabilitation programs will also be briefly presented in this paper.

A survey was conducted pertaining to water loss, leaks, breaks, treatment and water costs as well as different aspects of trenchless rehabilitation. A total of six (6) Canadian cities who have implemented a water rehabilitation program for at least five (5) years have answered the survey. Other previously obtained data will also be used to complement the survey.

The purpose of this paper is to raise awareness to the problems, issues and costs associated with old deteriorating water mains and to help utilities save money. This paper will also put forward both the technical and economical benefits as well as reflections as to how to overcome obstacles by implementing a structural rehabilitation program in their city.

2. BACKGROUND AND CONTEXT

It is well known that most cities throughout North America face deteriorating water mains along with the financial headaches of replacing them. In general, old water mains in distribution systems experience, to various degrees, non structural and structural problems. Non structural problems typically include diminished flow and pressure capacity and red water complaints due to tuberculated unlined metal pipe. Structural problems such as leaks and breaks arise for many reasons ranging from pipe material, age, past installation practices, corrosive environment, etc.

The consequences of these problems are tremendous not only to the city that has to cope with them, but especially to the end user who is too often subjected to water service stoppages. Of course, the financial burden to both the city and end user are also considerable. Repairs are typically carried out on an emergency basis, large amounts of water are lost in the ground and, many times, the user is left to cope with a flooded basement along with the repair costs and associated inconveniences.

For decades, technologies such as cement mortar lining have been used to deal with non structural or water quality issues with a great deal of success as long as the existing pipe was structurally sound. Unfortunately, these technologies did not address the structural issues at hand. These were commonly taken care of by simply replacing the water main altogether. For the last 10 years, structural lining technologies have been available to cities to help them deal with these structural problems and many of them have started using them. For example, an estimated 1.5 million feet of water mains have been rehabilitated so far with cured-in-place structural liners in North America.

3. SURVEY AND GENERAL DATA

In 2009, a questionnaire was put together to survey several cities to examine whether structurally rehabilitating their water mains was an effective way to solve their issues. As mentioned before, the survey was answered by 6 cities who have already implemented a potable water rehabilitation program for at least five (5) years. Data was also available from another small sized city which had previously provided similar data concerning their rehabilitation work. Throughout the paper, the Cities are named A through G so as to keep their identity confidential. However, those cities will be happy to answer questions on a referral basis.

Table 1 provides general information from the survey with regards to population, potable water system length and average age of the each of the systems.

Table 1: General Data on Cities Surveyed

	City A	City B	City C	City D	City E	City F	City G
Population	510,000	505,000	3,300,000	1,800,000	900,000	50,100	14,200
System Length (mi)	1,553	1,225	3,700	2,220	1,710	120	62
Average Age (yrs)	40	41	58	65	30.5	40	35

One can easily observe that water systems average from 30 to 65 years of age which is very similar to other cities in North America. Also, the populations of the cities surveyed, varying from 14,200 to 3.3 million people, allows for the consideration of small, medium and larger cities.

4. PROBLEMS AND ISSUES

Before discussing the benefits of implementing a structural water main rehabilitation program, it is important to examine the problems and issues of old deteriorating water mains as indicated in the survey. For this exercise, we will examine the most common problems such as user complaints, leaks and breaks.

4.1 USER COMPLAINTS AND COSTS

User complaints are generally based on rusty water, water quality issues and poor pressure flow.

Rusty water complaints are generally complaints dealing with red or rusty water. Customers often call the water utility informing them of the presence of red water causing their wash to be compromised and of an unacceptable drinking water quality.

Other quality issues are generally odor, taste or color. The survey results indicate that this issue is the second most inquired complaint by users.

Poor pressures and flows in water mains are other typical customer complaints. Customers will call to complain about poor water pressure from their shower heads or faucets. Fire Departments will also inquire about poor pressure and flow from fire hydrants needed for fire fighting.

To give the reader an idea of the importance of this issue, the survey indicates that the number of complaints from customers based on water quality ranges from 65 to 3,775 for our six cities surveyed. The results in Table 2 indicate that those cities receive a relatively large amount of complaints annually. Most of them concern quality and poor pressure or flow problems with the latter being the most important. These problems generally arise because of tuberculation forming in unlined metal pipe such as cast or ductile iron.

Table 2: Surveyed Cities Annual Water Complaints

	City A	City B	City C	City D	City E	City F
Rusty water	18	79	432	NA	315	20
Water quality	133	238	318	NA	153	10
Water pressure	313	350	3025	NA	831	20
Total complaints	464	667	3775	NA	1299	65
Ratio (complaint/mile)	0.30	0.54	1.02	NA	0.76	0.54

From the data in Table 2, one can observe that the ratio relative to the number of complaints per mile of water main varies from 0.30 to as high as 1.02. The higher the ratio the greater there are customer complaints that are called in that need to be addressed by the city. A high ratio indicates that the utility owner is in a reactive mode in answering to customer complaints rather than in a proactive mode that leads to a better customer level of service. Although customer complaints cannot be eliminated, a utility in a proactive mode will tend to decrease customer complaints, provide a better service and lower unplanned reconstruction costs in the long run.

User complaint costs can be attributed to administrative costs for dealing with the complaints, direct costs for repairing or relining the pipes and to increased insurance costs to the customers due to lack of pressure and fire protection.

Cities that tend to be constantly reacting to emergencies and not addressing the problem in a planned manner will most likely tend to decrease their level of service. Basically, the processing of unsolved complaints will only cost the city more money.

4.2 SYSTEM LEAKS AND COSTS

Leaks in the systems are a major contributing component of unbilled water. They can be caused by many factors such as pipe subjected to a corrosive environment, leaking joints due to soil displacements or pipe movement as well as poor installation practices. For North American cities, the leakage rate, or unaccounted-for-water, can be as high as 15% (AWWA 2006 Benchmarking survey). In extreme cases this percentage can be more than 40% and in many cases it is not even quantified. Other studies indicate leakage rates from 10% to 50% (Upflow, ESE Magazine, Summer 2009). As per Table 3, the cities surveyed have a percentage leak rate from 10 to as high as 35%.

Table 3: Surveyed Percentage Leak Rate

Year	City A % loss	City B % loss	City C % loss	City D % loss	City E % loss	City F % loss	City G % loss
2009	22	NA	10	35	NA	30	31

A literature review allowed us to obtain data on the amount of water recovered from water main leaks. A study indicated (Jones and Laven 2009) that after undergoing leak detection in Gwinnett County, Ga and SW Florida Water Management District, the number of water leaks detected were 534 and 735 respectively. This same study found that for small leak detection, although there are fewer leaks on water mains than on the remaining hardware, can account up to 49% of the water loss recovered. It was found that trunk main leaks account for water losses anywhere between 20,000 to 50,000 gallons per day with some large leaks being reported at 10 times those levels.

As per a study from the Residential and Civil Construction Alliance of Ontario (RCCAO 2009), the leakage costs for the province of Ontario water systems are 700 million dollars annually (www.rccao.ca) for a population of 12 million. Other results (Jones and Laven 2009), from a survey done in Gwinett County in Georgia indicate that in less than 12 months, the county located more than 500 leaks, achieved a water savings of 1.8 mgd and saved $400,000 per year.

4.3 PIPE BREAKS AND COSTS

Pipe breaks, small or large, can be caused by a contractor during construction, corrosion, soil movement, or pipe material weaknesses or defects. Most of the breaks in distribution systems tend to occur between the fall and spring seasons. Of course they occur unexpectedly and unfortunately the city is often faced with expensive emergency repair costs. Other consequences include high water loss and customer impact and if they occur to often, the city water system gets a bad image.

The number of breaks per year from the cities surveyed is staggering and Table 4 shows the break history of the cities surveyed.

Table 4: Surveyed Yearly Number of Breaks

Year	City A # breaks	City B # breaks	City C # breaks	City D # breaks	City E # breaks	City F # breaks	City G # breaks
2001	-	253	1,187	-	255	-	55
2002	-	300	1,195	-	295	-	60
2003	-	400	1,668	-	328	-	60
2004	-	307	1,513	-	277	-	55
2005	-	320	1,518	-	272	-	42
2006	-	281	979	-	267	-	35
2007	-	362	1,513	-	320	-	-
2008	-	249	1,053	-	263	-	-
2009	603	271	968	700	251	20	-
Avg. # breaks	603	305	1,288	700	281	20	51
Ratio (annual avg. breaks/mile	0.39	0.25	0.35	0.32	0.16	0.17	0.82

The water lost from breaks and leaks is typically lost in the surrounding soil and in many cases infiltrates inside the sewer system and returns back to the sewer treatment plant. In this case, the lost water is pumped and treated twice.

That is, once at the water treatment plant and a second time at the sewer treatment plant. The energy lost and, by the same token, the monetary impact of the water loss can be quite high.

The annual average break/mile ratio allows us to compare each city to each other no matter the size of their system and possibly provides us with an indication to their tolerance to water main breaks. For example, city B's ratio is .25 or 1 break per 4 miles length of pipe. Although, there does not seem to be any set tolerance as a basis to help cities decide whether to replace, rehabilitate or do nothing, the survey results do provide some indication in that regard.

Break costs depend on many factors such as labor wages, overtime charges, material and equipment costs. Typical break costs can be evaluated anywhere between $5,000 and $10,000 (Press 2009 & Fricke 2008). In some larger cities, especially downtown areas, the cost can be even higher since many street foundations have a concrete slab underneath the pavement and are located in high traffic areas. However, these costs do not take into account the social impacts to the customer and the impact on traffic.

The following is an example of the cost of a typical water break in 2006 located in a small city with a population of 65,000 and 203 miles of water mains (Alarie and Loiacono 2007).

Example: Break cost :

Cost of break repair = $5,000
Cost of water loss = $60 (loss of 120 000 liters for the break)
Water analysis = $230 (laboratory analysis)
Total estimated cost = $5,280 + social costs that are not accounted for

Essentially, the total estimated cost was estimated at $5,280 for a typical water break located in a rural area without taking into account the social costs.

5. SOLUTIONS

As mentioned, most water utilities in North America are faced with deteriorating water systems and regularly experience the types of problems that were discussed earlier. That is, the older the water main, the higher the probability that the water authority is loosing considerable amounts of water through their breaks and leaks. In the past, most water utilities would build the system but would not invest in maintaining it.

How do water utilities recover from previous neglect in maintaining their water mains? Many proactive utilities are now implementing water leak detection programs to detect and repair leaks. They vary from simple water leak detection routines performed by city crews using simple acoustic methods to the more sophisticated correlators that detect leaks that may be present on water mains. They also consult and use their break and leak repair registries to find the main problem areas in their water system and slowly start replacing them. Other utilities have put in place strategic water asset management plans which help them prioritize the work that needs to be carried out over a long period of time. As a result, their master plan will include some water mains that will need to be reevaluated, maintained, rehabilitated or replaced. Many water utilities have, therefore, put in place a structured water main replacement and rehabilitation programs.

In the past, non structural problems such as water quality and poor pressure flows were dealt with by cleaning and relining the cast and ductile water mains with cement mortar or simply replacing the water main. This is also true today as long as the existing pipe is structurally sound. Structural problems were solved by simply replacing the water main.

Most major cities in North America are aware of the benefits of trenchless technologies from their experience with the wastewater systems. Today, various solutions are also available to water utilities and they are well documented in industry literature. Some of these are briefly described in Table 5.

Table 5: Solutions Available For Deteriorating Water Mains

Solution	Description of the Solution
Cleaning (Swabbing)	This solution, although very effective in clearing the pipe of all deposits, is generally a temporary solution for tuberculated iron pipes. If the pipe is not lined after cleaning, the tuberculation will quickly return.
Non Structural Lining	Non Structural Linings such as cement mortar or epoxy can be used to solve many of the water quality and hydraulic problems. Again, it is important that the existing pipe be structurally sound to avoid future breaks and leaks.
Open-Cut Replacement	Open-cut replacement is the method which was and is still widely used. When compared to other solutions, this method is generally given preference over other alternatives when more than one underground infrastructure needs to be replaced and or the street infrastructure also needs to be replaced. It is generally very costly as can be seen by our survey results and also brings great discomfort to the population.
New Installations	Methods such as pipe bursting or directional drilling can be used to replace the old pipe with a new one, especially when upsizing is required. Although these methods have many advantages they require costly excavations at every house connection to reconnect the water services.
Sliplining	This method is also very good if the existing pipe needs to be renewed in a trenchless fashion. There are many variations of this technology but all provide the end result of inserting a new pipe inside the host pipe. As with pipe bursting and directional drilling slip-lining requires costly excavations at every house connection to reconnect the water services.
Structural Cured-in-Place-Pipe (CIPP)	Structural Cured-in-Place-Pipe (CIPP) has been used for the structural rehabilitation of distribution water mains for the last 10 years. Similar to replacement methods, these structural linings solve both the hydraulic and structural problems of the water main with the added advantage of being able to robotically reinstate the service connections from inside the pipe thus eliminating local excavations.

The open cut and the structural cured-in-place lining solutions referred to in the survey are an indication of the present solutions which are used by those water utilities to renew their water distribution system (6 to 12 inch diameter) which includes a considerable amount of service connections.

Tables 6 and 7 below show the amount of water main relining and reconstruction work that has been carried out for each of the cities surveyed. Some of these water utilities have been using structural CIPP to line their water mains since 2001.

Table 6: Surveyed Water Main Relining Work

Year	City A feet	City B feet	City C feet	City D feet	City E feet	City F feet
2001	0	0	0	0	31,826	33,013
2002	0	0	1,148	0	10,991	9,788
2003	11,775	2,624	3,936	0	14,452	14,711
2004	5,953	0	4,264	0	10,260	0
2005	9,348	12,464	656	0	16,656	7,643
2006	9,348	23,288	10,332	0	13,411	6,964
2007	14,400	22,632	10,496	0	11,326	9,112
2008	17,466	15,744	62,320	49,200	0	10,582
2009	19,303	13,448	104,960	37,720	380	12,860

Table 7: Surveyed Reconstruction Work

Year	City A feet	City B feet	City C feet	City D feet	City E feet	City F feet
2001	0	0	63,960	0	51,093	0
2002	0	0	124,640	0	17,135	0
2003	0	0	154,160	0	31,616	0
2004	0	0	108,240	0	45,225	0
2005	0	45,920	65,600	0	44,195	3,025
2006	6,560	32,800	95,120	0	71,829	0
2007	16,400	35,096	118,080	0	31,990	0
2008	19,680	32,800	134,480	NA	33,532	1,043
2009	29,520	35,424	229,600	40,344		3,661

Tables 6 and 7 provide an indication of the amount of water main relining and reconstruction work which has been carried out during a period of time in those cities. With the exception of City E which for years 2001and 2002 includes some non structural lining numbers the rest is mainly made up of structural lining only. The results clearly indicate the growing popularity of structural cured-in-place lining but also give us an indication that cities have only recently started investing in their potable water systems.

Tables 8 and 9 indicate the surveyed costs of structural cured-in-place and reconstruction respectively for different pipe diameters.

Table 8: Surveyed Structural CIPP Cost per Meter for Different Pipe Diameters

Pipe diameter inches	City A $/ft	City B $/ft	City C $/ft	City D $/ft	City E $/ft	City F $/ft
6	145	130	145	189	268	178
8	152	137	148	198	274	186
10	165	0	152	213	274	192
12	180	152	160	0	286	0

Table 9: Surveyed Reconstruction Cost per Meter for Different Pipe Diameters

Pipe diameter inches	City A $/ft	City B $/ft	City C $/ft	City D $/ft	City E $/ft	City F $/ft
6	229	229	284	793	562	290
8	236	229	314	854	583	299
10	252	0	0	0	0	0
12	259	229	345	915	581	0

One can observe, from Tables 8 and 9, a much higher cost for water main replacement as compared to structural CIPP. Replacement costs are typically 50 and 75% higher than CIPP and many times as much as double that of CIPP.

Table 10: Surveyed Reasons for Structural Relining in Percentage Values

	City A	City B	City C	City D	City E	City F
Breaks	80 %	80 %	20 %	100 %	20 %	50 %
Leaks	10 %	0 %	10 %	0 %	0 %	30 %
Water quality	10 %	20 %	20 %	0 %	80 %	10 %
Flow	0 %	0 %	10 %	0 %	0 %	10 %
Other	0 %	0 %	40 %	0 %	0 %	0 %

From the survey results, most municipalities surveyed are preoccupied by solving pipe breaks. It is important to note that other issues such as leaks, water quality, flow, and others are addressed at the same time when structural relining water main pipes. It is important to note that the 40 % indicated in "Other" for City C were specified as mainly issues pertaining to the age, water service density and maintenance history of the water mains.

The cities surveyed have indicated that most of the pipes rehabilitated were made of cast and ductile iron. From the survey data one can observe that the average system age, the type of materials that were used and the reasons for implementing a rehabilitation program are mostly to resolve water break issues. Therefore, this indicates that those cities are addressing the older pipes within their system with trenchless methods. Data show a direct benefit for structural rehabilitation versus replacement.

6. BENEFITS

The technical and economic benefits, to water authorities, of rehabilitating the small diameter water mains in the distribution system are described in the following paragraphs.

6.1 TECHNICAL BENEFITS

There are many technical benefits in structurally relining water mains and are summarized in Table 11.

Table 11: Technical Benefits

Technical Benefits	Reason
Improved water quality	Internal deposits are no longer existent
Improved flow and pressure capacities	Hazen-Williams coefficient is greater than 120. Pressures and flows are reinstated with respect to their original design.
No internal corrosion	Internal deposits will no longer form because of the new lining
Overall reduction of pipe breaks and leaks	Structurally rehabilitated pipe will prevent water breaks and leaks
Extended useful life	The life expectancy of the water main is extended by 50 years
Construction time is shortened	Structural relining work is completed in a much faster time than traditional open cut replacement
Less disruptive	Structural relining is less disruptive to the public and requires less traffic detours

These benefits lead to better customer service and allow the utility to be proactive implementing solutions before major costly issues occur in the future.

6.2 ECONOMIC BENEFITS

There are many economic benefits resulting from carrying out structural relining of water mains with CIPP and some are summarized in Table 12.

Table 12: Economic Benefits

Economic Benefits	Reason
Lower costs	Lower lining costs when compared to traditional open cut replacement.
Lower overall repair costs	Annual repair costs for breaks and leaks are decreased with the implementation of a structural rehabilitation program.
Decrease in water loss and costs	Because structural relining decreases the amount of breaks and leaks in the system, less water is lost thus saving the utility extra costs for additional treated water.
Energy savings	The more the water mains are watertight, the less water is lost and treated. Therefore the water utility will spend less pumping and treatment costs.
Lower administration costs due to complaints	A decrease in customer complaints will allow for an improved product and customer service. Staff time will be better administered and used for a more proactive approach in maintaining the water system.
Defer costly expenditures for water treatment plant expansion	In certain cases, implementing a proactive water relining program which creates a more watertight system will help defer costly expenditures for water treatment plant expansions.

Figures from Tables 8 and 9 indicate that the cost of structural CIPP is less than for open-cut replacement. These structural linings, although a little more expensive than non structural linings, will save utilities between 30 and 50% over replacement and in certain cases as high as 80%. These figures are also supported by other case study papers.

Table 13: Case Study Results from the City of Ottawa (Duclos, Willmets, and Salvo 2007)

Type of trenchless technology	Pipe diameter (inches)	Pipe length (feet)	Cost ($/ft) Structural relining	Cost ($/ft) Replacement	Costs ($) Savings	Costs (%) Savings
Epoxy Resin Lining	6	6402	$74.98	$168.00	$595,514	55
Epoxy Resin Lining	8	2014	$82.10	$168.00	$173,002	51
Structural Relining	6	9824	$107.26	$168.00	$596,709	36
Structural Relining	8	3648	$110.31	$168.00	$210,453	35

For example, Table 13 compares costs for different technologies such as epoxy lining, structural lining and replacement for distinct projects. The projects were completed in 2003 and the costs for epoxy lining, structural lining and replacement of 6 and 8 inch pipes are indicated. The numbers indicate that for an additional cost of 30 to 40 %, the use of a structural liner over a non structural one will allow the utility to solve, both, the structural and hydraulic issues with a minimum 50 year increase in life. Of course, these costs will vary from project to project and depend on many factors such as quantity, location, scope of work, etc. For instance, utility B which awarded 3 year relining contracts indicates the lowest prices.

Economic benefits that were calculated by using the results of our survey are demonstrated in Table 14 by examining the cost of water loss and water breaks. A great deal can be saved in the first years by tending to a potable water system. Actual survey units were used in the Table 14 to simplify calculations.

Table 14: Total Cost Due To Water Loss and Breaks

	City B	City C	City E	City G
Year	2009	2009	2009	2005
Cost of water per/m3	1,0387	1,8914	1,26	0,32
Amount of water m3 lost/yr	21,808,750	48,000,000	3,700,000	1,054,270
Total cost from water loss	$22,652,748	$90,787,200	$4,662,000	$337,366
Number of breaks	271	968	251	33
Cost per break	$7,500	$10,000	$7,500	$5,000
Total costs from breaks	$2,032,500	$9,680,000	$1,882,500	$165,000
Total cost due to water loss and breaks	$24,685,248	$100,467,200	$6,544,500	$502,366

From the results indicated in Table 14, one can understand that there are great economic benefits that can be obtained by dealing with the breaks and leaks issues. For example, City B has a population of 505,000 and a water system length of 1,225 miles. According to City B, the cost for treating 1 cubic meter of water is $1.0387 and the amount of water lost per year is 21,8 million cubic meters. This amounts to 22.6 million dollars of treated water that is lost from the system. That same city had 271 breaks in 2009 with an estimated cost of $7,500 per break. The total cost spent in repairing those breaks amounts to 2 million dollars. The total cost per year, to City B, due to water loss and water breaks amounts to 24.6 million dollars. If these savings were used to carry out additional water main rehabilitation, City B could renew an additional 34 miles of 8 inch diameter pipe per year or 2.7% of its total system.

It is evident from these results that important potential savings can be achieved by simply reducing or eliminating water main breaks. Whether through the use of asset management or by simply using the utility's break history records, a utility can target it's "hot spots" and rapidly reduce the number of breaks and water loss in the system.

6.3 OTHER BENEFITS

Table 15 summarizes important social costs (CERIU 2010) that are often not taken into account when opting for traditional open cut water main renewal.

Table 15: Social Costs (CERIU 2010)

Impact	Cost Descriptions
Impact on surrounding infrastructures	Lifecycle reductions on surrounding infrastructures such as wastewater mains, pavement, sidewalks, curbs, telecommunications, electrical and gas mains. The surrounding infrastructure will have to be renewed at an earlier date thus costing more to the customer.
	Service interruptions as well as temporary services required to maintain actual service can be costly.
Impact on traffic	Loss of revenues in metered parking spaces as well as parking fines are important losses in revenue.
	Waiting times due to traditional open cut methods can be attributed to high costs to pedestrians, drivers and passengers. Other important costs to businesses and those who deliver goods can be high when adding waiting times.
Impact on the environment	Costs for cleaning dust, dirt and garbage by customers located within the working zone of open cut renewal are not negligible.
	Vibration and noise is a nuisance to customers located within the working zone of traditional open cut renewal.
	Carbon gas emissions cause serious impacts to the environment especially when traffic is detoured or when a considerable amount of machinery are used on a jobsite. Carbon gas emissions have short and long term impacts on a human's quality of life.
Economic	Commercial activity often decreases when it is located within the working zone. Most clients will opt to go to another location due to reduced access or when no parking is available.
	Difficulty in receiving deliveries may lead to a decrease in stock availability which can lead to loss of revenue for businesses. Many deliveries are bound to be cancelled because of difficult access.
Security risks and damages	Traditional open cut renewal jobsites can be dangerous to the safety of the public and of the workers. Costs can be quite high when accidents occur. This can also entail difficulties for emergency vehicle accessibility.
	Claims pertaining to damages to buildings, cars, traffic lights, bus shelters are costs that need to be considered.

8.0 DISCUSSION AND CONCLUSION

This paper, with the help of a survey completed by several water utilities, has tried to describe the most important issues which plagues the utility's water distribution system along with several solutions which are at their disposal to help them solve these issues in an economical way.

There are potential savings that can be addressed by reducing the number of leaks and breaks. As presented, a water break may cost as high as $10,000 and according to the survey, the percentage leak rate in a water system can be as high as 35%. These issues can be very costly and repetitive to a water utility if they are not dealt with. Survey results indicated that a utility possessing 1,200 to 1,700 miles of water mains are losing from 6.5 million to 24.7 million dollars annually due to water losses and breaks. These are considerable amounts and are reason enough to entice utilities to proactively address these issues and decrease this annual loss.

Utility owners can immediately reduce these costs by properly planning a water main rehabilitation program and by proactively implementing a leak detection program.

There are many solutions available for repairing deteriorating water mains however; the utility owner must choose the one that provides the best technical solution and the most savings. Survey results clearly indicate that the cost of structural relining with CIPP is less expensive than reconstruction work. Figures show that utilities that have had a planned water main rehabilitation program have greatly reduced the annual number of breaks especially in their most troubled areas. Major results will be noticeable as long as the program continues to develop.

An important economic benefit, which unfortunately is often not taken into account, is the fact that a potable water relining program will reduce social costs unlike open-trench replacement. Social costs include dust, dirt, traffic detours, stress, noise, vibrations, decrease in commercial activity, public and worker safety that will last longer with open-trench replacement. It is well known that there are lower carbon dioxide emissions with the use of trenchless technologies versus traditional open-cut methods.

In conclusion, most water utilities across North America face the same problems and issues with their water distribution systems and the much needed funding required to replace them. Most of them are or will be looking for proven and affordable solutions which will solve their problems and at the same time make them save money. The survey results reflect that implementing a structural water main rehabilitation program is imperative and important. It is also important to have a proper leak detection program and have a proper inventory of where water breaks occurred to help focus on the more urgent areas. These actions will greatly reduce customer complaints as well as system leaks and breaks.

In the future, the Authors would like to expand this study further to quantify social costs such as the impact on surrounding infrastructure, traffic, environment, economic as well as the security issues based on past research and papers. They are very important costs which are often ignored into the decision making process when choosing trenchless technologies as compared to traditional open cut pipe renewal.

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