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350+ Towns and Cities Can't Be Wrong! Considerable Water, Money and GHG Savings with CIPP Water Rehabilitation

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ABSTRACT: Innovation in trenchless rehabilitation techniques has helped hundreds of towns, cities and water utilities in North America save millions of dollars in construction costs and reduce their water loss in distribution systems by using environmentally friendly cured-in-place pipe (CIPP) technology.

Large water utilities have struggled to maintain their water distribution systems to a point that some lose as much as 40% of the water treated. The lost water results in lost revenue and added pumping and treatment costs both at the water treatment plant and, too often, at the sewage treatment plant. This situation is costly and environmentally unsound.

This paper demonstrates, with the use of a case study, how a large water utility used a rehabilitation approach to significantly reduce its water loss. Actual test results demonstrate how water loss was reduced by comparing before and after water loss measurements of water distribution segments that were rehabilitated using a CIPP technology.

Further to the reduction of water loss, the paper also presents how the water utility saved millions of dollars in construction costs, the CIPP technology resulted in considerable savings in greenhouse gas emissions when compared to the open cut replacement method and the water utility benefited from the other trenchless advantages.

1. INTRODUCTION

Water utilities are well aware that massive investments in their water infrastructures will be required in the coming decades to renew their infrastructures and save this precious resource. Postponing these investments will only worsen the situation. In 2012, the AWWA published the "Buried No Longer" report which states, "More than one million miles of pipes are nearing the end of its useful life and approaching the age at which it needs to be replaced." The replacement costs and projected growth will amount to over $1 trillion over the next 25 years. The USEPA states that 60% of total water system costs are attributed to distribution and transmission mains.

These investment requirements have placed great stress on water utilities to find new funding alternatives and/or more innovative and economical technologies to help them carry out the work. For decades, trenchless technologies have been successfully used to renew and rehabilitate waste water pipes thus saving utilities a great deal of money and hardships. The same is happening for drinking water mains. Over the past few decades, trenchless technologies have been more readily used for water main rehabilitation thus providing water utilities the many promised benefits which are typically associated with trenchless methods. The use of environmentally friendly structural CIPP has helped hundreds of towns, cities and water utilities in North America save millions of dollars in construction costs and reduce the water loss in their distribution systems.

Results obtained in the case study will demonstrate how the City of Montreal, the 15th largest in North America located 360 miles north of New York City, used a CIPP rehabilitation approach to significantly reduce its water loss and, in addition, save in construction costs and greenhouse gas emissions.

2. INFRASTRUCTURE DETERIORATION AND COSTS

Studies have indicated that there are some 1.2 million miles of water mains installed in both Canada and the United States. In total, 84% of these water mains make up the distribution systems; mainly pipes from 6 to 12 inch diameters. Distribution mains typically include line valves, hydrants and small diameter service connections and piping that deliver drinking water to homes and businesses. The other 16% represent transmission mains with diameters 16 inches and larger.

Water utilities have struggled to maintain their water distribution systems to a point that some lose as much as 40% of the water treated in the distribution systems. The lost water often flows to the sewage system and is treated as sewage before being discarded. This situation is costly and environmentally unsound. In addition, water utilities are faced with costly issues such as breaks, leaks, colored water etc. which frequently result in traffic and water disruptions as well as water contamination.

These disruptions cost a great deal of money to the water utility and to the end user. The water utility must repair the water main breaks (Figure 1) and fix the many water leaks which occur from their water system. The water main must also be periodically flushed to manage the colored water. For example, over 850 water main breaks happen every day in North America costing over $8 million daily in repairs or $3 billion per year (watermainbreakclock.com website).

Too often drinking water is lost in the ground due to water main breaks and leaks. The water then enters the deteriorated sewer mains and is transported to the sewer treatment plant. Thus, the end user again has to pay for the pumping and treatment of this lost drinking water. Another important expense which is often overlooked is the proposed increase in water main diameter or the expansion of the water treatment plant which results from the lack of repairing or renewing the water system.

Figure 1: Typical Break Repair

In 2009, ASCE reported that leaking pipes in the United States lost approximately 7 billion gallons per day. For example the City of Montreal, which is the subject of our case study, repaired over 1,000 breaks and lost approximately 56 billion gallons of water in 2011. With an average repair cost of $7,500 per break and a very low variable water cost of $0.20 (includes cost of chemical products and electricity used for pumping and treatment) per 264 gallons lost (1 m^3), these breaks and leaks cost the City approximately $49.5 million in 2011; money which surely could have been put to better use. Using this same calculation for both Canada and the US, the breaks and leaks would cost approximately $4.5 billion per year. It should be noted that indirect costs due to water breaks are not included in the repair cost (such as costs due to flooding, insurance claims, legal actions, city employee involvement, etc.).

Other costly consequences resulting from water main deterioration include:

- Social costs such as traffic disruption and resulting pollution, etc.;
- Premature expansion of filtration plants;
- Loss of useful life of pavement;

- Accelerated deterioration of pipes due to inaction;
- Road collapses due to sink holes;
- Higher risks of water contamination and resulting legal impacts;
- Negative publicity for the city or water utility.

A 2012 *Trenchless Technology* water main survey indicates that by far the biggest problems faced by trenchless technology installations are connections (52%) and cost (43%) but the question is, **why do so many towns, cities and water utilities across North America decide to rehabilitate their distribution water mains with CIPP?** The main reason is that CIPP has proven time and time again that it provides solutions to these problems. In effect, CIPP provides a rapid and cost effective solution along with avoiding excavations for service connections reinstatement.

3. CASE STUDY DEMONSTRATION

General

The City of Montreal's Water Department is responsible for the production and distribution of potable water and the collection and treatment of its wastewater. At the turn of the century, the City of Montreal conducted several studies in an attempt to help it restructure its Water Department which at the time was decentralized between the City Center and its 19 boroughs. This restructuring led to the founding of the present Water Services Division (2005) and the setting up of a dedicated water fund. At the same time, the City also started an Asset Management Program whose master plan proposed massive investments in its water and wastewater infrastructures including the rehabilitation of its water mains, over the next 20 years.

As previously discussed, every year the City spends a significant amount of money to repair water main breaks in addition to the costs related to the water lost in the process. In order to reduce the number of breaks and leaks in their water system, the City started systematically rehabilitating their water mains with structural CIPP liners. To date, it has rehabilitated over 250,000 feet of small diameter distribution water mains with the use of structural CIPP liners. The following information is of interest with regards to Montreal's water system:

- 6 treatment plants;
- 14 reservoirs;
- 2,215 miles of distribution water mains (4 to 14 inch);
- 460 miles of water transmission mains (16 to 108 inch);
- Population of 1.6 million served;
- 171 billion gallons (650 M m^3) of drinking water produced annually;
- 34,248 valves and 22,605 hydrants;
- 260,000 water service connections;
- 1,003 breaks in 2011 (38/100 miles);
- Water loss = 56 billion gal/year or 33%

The case study involves the rehabilitation of 55,760 and 32,800 feet of water mains in 2010 and 2011 respectively. The total length in 2010 includes certain water mains which remained from a 2009 project. The rehabilitation technology used was the structural CIPP Aqua-Pipe® liner. The scope of work involved the structural rehabilitation of 6 to 12 inch diameter cast and ductile iron pipe, the robotic reinstatement of over 1700 small diameter service connections, replacement of valves and hydrants and the replacement of 550 lead service connections from the water main to the property line. Lead service replacements are carried out using trenchless technologies whenever possible. In this case, 75% of these lead service replacements were carried out in a trenchless manner using a pneumatic boring tool.

The Aqua-Pipe® technology has been used for water main rehabilitation in North America since 2000 and has since been used to renew over 2.1 million feet of cast and ductile iron, steel and asbestos cement pipes. It is a stand-alone Class IV structural solution which is certified by NSF to NSF/ANSI Standard 61 for potable water use. One of its unique features is the robotic reinstatement of service connections from inside the pipe. The technology is an accepted, proven and sustainable solution for water main rehabilitation.

Contract Requirement:

One of the requirements of the City of Montreal's contract documents and specifications is that a hydrostatic pressure test be carried out before the commencement of work as well as a similar test upon completion. The object of this requirement is to measure the amount of water lost before rehabilitation and compare it with the amount of water lost after rehabilitation. Three pressure tests were carried out for each water main section:

- The initial test includes the hydrostatic testing of the host pipe at system working pressure, including valves and hydrants and the water services from the main to the property line;
- A hydrostatic pressure test is also carried out on the rehabilitated pipe alone as per ASTM F1216 pressure test recommendations. This test is necessary and very important since it verifies that the liner performs as per contract specifications and is carried out before reinstatement of service connections.
- The final test is a repeat of the initial test including the rehabilitated pipe, new valves and hydrants and the same service connections reinstated from inside the pipe;

The hydrostatic pressure tests are carried out for a period of one hour and the volume of water required to maintain the pressure is noted and recorded. Figures 1 to 3 show typical field data sheets indicating the results of such tests. Figures 4 and 5 show a typical pump used to carry out these pressure tests along with the meter which measures the water amount. Considering the pump used for these tests has a maximum flow capacity of 580 gal/hr (2,200 L/h), it is not uncommon to surpass the pump capacity resulting in an incomplete test, as seen in Figure 2. Of course, the reason for this is that the water main has too many leaks and therefore has problems holding system pressure. All these field data sheets are signed by the contractor technician and countersigned by the owner's inspector.

FICHE DES ESSAIS HYDROSTATIQUES — N° FICHE 3556

1. Renseignements généraux / General information
Nom du projet / Project Name: MTL — N° du projet / Project No.: 5112-107
Chargé de projet / Project Manager: N. Éthier — Opérateur / Operator: Alexandre

2. Renseignements d'échantillon / Sample information
Rue(s) / Street(s): avenue Fairmount ouest
Longueur / Length: 105 m — Date: 21/9/12
Type d'essai / Type of test: HYDROSTATIQUE — Section /Section: P88 à RCV92
Diamètre/ Diameter:
Norme / Standard: ☒ ASTM F1216 ☐ 001 MEF ☐ Autres / Other:

3. Renseignements sur les essais / Test information
Nombre de jours après cuisson / Number of days after curing:

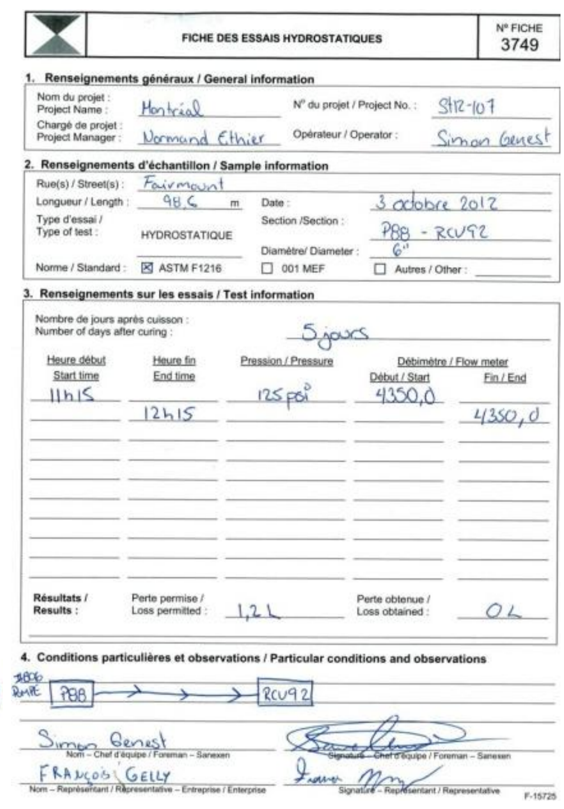
Heure début / Start time	Heure fin / End time	Pression / Pressure	Débimètre / Flow meter Début / Start	Fin / End

Résultats / Results: Perte permise / Loss permitted: Ø — Perte obtenue / Loss obtained: + de 2800

4. Conditions particulières et observations / Particular conditions and observations
P88 → RCV89 → PBF90 → PT90 → PBF91 → RCV92 — impossible de test, trop de fuite

Nom – Chef d'équipe / Foreman – Sanexen: Alex dufort — Signature – Chef d'équipe / Foreman – Sanexen
Nom – Représentant / Representative – Entreprise / Enterprise: Raymond Gaudreau — Signature – Représentant / Representative
F-15725

Figure 2: Field datasheet before rehabilitation



FICHE DES ESSAIS HYDROSTATIQUES — N° FICHE 3749

1. Renseignements généraux / General information
Nom du projet / Project Name: Montréal — N° du projet / Project No.: 5112-107
Chargé de projet / Project Manager: Normand Éthier — Opérateur / Operator: Simon Genest

2. Renseignements d'échantillon / Sample information
Rue(s) / Street(s): Fairmount
Longueur / Length: 98,6 m — Date: 3 octobre 2012
Type d'essai / Type of test: HYDROSTATIQUE — Section /Section: P88 - RCV92
Diamètre/ Diameter: 6"
Norme / Standard: ☒ ASTM F1216 ☐ 001 MEF ☐ Autres / Other:

3. Renseignements sur les essais / Test information
Nombre de jours après cuisson / Number of days after curing: 5 jours

Heure début / Start time	Heure fin / End time	Pression / Pressure	Débimètre / Flow meter Début / Start	Fin / End
11h15		125 psi	4350,0	
	12h15			4350,0

Résultats / Results: Perte permise / Loss permitted: 1,2 L — Perte obtenue / Loss obtained: 0 L

4. Conditions particulières et observations / Particular conditions and observations
P88 → RCV92

Nom – Chef d'équipe / Foreman – Sanexen: Simon Genest — Signature – Chef d'équipe / Foreman – Sanexen
Nom – Représentant / Representative – Entreprise / Enterprise: François Gelly — Signature – Représentant / Representative
F-15725

Figure 3: Field datasheet for liner alone

FICHE DES ESSAIS HYDROSTATIQUES

N° FICHE 3658

1. Renseignements généraux / General information

Nom du projet : / Project Name : MONTRÉAL
N° du projet / Project No. : JT12-107
Chargé de projet : / Project Manager : MIKE DAVISON
Opérateur / Operator : MARC MALLETTE-L

2. Renseignements d'échantillon / Sample information

Rue(s) / Street(s) : FAIRMOUNT
Longueur / Length : 107 m
Date : 05-10-2012
Type d'essai / Type of test : HYDROSTATIQUE
Section /Section : RCV92 à P88
Diamètre/ Diameter : 6 po
Norme / Standard : ☐ ASTM F1216 ☐ 001 MEF ☑ Autres / Other : FINAL

3. Renseignements sur les essais / Test information

Nombre de jours après cuisson : / Number of days after curing : —

Heure début / Start time	Heure fin / End time	Pression / Pressure	Débimètre / Flow meter Début / Start	Débimètre / Flow meter Fin / End
08:55		VILLE -> 50 P.S.I.	1520,4	
	09:55	49 Psi		~~(1522,8)~~
				1521,8

Résultats / Results : Perte permise / Loss permitted : — Perte obtenue / Loss obtained : 1,48/R

4. Conditions particulières et observations / Particular conditions and observations

RCV92 BF91 PT BF90 RCV89 P88

ENTRÉE #6 31 SORTIE

MARC MALLETTE-L
Nom – Chef d'équipe / Foreman – Sanexen
Signature – Chef d'équipe / Foreman – Sanexen

FRANÇOIS GELLY
Nom – Représentant / Representative – Entreprise / Enterprise
Signature – Représentant / Representative

F-15725

Figure 4: Field datasheet after rehabilitation

Figure 5: Pressure pump

Figure 6: Meter used for measurement

4. RESULTS

Water Savings

In order to calculate the total amount of water saved, the results of every section tested before and after rehabilitation are added and compared. Table 1 shows the detailed volumes of water lost before and after rehabilitation of all the water main sections rehabilitated in 2010 and 2011. Table 2 shows a summary of the water savings. **The overall annual water savings after rehabilitation, for both projects, is over 99%.** These remarkable water volume savings can easily be transformed into cost savings by simply multiplying the overall volume of water savings with the cost of water per gallon or m^3 for the water utility. If we use the same water cost mentioned earlier, the water savings amount to **$238,484** for 88,560 feet or $14,221 per mile of rehabilitated pipe.

It is interesting to note that the 6 filtration plants in Montreal reduced their water production by 17% between 2001 and 2011 thanks to leak detection combined with the replacement and rehabilitation of deteriorated water mains.

TABLE 1: Detailed Water Loss before and after Rehabilitation

Borough (City of Montreal)	Total Loss before Watermain Rehabilitation (gal/h)	Total Loss after Watermain Rehabilitation (gal/h)	Overall Gain (gal/h)
Ahuntsic/Cartierville (2010)	1 028.7	0.6	1 028.0
Ahuntsic/Cartierville (2011)	919.2	4.5	914.6
Anjou (2010)	2 574.3	17.0	2 557.3
Anjou (2011)	1 066.1	2.0	1 064.1
CDN/NDG (2010)	2 626.1	12.9	2 613.2
CDN/NDG (2011)	310.9	9.0	301.9
Ile Bizard (2010)	74.1	18.0	56.1
Lasalle (2010)	2 308.1	45.9	2 262.2
Mercier/Hochelaga/Maisonneuve (2010)	1 888.8	22.7	1 866.1
Mercier/Hochelaga/Maisonneuve (2011)	1 510.0	2.8	1 507.2
Montréal-Nord (2010)	3 661.2	35.9	3 625.3
Monréal-Nord (2011)	2 853.4	19.5	2 833.8
Plateau Mont-Royal (2011)	153.3	0.0	153.3
RDP/PAT (2010)	2 209.9	49.1	2 160.8
RDP/PAT (2011)	1 522.6	32.3	1 490.4
Rosemont (2010)	730.1	3.6	726.5
St-Laurent (2011)	138.3	3.8	134.6
St-Léonard (2010)	55.6	12.4	43.2
Sud-Ouest (2010)	1 493.2	2.5	1 490.7
Sud-Ouest (2011)	901.7	3.4	898.3
Ville-Marie (2010)	4 570.7	12.2	4 558.5
Ville-Marie (2011)	713.3	0.0	713.3
Villeray/St-Michel/Parc Extension (2010)	852.9	12.2	840.7
Villeray/St-Michel/Parc Extension (2011)	2 143.1	10.1	2 133.0

TABLE 2: Summary of Water Savings after Rehabilitation

Description	2010	2011
Length of Aqua-Pipe® installed (feet)	55760	32800
Overall water (gains) savings (gal/h)	23,829	12,145
Overall water (gains) savings (gal/yr)	208,738,524	106,385,895
Amount saved per year ($/yr)	$158,119	$80,587

Other savings for Montreal:

Throughout the years, it has been demonstrated that water mains rehabilitated with a structural CIPP liner have not experienced subsequent breaks and have actually helped reduced the number of annual breaks experienced by water utilities. With a break rate of 37.3 breaks/100 miles in 2011, the City of Montreal **saves $45,000** for 88,560 feet or $2,800 per mile of rehabilitated pipe.

As mentioned, the City of Montreal has been rehabilitating their water mains with structural CIPP since 2008. An important benefit for Montreal is the direct construction cost savings. From 2008 to 2011, the City saved over **$86 million** in direct construction costs for the structural rehabilitation with CIPP of approximately 150,000 feet (28.4 miles) of water mains, compared to replacing the pipes using the open cut method. This cost saving amounts to $3 million per mile. Many Montreal streets are constructed with 8 inch thick concrete slabs which make trench excavation expensive. In addition, the replacement of lead service connections also requires more excavations in an open cut project. This has also been experienced by other cities such as Toronto. (No Dig 2009 Sarrami, Coté))

Another important benefit of the CIPP technology is the reduction of greenhouse gas (GHG) emissions. This benefit is very appealing to city upper management and elected officials. Aqua-Pipe®'s GHG emissions have been quantified according to international standards. Calculations were completed according to a rigorous quantification protocol based on the ISO 140642-2 International Standard, the principles of life cycle analysis and two other validated protocols. The quantification report has been verified by the BNQ, a Canadian standard development organization, according to the requirements of the ISO 14064-3 International Standard. It was determined that Aqua-Pipe® reduces GHG emissions by 378 tons per mile of pipe of GHG or 84% compared to traditional open cut replacements. This amount increases to over 95% when GHG savings due to other impacts are included such as traffic detours and increased vehicle idling.

If the 84% GHG savings are applied to our 2 case study projects, the total GHG savings for 88,560 feet amount to **6,340 tons of GHG** which is the equivalent amount of carbon dioxide produced by the combustion of 412,600 gallons of gasoline or 3.3 million lbs of coal.

Table 3 summarizes the savings by the City of Montreal for the two projects in question.

TABLE 3: Summary of Savings

Type of Savings	For 88,560 feet	per mile
No. of breaks (37.3 breaks/100 miles)	$45,000	$2,800
Water savings	$238,484	$14,221
Direct construction costs	$50.8 million	$3.03 million
Tons of GHG/mile (84% less)	6,340 Tons	378 Tons
Other (social costs, etc.)		

5. CONCLUSIONS

The testing carried out on these two projects clearly demonstrates and confirms why the City of Montreal continues to rehabilitate its water mains with structural CIPP. The city was able to renew its water mains much faster with much less impact and disruption to communities and businesses. Table 3 summarizes only a few of the important savings realized by the City.

The nature of the work and its location results in impressive savings in direct construction costs over open cut; typically these cost savings are in the order of 20 to 50%. Additional benefits beyond cost and water savings include: less disruption; full structural capacity for an additional 50 + years; increased pressure and flow capacities; prevents future tuberculation; can negotiate bends; prevents future water main breaks and leaks; less disruptive and rapid installation; reduces GHG emissions and other social costs among many other benefits.

With well over 3 million feet installed to date in North America, including 2.1 million feet using Aqua-Pipe®, structural CIPP is now considered a proven technology which is accepted and used by cities throughout North America including Anchorage, Boston, Cleveland, Columbus, Madison, Minneapolis, New York, Omaha, etc. Water system managers have at their disposal another viable alternative for the renewal of their deteriorating water mains. The Aqua-Pipe® technology not only provides construction savings but also significantly reduces water loss in water systems making it a sustainable and an environmentally friendly solution. **350+ Towns and Cities Can't be All Wrong!**

6. REFERENCES

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