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James Bay I&I Reduction Pilot Project

A Blueprint for Effective & Environmentally Sound Sewer Rehabilitation

SUBMITTED BY:

James Bay I&I Reduction Pilot Project

A Blueprint for Effective & Environmentally Sound Sewer Rehabilitation

Title:	James Bay I&I Reduction Pilot Project
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Location of Project:	Victoria, BC
Component being Submitted:	Analysis of constructed I&I reduction measures
Category of Entry:	Category 5, Soft Engineering
Project Owner:	City of Victoria
Project Client:	City of Victoria
Summary Description of Project:	The James Bay I&I Reduction Pilot project involved the design, construction, and assessment of four sewer rehabilitation methods to reduce I&I. The findings of this study set a benchmark and provide a blueprint for I&I reduction work not only in Victoria but throughout British Columbia and beyond.
Other Consultants Involved:	Golder Associates Ltd. (Archaeology) CommPlan Canada (Communications)
Construction Contractors Involved:	Mar-Tech Underground Services Ltd. (General Contractor) SFE Global Ltd. (Flow Monitoring)

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consulting engineers

Project Highlights

Inflow and Infiltration (I&I) of stormwater and groundwater into sanitary sewer systems is a major problem for municipalities with ageing infrastructure. This additional water does not belong in the sanitary sewer and can overwhelm the system, causing overflows of untreated sewer water into the environment. It can also add significantly to infrastructure costs because higher flows require larger conveyance sewers and larger treatment facilities.

The City of Victoria is committed to reducing I&I city wide. In April 2008, it retained Kerr Wood Leidal Associates to provided planning, design, construction management, and evaluation services for the James Bay I&I Reduction Pilot Project. The project received a $3 million Innovations Funds Grant from Infrastructure Canada. The objective was to find the most effective methods for reducing I&I in terms of cost, environmental impacts, and actual I&I reduction achieved.

Project Objectives

The primary objective of the Project was to find the most effective methods for reducing I&I in terms of cost, environmental impacts, and actual I&I reduction achieved. This would then be developed into a "blueprint" for future I&I reduction programs throughout the City of Victoria. Specific objectives were to:

- Determine which approach to I&I reduction has the highest cost/benefit ratio;
- Reduce the impact of construction-related greenhouse gas emissions by maximizing the use of trenchless technology;
- Eliminate or reduce the number of sewer overflows;
- Improve public safety by lowering risk of sewer collapse; and
- Improve hydraulic capacity of the sewer system by reducing peak wet weather flows.

Project Approach

The Project was carried out in three phases: Planning; Design and Construction; and Evaluation.

Planning - The first step in reducing I&I is to understand where it comes from. For this reason, KWL's engineers undertook an extensive planning study to identify the sources, characteristics, and entry points of I&I. This involved analyzing CCTV and smoke/dye tests, and collecting and analyzing flow monitoring data.

Design and Construction – KWL's engineers designed and implemented four approaches to I&I reduction with a focus on using trenchless technology construction methods to minimize the carbon footprint of the project. The approaches applied were mainline rehabilitation using pipe bursting and cured-in-place pipe (CIPP) lining; manhole rehabilitation using a coating system and internal chimney seals; lateral rehabilitation using pipe bursting and CIPP lining; and stormwater inflow redirection, which consisted of stormwater pipes cross-connected with sanitary sewers being redirected away from the sanitary sewer system.

Three sewer sub-catchments were rehabilitated, each with different trenchless approaches. The three sewers were of similar size, age, and composition as was a fourth sewer catchment that was not rehabilitated and was used as a control to assess the degree of improvement in the rehabilitated sewers.

Evaluation – Following the rehabilitation works, flow monitoring was conducted to measure the degree of I&I reduction.

Outstanding Achievements

Before rehabilitation, peak hourly I&I rates in the study area ranged from 100,000 L/ha/d (litres per hectare per day) to over 400,000 L/ha/d for a 1-in-5 year storm event. Of the four rehabilitation methods constructed and assessed, two produced significant reductions in I&I. Post-rehabilitation measurements revealed that the mainline sewer and lateral sewer rehabilitation approaches had reduced I&I by 60%. KWL's engineers found that manhole rehabilitation and stormwater inflow redirection when done in isolation were not effective in reducing I&I.

Using a database that KWL developed to track sewer catchment age and I&I rates, the KWL team was able to plot the reduction of I&I in the study area. The area that received mainline rehabilitation showed an improvement to such an extent that it now behaves as a 40-45 year old catchment instead of the 100-year-old catchment that it is. This means that it should not require additional rehabilitation work for approximately 60 years. The area that received lateral rehabilitation is now behaving as expected for its age.

Innovation

One of the most innovative features of this project was the use of GIS data to develop a detailed understanding of the infrastructure and the nature of I&I in the study area. KWL's engineers mapped flow monitoring data, pipe video inspection data, and stormwater cross-connections. From this they developed a detailed picture of the infrastructure, its condition, and the characteristics of I&I throughout the study area. This enabled them to identify the areas of greatest need for rehabilitation and match those areas with appropriate rehabilitation approaches. This approach also allowed the team to optimize the I&I reduction program in terms of greatest I&I reduction within the allowable budget.

By using predominantly trenchless technologies for the constructed works, greenhouse gas emissions were reduced by approximately 95 tonnes as compared to open-cut construction methods.

This $3.6 million project provides new insight into effective I&I reduction. It also provides a blueprint for socially and environmentally responsible I&I reduction works. This will benefit not only the City of Victoria, but can also aid municipalities throughout British Columbia and beyond in managing and reducing their I&I.

Introduction

Inflow and infiltration (I&I) of stormwater and groundwater into sanitary sewer systems is an emerging and serious problem for municipalities with ageing infrastructure. This additional water does not belong in the sanitary sewer and can overwhelm the system, causing overflows of untreated sewer water into the environment. These overflows pollute and often damage property and pose health risks. I&I can add significantly to infrastructure costs because higher flows require larger conveyance sewers and larger treatment facilities. Old systems are prone to high I&I rates. Solving the problem of I&I is complicated and difficult, and effective techniques are just now being developed.

The City of Victoria is committed to reducing I&I city wide. In April 2008, it retained Kerr Wood Leidal Associates ("KWL") to provided project planning, design, construction management, and evaluation services for the two-year James Bay I&I Reduction Pilot Project ("the Project"). The Project included the design, construction, and assessment of four sewer rehabilitation methods to reduce I&I. Infrastructure Canada provided $3 million in funding for this project through its Innovations Funds Grant program.

Project Objectives

The primary objective of the Project was to find the most effective methods for reducing I&I in terms of cost, environmental impacts, and actual I&I reduction achieved. This would then be developed into a "blueprint" for future I&I reduction programs throughout the City of Victoria. Specific objectives were to:

- Determine which approach to I&I reduction has the highest cost/benefit ratio;
- Reduce the impact of construction-related greenhouse gas emissions by maximizing the use of trenchless technology;
- Eliminate or reduce the number of sewer overflows;
- Improve public safety by lowering risk of sewer collapse; and
- Improve hydraulic capacity of the sewer system by reducing peak wet weather flows.

Project Area

The City of Victoria is one of the oldest municipalities in Western Canada, and James Bay is one of its oldest neighbourhoods. Its sewer infrastructure is approximately 100 years old, and is composed mainly of clay pipe and a mix of brick and concrete manholes. Many of the sanitary sewer and storm drain systems were constructed in a common trench. Decades later, they are in poor condition, which allows for cross-filtration between the two systems. Interconnections between the storm drain and the sanitary sewer systems were originally built to prevent the sanitary sewer from flooding basements by allowing the sanitary sewer to overflow to the storm system. Over time, however, development changes have caused the reverse to occur. The 80 hectare study area encompassed four sanitary sewer sub-catchments and included 9.3 kilometres of mainline pipe and 6 kilometres of service laterals. The four areas selected for study were similar in size and infrastructure composition.

Project Approach

The Project was carried out in three phases: Planning; Design and Construction; and Evaluation.

Planning - The first step in reducing I&I is to understand where it comes from. For this reason, KWL's engineers undertook an extensive planning study to identify the sources, characteristics, and entry points of I&I. This involved analyzing CCTV and smoke/dye tests, and collecting and analyzing flow monitoring data. Flow monitoring was conducted at six temporary locations and at two pump stations in the study area between December 2008 and March 2009. From this analysis, the team identified and assessed potential combinations of rehabilitation methods based on cost and probability of effectiveness, given the predominant source of I&I.

Design and Construction – KWL's engineers designed and implemented four approaches to I&I reduction with a focus on using trenchless technology construction methods to minimize the carbon footprint of the project. The approaches applied were as follows:

- Mainline Rehabilitation – Pipe bursting and cured-in-place pipe (CIPP) lining were used to rehabilitate and replace aging clay pipes and eliminate abandoned sewer lateral connections. Pipe bursting consists of replacing old pipe by breaking it with a hydraulic ram and pulling a new pipe of equal or greater diameter through it. CIPP lining is a method whereby a resin-impregnated sleeve is inserted into the old pipe. The sleeve is then inflated using a bladder and cured with steam, hot water or UV light. The sleeve is the same diameter as the old pipe.

- Manhole Rehabilitation – A coating system and internal chimney seals were applied to manholes. The manhole coatings were a polymeric waterproof coating (Zypex) that was applied to manhole barrels.

- Lateral Rehabilitation – Pipe bursting and CIPP lining were used to rehabilitate and replace sewer laterals, which run from mainline sewers to buildings. Abandoned laterals, often a large source of I&I, were identified and eliminated.

- Stormwater Inflow Redirection – Stormwater pipes cross-connected with sanitary sewers were redirected away from the sanitary sewer system.

Three sewer sub-catchments were rehabilitated, each with different trenchless approaches. The three sewers were of similar size, age, and composition as was a fourth sewer catchment that was not rehabilitated and was used as a control to assess the degree of improvement in the rehabilitated sewers.

Evaluation – Following the rehabilitation works, flow monitoring was conducted to measure the degree of I&I reduction. This occurred between November 2009 and April 2010. A total area of 101 hectares was monitored. Actual I&I reduction was also measured against the costs to achieve it for each method applied.

Project Challenges

The project began in August 2008 and was completed in September 2010. Construction was initiated in mid-July of 2009 and scheduled for completion by October 31, 2009, but several challenging site conditions delayed completion of some work until December 2009. Despite these challenges, the overall project was completed on schedule.

The Dallas Road area of the Project proved particularly challenging. Some of the pipe bursting work crossed through an area of archaeological importance. As a result, an archeological monitor was hired to sift through the soils, causing delays. Pipe bursting in another section involved upsizing a 250 mm diameter pipe to 300 mm diameter. Unfortunately, when the original sewer was constructed, it was cut through a rock outcrop with minimal clearance to the outer pipe wall. This caused the burst head to become stuck several times, requiring excavation and rock removal. In addition, several lateral sewers on private property had wye connections. In some cases, more than one lot was connected to a single lateral. This made relining and bursting more difficult and caused additional disturbances to private property because the junctions had to be excavated to complete the construction work. These unforeseeable problems delayed the Project’s progress.

Budget

KWL prepared a Class A cost estimate of $2.38 million for the rehabilitation construction with item-by-item contingencies totalling $360,000, for a total construction budget $2.74 million. The project was tendered to invited contractors using a traditional design-bid-build process. Mar-Tech Underground Services Ltd. of Langley, BC was awarded the contract for $2.4 million. The final construction cost was $3.1 million, of which $2.7 million was spent on construction and an additional $400,000 was spent on consulting costs for construction management and archaeological work resulting from the unforeseeable site problems. The total project cost, including planning and design, was $3.55 million.

One fortunate discovery that KWL made from the video inspection was that one-third of the laterals did not require replacement. The contractor was compensated for loss in profit, but this was more than offset by the reduction in costs to replace the laterals. It also reduced the construction time thereby helping to keep the project on schedule.

Outstanding Engineering Achievements

Of the four approaches applied, KWL's analysis determined that only the lateral rehabilitation and mainline rehabilitation methods produced significant reductions in I&I. The lateral work had the highest ratio of peak hour 25-year I&I reduction to total cost, and compared well with other projects undertaken in North America. The mainline work resulted in post-rehabilitation I&I rate significantly lower than other areas in James Bay.

Before rehabilitation, peak hourly I&I rates in the study area ranged from 100,000 L/ha/d (litres per hectare per day) to over 400,000 L/ha/d for a 1-in-5 year storm event. This is very high but not unexpected in an old system such as James Bay. KWL's engineers determined that the mainline rehabilitation and lateral rehabilitation approaches reduced I&I by 60%. Engineers found that manhole rehabilitation and stormwater inflow redirection when done in isolation were not effective in reducing I&I.

Using a database that KWL developed to track sewer catchment age and I&I rates, the KWL team was able to plot the reduction of I&I in the study area. The area that received mainline rehabilitation showed an improvement to such an extent that it now behaves as a 40-45 year old catchment instead of the 100-year-old catchment that it is. This means that it should not require additional rehabilitation work for approximately 60 years. The area that received lateral rehabilitation is now behaving as expected for its age, which is an improvement, but still exceeds the City of Victoria's target threshold for I&I reduction and could likely benefit from mainline rehabilitation.

Innovation

One of the most innovative features of this project was the use of GIS data to develop a detailed understanding of the infrastructure and the nature of I&I in the study area. KWL's engineers mapped flow monitoring data, pipe video inspection data, and stormwater cross-connections. From this they developed a detailed picture of the infrastructure, its condition, and the characteristics of I&I throughout the study area. This enabled them to identify the areas of greatest need for rehabilitation and match those areas with appropriate rehabilitation approaches. This approach also allowed the team to optimize the I&I reduction program in terms of greatest I&I reduction within the allowable budget. Eight potential I&I reduction scenarios were assessed using multi-criteria decision analysis.

Use of a specialized lateral inspection camera to identify abandoned and damaged laterals was also a significant innovation. Lateral sewers often have no surface access points within the public right-of-way, which can make them difficult to inspect. A specially designed CCTV sewer camera was used to inspect the lateral sewers from the mainline to the buildings. The lateral probe launches off a mainline camera unit to a distance of up to 21 metres. This allowed the inspector to gain access to laterals without having to enter buildings or excavate. Significant cost savings were realized because newer PVC laterals were identified and not rehabilitated, and over 100 abandoned sewer connections were eliminated.

KWL's engineers concluded that it is important to assess the I&I rate versus the catchment age when considering I&I reduction projects. If a catchment is behaving according to its age, rehabilitation is unlikely to yield good I&I reduction results. Catchments requiring extensive structural repairs with high I&I rates are excellent candidates for I&I reduction, as are very old systems (e.g. 100+ years) with high I&I rates. The engineers also calculated a reasonable average budget for I&I reduction programs to be approximately \$750 - \$800/metre, which will assist the City of Victoria in setting budgets for future I&I reduction projects.

From its finding, KWL developed a five-step approach for designing and implementing I&I rehabilitation programs that provide a high benefit for their relative cost. The steps are: 1) Data Collection, 2) I&I Analysis, 3) I&I Reduction Planning, 4) Design & Construction, and 5) Program Evaluation. Extensive data collection and analysis using GIS is essential for implementing well designed and cost-effective programs.

Sustainability and Environmental Aspects

The entire Project, from initial planning through to program evaluation was based on achieving Triple Bottom Line principles (i.e., economically viability, socially responsible, and environmentally sound). Essential to achieving these goals was the focus on using trenchless technology for construction. Trenchless technology has several advantages over traditional open-cut construction. Greenhouse gas emissions are reduced because much less fuel is required for construction equipment. Generally, trenchless technology is a more efficient construction method because it requires much less excavation, backfilling and hauling of materials than open-cut construction. Because road disruptions are greatly reduced, so are fumes from idling vehicles in traffic jams. Using trenchless technology also minimized damage to landscaping on private property because excavation was minimized. Using trenchless technology for this project resulted in approximately 95 tonnes of greenhouse gas emissions being avoided as compared to open-cut construction.

The James Bay I&I Reduction Pilot Project provides new insight into effective I&I reduction. It also provides a blueprint for socially and environmentally responsible I&I reduction works. This will benefit not only the City of Victoria, but can also aid municipalities throughout British Columbia and beyond in managing and reducing their I&I.

Photo 1: Aerial view of the James Bay study area in Victoria, BC

Photo 2: Using an innovative camera launched from this truck eliminated the need to inspect lateral sewers by either entering building or excavating.

Photo 3: Fusing replacement pipe before trenchless installation

Photo 4: Pipe bursting entry pit

Photo 5: Axe head found in archaeological area

Photo 6: Rehabilitating a service lateral with CIPP (cured-in-place pipe)

Photo 7: Manhole before rehabilitation

Photo 8: Manhole, with coating applied, after rehabilitation

City of Victoria
James Bay I&I Reduction Pilot Project

Legend

- Study Areas
- Existing Sanitary Manhole
- Existing Gravity Sewer
- Existing Forcemain

Area 1A - Mainline Rehabilitation

Method

- CIPP
- Pipe Burst

Area 1B - Manhole Rehabilitation

- Manhole Rehabilitation

Area 2 - No Works

- No Works

Area 3A - Lateral Rehabilitation

Method

- CIPP
- Pipe Burst
- Storm Line Replaced
- Storm Cross-Connection

Area 4 - Stormwater Inflow Redirection

Method

- Storm Line Replaced
- Storm Cross-Connection

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Scale in Metres 1:7,500

I&I Reduction Works Completed