(UR - 7) Region of Peel Trunk Sewer Inspection and Condition Assessment Program: A Multi-level, Staged Approach

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Overview

The Regional Municipality of Peel is located on the west side of the City of Toronto adjacent to Lake Ontario. Peel's wastewater scheme consists of 2 major drainage systems (the East and West systems) each of which outlets to a treatment plant located on the shores of Lake Ontario. The lake-based wastewater system currently services approximately 1 million people.

In 1997 the Region commenced a pilot program to inspect two large diameter trunk sanitary sewers using combined Closed-circuit Television (CCTV) and Sonar equipment. Successful completion of the pilot program lead the Region to initiate a comprehensive Trunk Sewer Inspection and Condition Assessment Program to address the needs of the entire trunk sewer system. This involves some 210 km of pipes ranging in size from 750 mm to 3050 mm in diameter (see summary in Table 1). Based on known needs and available technology a multi-year, staged program was developed. Approximately 50,000 m of pipeline and some 500 structures have been inspected each year since 1997. Stage 1 of the annual program involves an initial "First Order" inspection of the assigned sewers and manholes for that year. In Stage 2, assets are rated according to a defined set of criteria, needs are identified and priorities ranked. For the most part condition assessment results are clear cut with the majority of pipelines and structures found to be in good condition while only a few need obvious repair or rehabilitation. However, in some cases the implications of the First Order inspections are not obvious and further detailed investigations are warranted in order to finalize condition assessment conclusions; these detailed, "Second Order" investigations are carried out in Stage 3. Selecting from a menu of available techniques, detailed investigations are tailored to suit site specific problems and objectives. These have involved in-depth hydraulic analysis, monitoring of corrosive environments, person-entry inspections, concrete coring and detailed structural investigations. The Stage 3 findings are then used to finalize and update the Stage 2 condition assessment rankings. Finally, in Stage 4, findings are compiled and feasible remedial techniques are programmed into the next year's Capital Budget.

The purpose of this paper is to explain the importance of a systematic and proactive approach for managing large diameter trunk sewers. The paper highlights how this program has evolved to become an important tool in developing and prioritizing the Region

Table 1 Assessed Infrastructure

Year	Sewers		Manholes
	Length (m)	Section	
1998	14,600	113	0
1999	25,200	134	0
2002	45,700	355	354
2003	61,500	704	820
2004	60,000	438	450
Total	**210,000**	**1744**	**1624**

of Peel's short and long term trunk sewer needs and in setting the Region's ongoing budget requirements. The way in which the program has been adapted to ensure broad-based communication and coordination amongst the various engineering, planning and operations groups at the Region is also explored. A brief overview of the work completed to date is used to highlight the diversity and extent of the trunk system and to illustrate the staged approach.

Stage 1 - First Order Inspections

First Order investigations are intended to quickly and cost-effectively scan large parts of the system. As most sewer sections and manholes are in either Good or Fair condition (about 88% of the total as shown in Table 2) First Order investigations are all that's needed. In effect these investigations are a screening tool used to identify those sections that are in Poor or Bad condition. For the Region of Peel program First Order Inspections included standard CCTV inspections, combined CCTV/Sonar inspections of the trunks and visual inspections of manholes.

The Water Research Center (Great Britain) (WRC) methodology and guidelines were selected by the Region as the standard for the inspections (and subsequent assessment). The use of WRC guidelines were intended to ensure consistency from year to year, from one sewer to an other and between individual reviewers. The WRC coding and definitions have been used throughout the program.

As an example of Stage 1 activities, a typical First Order Inspection was carried out in 2002. In that year some 45 km of trunk sewers and 350 manholes were inspected. Each sewer inspected was running at least 50% full, hence CCTV equipment combined with specialized Sonar equipment was used to carry out the inspections. The Sonar images provided information from below the waterline including analysis of the degree of sedimentation and, for this particular year, allowed for close examination of the invert in a corrugated steel segment of one of the sewers.

Table 2 Overview of Assigned Conditions

Year	Number of Sewer Sections in Assessed Category				
	Good	Fair	Poor	Bad	Failed
1998	80 (71%)	26 (23%)	7 (6%)	0	0
1999	105 (78%)	28 (21%)	1 (1%)	0	0
2002	259 (73%)	57 (16%)	36 (10%)	2 (0.6%)	1 (0.4%)
2003	492 (70%)	142 (20%)	61 (9%)	9 (1%)	0
2004	270 (62%)	85 (19%)	83 (19%)	0	0
Total[1]	**1206 (69%)**	**338 (19%)**	**188 (11%)**	**11 (0.6%)**	**1 (0.4%)**

Note 1: Percentage share shown for the totals represent average share over the total system.

Stage 2 - Initial Condition Assessment

Assessment is completed on a section by section basis using the Stage 1 findings. Each trunk sewer is arranged into sections defined by the upstream and downstream manholes. Manholes are dealt with as discrete structures. Structural and service characteristics are both reviewed in considering condition. Hydraulic issues are considered to the extent that they effect, or are affected by, the sewer condition; otherwise hydraulic loading and transmission is dealt with as part of other planning exercises.

One of five condition ratings is assigned to each section of sewer or manhole. The worse condition in each sewer section sets the overall rating for the entire section. These ratings follow the definitions set out in the WRC rehabilitation manual. If there are no meaningful defects and no remedial action is indicated then the section is deemed to be in Good condition. Fair indicates that minor defects were observed which suggest the onset of asset deterioration. On-going monitoring, such as re-inspection within 5 to 10 years is warranted in order to establish a potential rate of deterioration. Otherwise remedial action within the foreseeable future is not warranted. More significantly damaged sections are deemed to be in Poor condition. This condition indicates that remedial action is warranted in the near term and that planning and budgeting for such work should be considered. Sections rated in Bad condition require remedial action in the near future and plans should be put in place to commence work within about a year. Failed sections require immediate action, and in extreme cases may warrant an emergency response. The relationship between rating, condition and required action is set out in Table 3.

The conventional approach to assessing the condition of sewers is to review and consider the observed condition of only the pipe itself. This approach is appropriate for the vast majority of sewers where the required level of performance and the installation situation is well understood and generally uniform. In the case of large diameter trunk sewers where there can be wide ranging installation conditions, environmental sensitivities, a large number of nearby utilities, important transportation corridors, and large differences in

Table 3 Condition Grades - Action Plan

Condition Grade	Condition	Action
Good	Acceptable condition	No action other than on-going maintenance
Fair	Minimal risk of collapse in short term but potential for further deterioration	Re-inspect within 5 years. If conditions worsen downgrade to Poor and adjust actions accordingly
Poor	Collapse unlikely in short term but further deterioration likely	Develop rehabilitation strategy and incorporate into regular, on-going program
Bad	Collapse likely in foreseeable future	Develop rehabilitation strategy and plan for early implementation. Consider options for emergency response.
Failed	Structural or service failure already occurred. Full collapse imminent.	Begin process to reconstruct or repair. Prepare emergency response plan and/or temporary measures.

construction techniques and soil conditions, this conventional approach may not necessarily be sufficient.

In the case of large diameter sewers an integrated approach was thought to be more in keeping with the importance of the system. That is, it was necessary to consider all aspects of the sewer when it came to making decisions regarding condition and need for action. More specifically, in addition to the basic structural condition of the pipe it was necessary to consider depth of cover, local soil conditions, interrelationship with adjacent utilities, potential for traffic disruptions and possible effects on nearby above-ground structures. Condition ratings were adjusted in the critical areas where the sewers were not found in Good condition to account for these various external factors.

The purpose of assessing the condition of these sewers is to determine the risk associated with failure and the associated potential effects, or consequences, of failure. Various factors that influence the operation of the systems, the possible modes of failure, and the approach used to assign risk levels must all be considered in an integrated approach.

Stage 3 - Second Order Investigations

In some situations the results of the First Order investigations are not clear or obvious. The extent of structural damage or the depth of corrosion, as two examples, may be difficult to establish based on CCTV results only. In these cases further detailed investigations are needed in order to determine the condition rating for the section. These Second Order investigations are typically costly, even when closely focused on a specific problem point. Worker health and safety issues in confined spaces often makes the work labour intensive and time consuming. Person-entry into live trunk sewers is challenging and can require significant lead time to organize.

None-the-less, precise, meaningful results are usually obtained. The information can be readily used to make decisions regarding the condition of the structure and, in many cases, can be used as the foundations for further project planning and design. Only in rare cases do results indicate that further investigations are needed.

In the Region of Peel, Second Order investigations have included person entry to carry out internal distortion measurements in deformed sewers, depth of corrosion measurements, material testing (including pH sampling), concrete coring and strength analysis, hydraulic assessment and hydrogen sulphide monitoring. Two specific examples illustrate the range of issues that can be addressed.

1. **Large Tunnel Distortion:** CCTV/Sonar inspections revealed significant fractures and cracks with possible distortion in a 3000 mm diameter trunk sanitary sewer. Initial research revealed that this particular tunnel installation had undergone distortion due to rock squeeze phenomena soon after construction. Second Order investigations, in the form of precise internal measurements and concrete coring, were undertaken in several representative areas. The concrete coring and subsequent laboratory analysis showed that the concrete itself was in good condition and matched the original design requirements of the sewer. Internal measurements confirmed that significant distortion had occurred but had not yet reached critical values. Explicit concrete laboratory results helped provide confidence in establishing these critical values. Final conclusions indicated that notwithstanding the observed damage, the sewer was otherwise in acceptable condition and that no intervention is required in the short to medium term.
2. **Hydrogen Sulphide Assessment:** CCTV inspections indicated moderate to heavy corrosion in a 2400 mm diameter trunk sanitary sewer. Second Order investigations confirmed that the observed corrosion was related to hydrogen sulphide generation in the trunk sewer system. In this particular case it was felt that significant off-gassing from an adjacent drop chamber on the trunk was contributing heavily to the corrosion problem. Further investigations were carried out to confirm the depth of corrosion, the extent of damage to the concrete pipe and the chamber itself and to provide estimates of the rate of corrosion. It was finally concluded that although the damage was significant, the assets were not in immediate danger and in fact could remain in service indefinitely if the corrosion problem could be arrested. Unfortunately, the corrosion issue was found to be widespread throughout the system and as a result could not reasonably be stopped. Therefore, a short term action plan to repair or replace the damaged pipe and to reconstruct the drop chamber to minimize or reduce off-gassing has been implemented.

Stage 4 - Planning and Governance

Once the results of the Second Order investigations are known the condition assessment ratings for a particular sewer can be compiled and finalized. Development of an action plan can now begin. Consistency gained through use of a recognized standard, such as WRC, facilitates the process. As previously noted the relationship between assessed condition and required action is predetermined (see Table 3).

Governance of Rehabilitation Recommendations

A wide range of type and magnitude of issues and deficiencies were identified as the trunk sewer inspection and condition assessment program evolved. An action plan of "who does what" was required to ensure clear accountability for the required remedial works. A "governance" matrix was established within the Public Works Department to define whether the works were maintenance or capital related and which Division would be responsible to undertake the works. At one end of the spectrum there were structural and hydraulic issues identified for which longer term capital planning and expenditures were required to address the problems. While at the other end of the spectrum, short term planning and budgeting was identified to correct more immediate problems whether or not they were large or small in scope.

Operations and Maintenance related activities were generally more short term, reactive measures with smaller scope and/or identified regular preventative maintenance activities. Although relatively minor, these issues were numerous and spatially diverse and included things such as defective manhole covers and safety platforms and grease or rubble deposits in the sewers. Left unattended, these maintenance issues could eventually evolve into larger capital intensive issues.

The groups responsible for these issues within the Region's Public Works are as diverse as the issues to be addressed. The lead group, Infrastructure Planning, is responsible for long term capital planning and budgeting. Operations and maintenance is dealt with by two groups; one for the linear pipe systems and another for the pumping stations and treatment plants. Capital works including design and construction administration is dealt with by a separate group. The material review committee addresses the issues pertaining to change in the material standards and specifications for the Region required due to the issues identified during the trunk sewer inspection program. The Region needed a way to manage the dissemination of the inspection findings amongst the members of this group and to coordinate activities of each of the groups as actions plans are implemented.

The governance matrix was developed listing major issues identified during Stages 1, 2 and 3 of the program and identifying the lead group and stakeholder for each issue. A trunk sewer stakeholders group meets quarterly to discuss various issues and to get an update on any works that have been completed. The governance matrix is then updated and re-circulated to the stakeholders. The infrastructure group programs the works in Capital Budget which are completed by the Capital Works group. The completed works are then monitored, operated and maintained by the Operations and Maintenance Group. Any issues related to material and specifications are addressed by the Material Review Committee and implemented by, again, the Capital Works Group.

The planned Hydrogen Sulphide Management Strategy is a good example of the effectiveness of this multi-group, governance approach. In numerous locations over a number of years, areas of moderate to heavy corrosion were observed. Various follow-up, Second Order investigations, clearly showed that the corrosion is related to hydrogen sulphide and is causing damage to various degrees throughout the East Trunk system.

Investigations also revealed that a complex combination of factors leads to the generation of the H2S and subsequent corrosion. The ways in which new sewers are designed and constructed, how the sewer is operated and how pumping stations are operated all have important influences on H2S generation; each of these activities are managed independently by different groups. The established trunk sewer working group, through the governance matrix, easily identified all the factors to be considered and showed that close coordination amongst the various groups would be required in order to effectively manage H2S. Preparation of a comprehensive, global planning Strategy was seen as the best means to accomplish the required goal of reducing H2S related damage. The strategy will set out clear objectives and guidelines for short and long term programs and will show how each group's activities and works will need to be coordinated in order to achieve the expected results.

CONCLUSION

A coordinated and integrated approach to major trunk sewer asset management is necessary to properly maintain such vital infrastructure. The problems with maintaining such a system can be complex involving many stakeholders and disciplines. To 'wade' through all of the challenges it is important to have an integrated approach which follows up on the recommendations and findings of the previous stages and culminates with defined actions and accountability for those actions.

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