Chapter 20

Comparison of Two Methods of End-of-pipe Control for CSO and Stormwater

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Control and treatment of stormwater discharges and combined sewer overflows (CSO) from urban areas are issues of increasing importance in the field of water quality management. The City of Toronto has identified water quality problems resulting from these discharges and has undertaken to develop a Sewer System Master Plan for the virtual elimination of CSO and the control/treatment of stormwater runoff prior to discharge to receiving waters. The CSO outfalls contribute approximately 71% of average annual volume and the stormwater outfalls 29%. It has been determined that for the City of Toronto the most effective means of controlling the CSO problem is to intercept CSO in a storage facility and then direct the intercepted CSO to a treatment facility at an

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acceptable rate of treatment. This paper presents a comparison of two methods of end-of-pipe control for CSO and stormwater to improve water quality. The two methods considered include a storage tunnel with one storage element and storage in scattered subsurface storage tanks. The tunnel system would consist of a 13,000 m long storage element along the lakefront from Parkside Drive to east of the Main Treatment Plant and a 3,400 m long tunnel along the Don Valley connecting to the lakefront tunnel. The subsurface storage tank system would consist of fifteen separate CSO and eleven stormwater tanks located at various outfall locations within the area identified above. Comparison of the two methods was undertaken in terms of effectiveness, environmental impacts, capital cost, treatment flexibility and operation and maintenance requirements.

20.1 Introduction

In recent years, the effect of sewer discharges on receiving water ecosystems has received increased attention from municipalities, environmental regulatory agencies and the public. As a result of the discharges of untreated wastewater from combined sewers and stormwater from storm sewers to receiving water bodies, substantial degradation in the water quality has resulted in many areas. A rainfall event can result in significant discharge of organic material, nutrients, bacteria, oil and grease, metals and other potentially toxic substances to receiving waters.

The City of Toronto has faced similar water quality related problems. The City's sewer system includes 47 combined sewer overflow (CSO) structures and 77 storm sewer outlets to the lower Don River, lower Humber River and the shores of Lake Ontario. From the April 1 to October 31 period, the sewer system discharges on an average of 60 - 80 times to the receiving waters. The combined pollution loadings from CSO and stormwater discharges into receiving waters have significantly contributed to beach postings, reduced water related activities, loss of fish habitat in the rivers and general water visual impairments.

To improve the quality of the receiving waters, the City of Toronto authorized a study to develop a master plan for the long term improvement of the City's sewer system. The main objective of the master plan is to provide for the virtual elimination of CSO, and for the control and treatment of stormwater discharges to the receiving water.

20.1.1 Data Analysis

To assess the overflow occurrences of the sewer network with respect to frequency, duration and total pollution loads, a continuous simulation model was applied. The City of Toronto's Quantity-Quality Simulation (QQS) Model was used for this purpose. The model is a continuous simulation model that is able to simulate both quantity and quality parameters. The magnitude of pollutant

loadings is computed by simulating pollutant build-up on the land and subsequent washoff and discharge by each of the sewer outfalls during rainfall events. The four pollutants considered in the modelling were biological oxygen demand (BOD), total suspended solids (TSS), faecal coliform (FC) and lead (Pb).

The City of Toronto sewershed area is approximately 8,200 ha. Due to the size of the City’s sewer model and hence computational time requirements, only a limited number of years could be simulated. For this reason, four years of rainfall record were selected for simulation as representative of the last twenty years of record. Statistical analysis compared the characteristics of the four years record with the twenty years record and confirmed the validity of the selection. Two of the years represent average years and the other two represent dry year and wet year conditions.

The QQS model was applied to the selected four years of rainfall record to estimate the existing volumes and loadings to the receiving waters from both CSO and storm sewer discharges. The results of the four year simulation for the April 1 to October 31 period are summarized in Table 20.1. This table shows that approximately 71% of the total volumetric loading to the receiving waters is contributed from CSO and the remaining 29% from stormwater. Pollutant loadings for BOD, TSS and FC are also shown for both CSO and stormwater. Lead pollutant loadings are not shown since lead was not simulated by the QQS model but estimated on the basis of TSS.

Table 20.1
Summary of Existing CSO and Stormwater Loadings

Receiving Water	CSO				Stormwater			
	Volume (m ³)	BOD (kg)	TSS (kg)	F.C. (#10 ¹⁰)	Volume (m ³)	BOD (kg)	TSS (kg)	F.C. (#10 ¹⁰)
Lake Ontario	7107100 51%	71600 82%	675800 54%	2594100 56%	535400 4%	600 1%	93600 7%	149700 3%
Don River	2833200 20%	12200 14%	213800 17%	958100 21%	3241800 23%	2200 3%	237100 19%	854800 18%
Humber River					337900 2%	250 0%	28300 2%	83500 2%
Totals	9940300 71%	83800 96%	889600 71%	3552200 77%	4115100 29%	3050 4%	359000 29%	1088k 23%
Overall Totals	14055400 100%	85850 100%	1248600 100%	4640200 100%				

20.2 Criteria

To develop criteria for controlling sewer discharges, the receiving waters were categorized into specific geographic areas, and issues of concern relating to water quality objectives were identified for each area. The receiving water sectors are the Eastern Beaches, the Western Beaches, the Inner Harbour, the Don River and the Humber River. The criteria were then established for CSO and stormwater control according to water use. For CSO, the criteria are:

- one CSO on average per season for body contact areas;
- 90% reduction by volume of overflow on a seasonal basis (April 1 to October 31) for all other areas.

Specific goals established on this basis were to limit to one CSO overflow event per season on average for the Eastern Beaches, Western Beaches and Don River area, and to achieve a 90% reduction by volume of overflow to the Inner Harbour.

Stormwater quality objectives were developed for the City based on concerns expressed by various agencies. The following criteria were recommended in the study to address the concerns raised:

Concern		Criterion
Swimming	-	Control bacteria
Fishery	-	Control sediments
Aesthetics	-	Control floatables and turbidity

20.3 Alternative Control Schemes

Alternative methods of reducing and/or eliminating pollutant loadings discharged from sewershed areas were categorized into two basic components: management practices and structural measures. Management or non-structural measures refer to source control methods, watershed housekeeping and sewer system maintenance practices. The study recognized that these measures are environmentally-beneficial and cost-effective but are not adequate alone in reducing pollutant loadings to the levels necessary for protection of the receiving waters. Structural measures considered in the study included storage and treatment, end-of-pipe treatment, full sewer separation and offshore measures such as Dunker’s Flow Balancing Method, extending outfalls inside the Lake and diversion of discharges to less sensitive receiving water areas. From the various structural measures identified, five CSO and seven stormwater control schemes were developed. Subsequently the various schemes were evaluated in detail with

respect to their impact considering environmental, technical and cost categories to select the preferred overall sewer system master plan for the City of Toronto.

For the City of Toronto, it has been determined that the most effective means of controlling the CSO problem is to intercept CSO in a storage facility and then direct the intercepted CSO to a treatment plant facility at an acceptable rate of treatment. This chapter compares two methods of end-of-pipe control considered in the various schemes to improve water quality. The two methods considered include a storage tunnel with one storage element, and storage in scattered subsurface storage tanks.

20.4 Characteristics of Storage Tunnel and Tanks

For the virtual elimination of CSO, the storage tunnel system would consist of a 13,000 m long storage element along the lakefront from Parkside Drive to east of the Main Treatment Plant (MTP) and a 3,400 m long tunnel along the Don Valley connecting to the lakefront tunnel. The tunnel would be 6 m in diameter west of the Don River and 8 m in diameter along the Don Valley and east of the Don River.

The storage tunnel would intercept 45 CSO outfalls. It would have four overflow structures to discharge flow exceeding available storage. The overflow structures would be located at Strachan Avenue, Portland Street, Sherbourne Street and Leslie Street and discharge in non-body contact water areas.

The flow in the tunnel system would be by gravity towards the Main Treatment Plant area. At this location, the flows would be pumped from the tunnel to a treatment facility for treatment prior to discharge into Lake Ontario. In this control method the CSO reaching the MTP can be treated either by expansion of the existing plant facilities or by newly constructed treatment facilities. The alignment of the proposed tunnel system is shown in Figure 20.1.

The subsurface storage tank system would consist of fifteen separate CSO tanks. Attempts were made to minimize the number of storage facilities by connecting more than one outfall into one detention tank, where possible. The detention tanks were sized to retain flows such that one overflow per season would occur on the average, or 90% reduction of the present CSO volume, depending on the area to be protected. The retained flows would then be released at a controlled rate into the existing main interceptor system where it would be mixed with dry weather flow. The flow would be conveyed to the MTP where it would undergo primary and secondary treatment. The locations of the proposed CSO tanks are shown in Figure 20.2.

Along the proposed storage tunnel, there are 28 stormwater outfalls. Consideration was given to the connection of the stormwater outfalls to the CSO tunnel. To store the stormwater in the proposed CSO tunnel, it is estimated that the tunnel would need to be increased from 6 m to 6.5 m diameter from Parkside Drive to the Don River and from 8 m to 8.5 m diameter along the Don River.

Figure 20.1
Storage tunnel system.

Figure 20.2
Subsurface tanks for CSO control.

For stormwater control, consideration was given to the use of sedimentation to remove primarily inorganic materials such as grit and suspended solids by allowing sufficient detention time for the particles to settle out. The sedimentation tanks were designed to store the volume of runoff from a one-year storm (25 mm rainfall) with a detention time of about 12 hours for sedimentation to occur.

Eleven subsurface sedimentation tanks would be required to control stormwater runoff from outfalls along the storage tunnel. The locations of the proposed sedimentation tanks are shown in Figure 20.3.

20.5 Level of Effectiveness

Pertinent information related to the storage tunnel and subsurface storage/sedimentation tanks for CSO and stormwater is presented in Table 20.2.

Table 20.2 shows that the overall storage volume required for the tanks is approximately 169,250 m³ (26%) greater than the tunnel. In addition, the number of proposed overflow locations are four for the tunnel and 25 for the tanks.

Table 20.2
Pertinent Information for Control Alternatives Identified

Control Alternative	CSO				Stormwater			CSO and Stormwater		
	No. of Existing Outfalls	Total Storage Volume (m ³)	No. of Proposed Overflows	Discharge/Treatment Rate (m ³ /s)	No. of Existing Outfalls	Total Storage Volume (m ³)	No. of Proposed Overflows	No. of Existing Outfalls	Total Storage Volume (m ³)	No. of Proposed Overflows
Storage Tunnel	45	617,000	4	1.0	28	21,850	*	73	638,850	4
Subsurface Storage/Sedimentation Tanks	45	775,400	14	7.0	28	32,700	11	73	808,100	25

* No additional overflows required.

The storage tunnel would protect the sensitive areas along the Western Beaches and the Don River since overflows would occur within the Inner Harbour where the water quality is less sensitive. However overflows from the tanks would occur in all areas, therefore this control alternative does not provide the same level of protection as the storage tunnel.

Figure 20.3
Subsurface sedimentation tanks for stormwater control

20.6 Environmental Impacts

The environmental impacts from the storage tunnel and storage/sedimentation tanks were evaluated with respect to three major categories. These are environmental, technical and cost. The parameters considered under each of these categories are summarized in Table 20.3.

In the City of Toronto study, a second component was considered in the evaluation process to develop a methodology for ranking the various control

Table 20.3
Parameters Considered in Evaluation

Category		Parameter
Environmental	Natural Environment	<ul style="list-style-type: none"> - Groundwater - Surface Water - Soils - Air Quality
	Biological Environment	<ul style="list-style-type: none"> - Terrestrial Ecosystems - Aquatic & Wetland Ecosystems - Environmentally Significant Areas
	Social/Cultural Environment	<ul style="list-style-type: none"> - Existing Development - Aesthetics - Recreation - Heritage Resources - Noise & Vibration
	Economic Environment	<ul style="list-style-type: none"> - Property Value - Local Economy
	Construction Impacts	<ul style="list-style-type: none"> - Natural Environment - Biological Environment - Social/Cultural Environment - Economic Environment
Technical		<ul style="list-style-type: none"> - Upstream Impact - Treatment Flexibility - Operation Flexibility - Impact on Operation/Maintenance - Priority Flexibility - Effectiveness - Existing Utilities
Cost		<ul style="list-style-type: none"> - Capital Cost - Operation/Maintenance Cost - Phasing Flexibility

alternatives. Each parameter shown in Table 20.3 was evaluated according to the criteria described and all parameters were given equal weight. The evaluation categories shown in Table 20.4 were then used to rank five CSO and seven stormwater control schemes.

The results of the evaluation are summarized in Table 20.5 for the two control alternatives considered in this chapter.

The storage tunnel system rates higher for all three categories considered. It provides the least surface and near surface disruption to the natural and biological environment since it is built in bedrock about 50 m below ground, provides least impact on social and cultural environment and eliminates all discharges to sensitive areas. In addition, it is superior technically since it is more effective in reducing the number of overflows and requires less storage. The cost aspects are discussed below.

Table 20.4
Evaluation Categories

Category			Symbol	Rating
Environmental	Technical	Cost		
Positive impact	Good	Low cost	•	1
No impact	Fair	Average cost	⊖	2
Negative impact	Poor	High cost	o	3

Table 20.5
Evaluation Summary

Control Alternative	Environmental	Technical	Cost	Rank
Tunnel system	•	•	•	1
Storage/ Sedimentation Tanks	o	⊖	⊖	2

20.7 Capital Cost

The costs were estimated using unit costs derived for the study. The unit construction costs were generally developed using various Toronto area based projects and updated to reflect 1992 costs. Unit costs were derived for the various system elements including tunnels, sewers, forcemains, detention facilities, pumping stations and treatment.

Based on the unit costs derived, it is estimated that the storage and pumping cost for the storage tunnel would be approximately \$267 million and that for the storage/sedimentation tanks would be \$383 million. The cost estimate is for both CSO and stormwater control/treatment and includes a 10% engineering and 15% estimating allowance.

Treatment costs are not included in the comparison between the storage tunnel and storage/sedimentation tanks since the costs are highly variable depending on considerations such as level of treatment and discharge rates. For the tunnel system, primary treatment at the MTP area could be considered since the CSO and stormwater can be separated from the main sewage stream. However for the CSO subsurface storage tanks, secondary treatment at the MTP needs to be considered since the CSO would be mixed with the dry weather flow in the existing sewer system. In addition, as shown in Table 20.2, the total discharge/treatment rate from the tanks is higher at approximately 7.0 m³/s as compared to 1.0 m³/s for the tunnel.

The treatment aspect of the two control alternatives are discussed below.

20.8 Treatment Flexibility

The storage tunnel and storage tank systems both allow for flexibility in the location of the treatment facility and the level and method of treatment. The options available for the location of the treatment facility for the tunnel alternative include individual satellite treatment facilities at key locations along the tunnel, one new central CSO treatment facility, or expansion of the MTP. The levels of treatment that can be considered include primary treatment for a separate central CSO facility or secondary treatment for the expansion of the MTP. Similarly for the storage tank system the options available for the location of the treatment facilities include satellite treatment facilities at the various outfalls or expansion of the MTP. The levels of treatment considered include primary treatment at the satellite facilities or secondary treatment for the expansion of the MTP. A summary of the various treatment flexibilities provided by the two control alternatives is shown in Table 20.6.

For the City of Toronto study, it was determined that since the tunnel would act as a single storage and conveyance element, complete separation of the

Table 20.6
Treatment Flexibility

Control Alternative	Location Flexibility	Level of Treatment
Storage Tunnel	new central treatment facility	primary
	expansion of existing treatment facility	secondary
	satellite locations along tunnel	primary
Storage Tanks	expansion of existing treatment facility	secondary
	satellite treatment facilities at the various outfalls	primary

CSO could be obtained. Since the CSO is fairly dilute sewage, only primary treatment with disinfection needs to be provided by means of a separate central CSO treatment facility along the tunnel route. For the storage tanks, it was determined to be more efficient and practical to provide treatment at one central treatment facility than to provide satellite treatment at the fifteen CSO tank locations. The stored flow could be discharged into the existing sewer system for treatment at the MTP in which case expansion of the plant will be required.

A separate Environmental Assessment (EA) is presently underway to assess the various options for meeting future wastewater treatment needs in the MTP service area. The recommendations from that EA may impact on the treatment option that will be selected for the treatment of CSO and stormwater from the City of Toronto.

20.9 Operation and Maintenance Requirements

A comparison of the operation and maintenance requirements of the two control methods shows that the storage tunnel has the following advantages:

- Regular clean-up after each storm event will not be necessary , but would be required for detention facilities.
- There is more flexibility in the operation of the system.
- Less maintenance staff are required.
- The system is simple and easily understood.
- Treatment facility operating costs are lower.

20.10 Conclusions

From a comparison of the two CSO and stormwater control methods investigated, it can be concluded that for the City of Toronto the storage tunnel has the following advantages over distributed storage/sedimentation tanks:

- Least surface and near surface disturbance.
- Least impact on social, cultural and natural environment.
- Flexibility in the location of the treatment facility and the level and method of treatment.
- Entire elimination of CSO from the Western Beaches and the Don River.
- More effective usage of the storage volume.
- Least operation and maintenance requirements.
- Least capital cost.

Reading List

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