Chapter 25

City of Etobicoke Exfiltration and Filtration Systems Pilot/Demonstration Project

A.M. Candaras and Luis M.J. Carvalho

A.M. Candaras Associates Inc.
8600 Keele Street, Suite 68
Concord, Ontario, L4K 4H8

Man-Kit Koo

Works Department
City of Etobicoke
399 The West Mall
Etobicoke, Ontario, M9C 2Y2

The timely development of the Etobicoke Exfiltration System (EES) occurred at a period when engineers, biologists and scientists were actively investigating infiltration as a technique to manage stormwater.

In most areas which can be significantly impacted by urbanization, infiltration is a major component of the hydrologic cycle. Consequently, the reduction in pervious land cover due to urbanization has a direct and detrimental impact on fluvial geomorphology, erosion, water temperature, chemistry, aquatic environment (fisheries) and adjacent terrestrial environments.

Candaras, A.M., L. Carvalho and M-K. Koo. 1995. "City of Etobicoke Exfiltration and Filtration Systems Pilot/ Demonstration Project." *Journal of Water Management Modeling* R183-25. doi: 10.14796/JWMM.R183-25.

© CHI 1995 www.chijournal.org ISSN: 2292-6062 (Formerly in Modern Methods for Modeling the Management of Stormwater Impacts. ISBN: 0-9697422-4-X)

Traditionally, stormwater management techniques were concerned with transport, detention and reduction of peak flows with end-of-pipe solutions. Infiltration technology offers the opportunity to address two major stormwater management components: volume control and base flow augmentation. These components reduce the volume of runoff, the duration of flooding and increase duration of baseflow during dry periods.

The Etobicoke Exfiltration System was developed as a new stormwater management approach to eliminate the discharge of storm runoff for frequent rainfall events while maintaining or improving the level of "convenience" of traditional municipal storm sewer systems. This system was designed to complement traditional stormwater management concepts by introducing a "micro" system, which increases the functionality of traditional systems while addressing stormwater quality and environmental concerns.

The City of Etobicoke has adopted a new stormwater management concept which promotes three levels of control:

1. Major systems (i.e. overland system) designed to *transport* runoff from large and infrequent storms such as the 100 year storm.
2. Minor systems (i.e. convenience systems) designed to *transport* the smaller and more frequent storm such as the 2-year and 5-year storm.
3. Micro systems designed to *eliminate* runoff from the very frequent storms producing rainfall accumulation in the range of 10 to 15 mm.

Although the Etobicoke Exfiltration System was originally developed for implementation in existing urban areas, it can be successfully implemented in new developments.

25.1 System Development Rationale

The development of this system was a direct result of the City of Etobicoke Work Department's effort to provide solutions in response to the new direction set by the Province of Ontario Interim Storm Water Quality Guidelines (MOE and MNR, 1991). In doing so, the City of Etobicoke created five criteria intended to focus design efforts on practical and feasible solutions:

1. *Solution must be cost-effective.* Since the City of Etobicoke is fully developed, there is little opportunity, without substantial

land acquisition cost, for end-of-pipe technology commonly used in new developments. If the facilities are located entirely within existing rights of way (ROWs), land acquisition is not a concern.

2. *Solution must be simple and not rely on mechanical, or chemical treatment components.* The introduction of mechanical and chemical treatment methods creates a new level of complication (design, construction and maintenance), which is not desirable at the local municipal level.
3. *Solution must be constructed using existing "off the shelf" materials and conventional construction techniques.* The Etobicoke Exfiltration System uses standard PVC pipe, perforated by the manufacturer to the specification of the City. Granular material is a standard 16 mm clear stone used in type B Sewer Bedding. Filter cloth, which wraps the perforated pipes and bedding, is an industry standard. End-of-pipe plugs are standard compression plugs designed to accept 30 ft (9.1 m) of head.
4. *Solution must meet Provincial Guidelines.* In the areas selected for demonstration, the systems meet provincial "Reasonable Use Guidelines". The Etobicoke Exfiltration System was designed to capture and store 15 mm of rain, which exceeds the Province's Interim Stormwater Quality Guidelines.
5. *Solution must be maintained using existing equipment.* Compared to other infiltration facilities, the Etobicoke Exfiltration System is intended to eliminate the need to reconstruct and replace the filtration medium. Access to the system is provided by a standard maintenance hatch and perforated pipes are high-pressure flushed using a standard flusher. Accumulated sediments are collected by standard vacuum trucks, commonly used for catchbasin cleaning. Maintenance tests were carried out successfully on location in the fall of 1993.

25.2 System Description

In 1992, the Works Department applied the five point criteria to develop the Etobicoke Exfiltration System and the Etobicoke Filtration System (EFS). The Exfiltration System was applicable for soils with good percolation potential, while the Filtration System is suitable for soils with

low percolation rates. In 1993, with the assistance and active participation of staff of the Federal Great Lakes Cleanup Fund, the Ministry of Environment and Energy and Ryerson Polytechnic University, the City of Etobicoke constructed 2.5 km of Minor/Micro systems as part of this pilot project. To study these new systems, Environment Canada has funded this on-going research project through the Great Lakes Cleanup Fund.

25.2.1 Exfiltration System

The exfiltration system consists of conventional storm sewer systems with two perforated PVC pipes located below the storm sewer. The entire system is contained within a clear stone trench wrapped in filter cloth. The system is shown in Figures 25.1 and 25.2. First-flush storm flows conveyed within the storm sewer are diverted through the perforated pipes to the stone trench and allowed to exfiltrate into the surrounding soil.

The downstream ends of the perforated pipes are plugged, thereby eliminating short-circuiting of the system. For storm events exceeding the storage capacity of the stone trench, runoff is conveyed through the storm sewer system.

25.2.2 Filtration System

The system consists of a perforated PVC pipe above a conventional storm sewer plus parallel smaller perforated pipes located below the storm sewer, extending half the length of the storm sewer. The storm sewer and the perforated pipes are all contained within a stone-filled trench wrapped in filter cloth. The filtration system is shown in Figure 25.3 and 25.4.

Storm flows are conveyed to the system via catchbasins equipped with two leads. The lower lead, through which the first flush will be conveyed, is connected to the upper perforated pipe. The perforated pipe distributes and disperses the first flush into the filtration trench. The first flush filters through the trench, removing sediments and pollutants. The filtered runoff is collected in the perforated pipes below the storm sewer and outlets to the downstream maintenance hatch. Runoff, which exceeds either the inlet capacity of the upper perforated pipe or the trench, will discharge through the upper catchbasin lead, which is directly connected to the storm sewer as in a conventional system.

Figure 25.1
Queen Marys Drive exfiltration system longitudinal section.
(MH12, MH14 and MH15 correspond to MH1, MH2 and MH3 in the Princess Anne Crescent system).

Figure 25.2
Queen Marys Drive exfiltration system cross-section.

Figure 25.3
Braecrest Avenue filtration system - longitudinal section.

Figure 25.4
Braecrest Avenue filtration system - cross section.

25.3 Pilot/Demonstration Project

The EES and EFS BMPs were designed to remove and exfiltrate or filter the first-flush volume. This volume was calculated based on runoff from an AES one hour rain event with a total accumulation of 15 mm. The system must then perform to this specification in addition to those already discussed in the set of five criteria.

The Etobicoke BMP pilot projects will be tested to ascertain whether they comply with two of the main criteria:

1. exfiltration or filtration of 15 mm or more of accumulated rainfall, and
2. complete exfiltration or filtration in two days or less.

In addition, the Etobicoke BMPs must not affect the existing water table to the extent that the sanitary sewer system will surcharge. Conversely, the BMPs must also not lower the existing water table to such an extent that it imperils existing vegetation.

To test these objectives, three pilot project sites were chosen, based on their hydrologic characteristics and their suitability for implementation of the two BMP design types. These are:

Queen Marys Drive -Exfiltration System

Princess Margaret Blvd. / Princess Anne Cres.-Exfiltration System

Braecrest Avenue -Filtration System

These systems have been constructed and are currently functioning. A monitoring program has been designed and instrumentation purchased. Full monitoring and data collection is expected to commence by mid-March 1994.

The principal purpose of the instrumentation and monitoring is to ascertain whether or not the BMPs meet the criteria listed above. However, given the potential benefits and exportability of this technology, steps have been taken to monitor additional parameters, for modeling the EES or EFS in other areas and other projects.

Event and continuous models will be used to simulate performance and establish a modeling methodology. Water quality and quantity modeling of the sewer system will be addressed as well as groundwater and groundwater pollutant movement. It is already evident that current models are not designed to simulate the Etobicoke BMPs and consequently steps are currently being taken to develop an appropriate algorithm.

25.3.1 Queen Marys Drive - Exfiltration System

The Queen Marys Drive study site has an area of 13.3 ha characterized by low-density high-quality residential housing (Figure 25.5). The entire area slopes gently toward the Humber River, providing adequate conveyance for storm drainage. Drainage is generally through swales created by grade differences between the pavement and boulevard. Queen Marys Drive does not have curbs and gutters.

Soil profiles were logged in a recent geotechnical study of the area along Queen Marys Drive. Boreholes 1 and 2 were characterised by sand to sandy silt while Borehole 3 had sand to sandy silt in the top 0.9 m and clayey silt from 0.9m to 2.1m (the end of borehole). These results illustrate the heterogeneity of soils and the variability of exfiltration potential within a short length of the exfiltration system. It also underscores the importance of an adequate soils investigation.

Soil and groundwater information was obtained from a nearby water well. It is identified by the MOEE as 69-1040 (June, 1961) and is located on Humber Blvd close to Woodhaven Heights. Records from this well suggest that groundwater elevation at this site is approximately 1.2m from the surface. This general level was confirmed by a geotechnical investigation which measured water levels at 1.6m to 2.5m below the ground surface.

This site has high infiltration potential by virtue of its pervious soils but its actual infiltration will be highly dependent on the location of the water table. Thus the effectiveness of this exfiltration system will depend on the water table location.

25.3.2 Princess Margaret Boulevard and Princess Anne Crescent - Exfiltration System

This site (Figure 25.6) is 30.5 ha characterized by low-density high-quality residential housing. The study area has two drainage paths which outlet to the Humber River and Mimico Creek drainage systems. Princess Margaret Boulevard has a ditch drainage system providing adequate overland routing for surface drainage. With the road reconstruction planned for Princess Margaret Boulevard, the overland flow drainage will be handled by a curb and gutter system.

Soil conditions in the area were identified as clay loam, Chinguacousey class, providing imperfect drainage. A more detailed

25.5 Queen Marys Drive exfiltration system plan.

25.6 Princess Margaret Boulevard/Princess Anne Crescent exfiltration system plan.

geotechnical investigation was carried out in which seven boreholes were dug between January 18 to 20 1993. The borehole locations were chosen based on proximity to storm sewer and sanitary sewer crossings. The investigation confirmed that the subsurface soils were dominated by silty clay to clayey silt till underlain by silty sand till.

The underlying soils were observed to be very dense due to the geomorphological processes which created them. Thus the hydraulic conductivity of these soils were lower than would normally be expected for these soil types. Quantification of this characteristic was accomplished by carrying out falling-head tests on all of the boreholes. The hydraulic conductivity for the silty sand to sandy silt till ranged from 6×10^{-6} m/s to 1×10^{-7} m/s.

All boreholes were dry on completion of drilling. Depth of drilling ranged from approximately 4.5 m to 14.0 m below ground surface.

25.3.3 Braecrest Road - Filtration System

The Braecrest Road (Fig 25.7) study area has a tributary area of 2.38 ha of low-density residential housing. The site drains to the west, at approximately 2% to Royal York Road. The high point of Braecrest Road in this area is approximately at the intersection of Braecrest Avenue and Roxaline Street. East of this high point Braecrest drains to Westona Street. The similarity of the east and west draining areas is further discussed below in the monitoring section. The roadway is presently ditched, but will be "upgraded" to curb and gutter.

A geotechnical investigation was carried out during which two boreholes were drilled on Royal York Road. Study results suggested that the controlling soil types are brown silty clay and dark grey organic sand loam with organic matter. Additional soils records from the City of Etobicoke show that on Braecrest Avenue the dominant soils are clay loam. Local well records indicate that the upper soils in the area (up to 7 m deep) are brown clays. These studies corroborate the dominance of relatively impervious soils in the area of the proposed system.

Records of water table locations are not available for this site. However, this lack of information is not of significance since the filtration system will be used and the site is relatively high in relation to the adjacent lands. Exfiltration to the surrounding soil will not be a feasible method of transporting the stormwater due to the relatively impervious local soils.

25.4 System Monitoring

25.4.1 Precipitation

Local precipitation is currently being measured by the City of Etobicoke at a station located on the roof of the Ecole Catolice de Youville near the intersection of Royal York Rd. and Norsemen St. This site is approximately 2350 m from the Queen Marys pilot project study area. The instrument is a tipping bucket gage with 1mm buckets and data logger which records data in 5 minute intervals. In addition to this site, two more precipitation gages will be installed in the immediate area of the three sites to ensure good coverage. One gage will be located just east (300 m) of the Braecrest Avenue site on the roof of a local school. The second gage will be located on the roof of a fire station approximately 500 m from the Princess Margaret Boulevard. These gages will be the primary source for data to be used in the modeling of the EES. This spatial resolution will help to ensure that rainfall will be representative, especially in the summer when very localized significant events of high intensity occur as a result of unstable moist air masses. These thunder storms can have footprints of 1 km wide by 10 km long and as a result can be easily missed if gage coverage is not adequate.

Quality of this data is paramount if hydrologic, hydraulic and ground water models are to be properly calibrated and verified. Records from existing stations in the area such as at Pearson International Airport will be compared. This check is currently being performed on the recorded data from the existing station at the Ecole Catolice de Youville.

25.4.2. Etobicoke Exfiltration System

The exfiltration system will be implemented on the Queen Marys Drive and Princess Anne Crescent/Princess Margaret Boulevard sites. The two sites were chosen for their different soil permeabilities. Consequently, the system will be tested to ascertain its effectiveness in low-to-medium permeable soils and high-permeability soils. Two monitoring programs have been developed and are presented in the following section.

Queens Marys Drive

Monitoring will be conducted at the upper end of the system between maintenance hatches MH14 and 15. Nine catchbasins drain the

connect directly to the storm sewer between MH1 and MH2 at the upstream end of the local drainage system. The four catchbasins connecting to the storm sewer between MH2 and MH4 will be temporarily sealed to prevent runoff entering the monitored section. Only one runoff input source to the monitored section (at MH2) will be allowed, in order to simplify monitoring and increase equipment cost-effectiveness. Road grading will convey this surface runoff downstream of MH3 to the catchbasins between MH3 and MH4. Similar to the Queens Marys Drive site, the exfiltration system upstream of MH2 will be temporarily put off-line by plugging the perforated PVC pipes between MH1 and MH2. System monitoring within the section will be essentially identical to that in the Queens Marys Drive site.

The major difference in monitoring between the two exfiltration sites is that piezometers will not be installed on Princess Margaret Boulevard. A geotechnical investigation suggests that groundwater in the area is located at depths exceeding 15 m below the ground surface. The exfiltration rate from this EES will therefore not be affected by local ground water conditions.

As in the Queen Marys Drive site, monitoring will also be carried out to ascertain the effectiveness of this system on a larger scale. Total flows and water quality will be monitored near the end of the EES at MH7 on Princess Anne Crescent.

25.4.3 The Etobicoke Filtration System

The exfiltration system is not appropriate for the Braecrest Avenue site due to the local low permeability soils. This condition will not permit the exfiltration of the first flush in less than 48 hours. Therefore, the Braecrest site will use the filtration system.

Braecrest Avenue

Monitoring of the EFS will be conducted at the upstream end of the drainage basin. A single catchbasin drains directly into the upstream maintenance hatch (MH1) and two others connect directly into the storm sewer between MH1 and MH2. The catchbasin connected to MH1 and the catchbasin north of the storm sewer between MH1 and MH2 will be temporarily plugged. This will ensure that the only input to the EFS at this section is the single catchbasin. The catchbasin south of the sewer was chosen over the one to the north as it drains a much greater area.

A low-head pressure transducer with weir connected to a data logger will record flow rate while an ISCO 3700 will sample the runoff (Table 25.1). The head on the pressure transducer in the catchbasin will also indicate when the capacity of the lead to the trench has been exceeded. At this point, runoff from the catchbasin flows into the storm sewer between MH1 and MH2 through the upper catchbasin lead. This flow rate can be measured in the sewer, immediately upstream of MH2 with a second pressure transducer and weir. Stormwater which has drained into the trench flows through the clean stone to the perforated pipe under the storm sewer and outlets into MH2. A third pressure transducer and weir in MH2 measure the total inflow rate to the maintenance hatch. Knowing the flow in the sewer and the total flow in the maintenance hatch, the outflow from the trench can be calculated.

Stormwater samples will also be taken in MH2 using a second ISCO 3700 sampler. Comparing the stormwater quality in the catchbasin and the maintenance hatch will indicate the effectiveness of the EFS to reduce pollutant loadings. Some of this reduction will occur as the result of mechanical trapping of particles greater than 40 microns in size in the geotextile-wrapped perforated pipe above the storm sewer. Accumulated sediment in this pipe will be periodically collected and sampled to determine sediment contamination and confirm that particles 40 microns and larger are being trapped.

A piezometer will be drilled through the wall of MH2 into the trench to measure the head within the trench. This information is essential, in order to calculate the amount of storm water in the trench. This is particularly important when two precipitation events follow each other closely and the stormwater from the first is occupying the available trench volume. This will affect the performance of the EFS during the second event.

The trench piezometer will also assess the exfiltration capacity of the trench. The EFS has been chosen for this site due to the impervious soils, but this does not mean that exfiltration will not occur. Exfiltration can be best assessed by monitoring the trench head after a single precipitation event and when the water level in the trench is below that of the invert of the perforated pipe. All pressure transducers are connected to data loggers which record data at 5 minute intervals (this will be adjusted if necessary).

As in the Queen Marys Drive monitoring program, two piezometers will be located along the boulevard to monitor the location of groundwater and allow access to groundwater sampling. The purpose of these

piezometers is the same, although it is recognized that groundwater flow through the local soils will be extremely slow and changes in the groundwater may not be identified in the relatively short monitoring period of two years.

End-of-system monitoring will also be conducted on Braecrest Avenue to determine the effectiveness of the EFS system on a larger scale. End-of-system flow rate will be measured and stormwater will be sampled in the sewer at the downstream end of the EES at MH5 on Braecrest Avenue. The data will be analyzed in the same manner as the Queen Marys Drive program.

A new, conventional storm sewer system has also been installed on Braecrest Avenue east of Roxaline Street. This system is separate from the EFS and drains east towards Westona Street. The land use, catchment area, and soil type of this area is very similar to that of the EFS drainage basin. The similarity of these two adjoining catchments will provide a good opportunity to compare the performance of the EFS with the conventional stormwater sewer system. End-of-pipe monitoring will be carried out at MH5 (west draining basin) and the maintenance hatch at the intersection of Braecrest Avenue and Westona Street (east draining basin). At these points stormwater sampling will be undertaken and flows measured.

25.5 Preliminary Monitoring Results

Monitoring results have been collected on a continuous basis from the Spring of 1994 through to the Fall of 1994. The collected data is currently being analyzed.

The preliminary monitoring results indicate that the system is performing at, or better than, the design expectations.

Throughout the monitoring period, no rainfall event resulted in the volume of the stone trench being exceeded.

Monitoring results for the storm of May 26, 1994 as recorded at Princess Margaret MH2 and MH3 are presented in Figures 25.8 and 25.9. Figure 25.8 presents the incoming flows (main pipe) at MH2 along with the head in the stone trench and the accumulated rainfall of 30mm. Monitoring results at the downstream maintenance hatch (MH3) are presented in Figure 25.9. The results indicate the initial increase in head within the stone trench during the rising limb of the rainfall event. However, this decreased rapidly as rainfall subsided.

Some minor flows were measured at the downstream and the storm sewer (main pipe) however, these flows were due to extraneous flows from an abandoned culvert downstream of MH2 that had not been properly sealed, rather than overflows at MH2.

Analysis of the results of the May 26, 1994 storm indicate that at present the system has sufficient capacity to accommodate a 30mm rainfall which exceeds the design value of 15mm. Furthermore, the surrounding

Figure 25.8
Princess Margaret MH2 flowrate.

soils appear to have greater permeability than had been used in the design as shown by the rapid decrease in the head in the stone trench. The design permeability values were based on saturated conditions whereas the actual in-situ conditions are unsaturated.

At this time we do not recommend a reduction in design criteria, until further analysis of the long-term performance can be assessed. The monitoring program will continue through 1995.

Figure 25.9
Princess Margaret MH3 flowrate.

25.6 Conclusions

The implementation of this monitoring program will provide designers of the EES and EFS with data to assess quantitatively the performance of these BMPs. Specifically, the results will show whether the Etobicoke BMPs continue to meet or exceed the stated criteria discussed in section 25.3.

Based on the data obtained, maintenance of the two Etobicoke BMPs can be better planned and scheduled. Sediment disposal options can be anticipated as sediment pollutant loadings in the perforated pipes will be better understood and computable for low density residential areas.

These systems will also be modeled and calibrated using the collected data from this monitoring program. Algorithms and methodologies will be established to facilitate the application of these BMPs in

computational models and calculations currently used in stormwater management.

Acknowledgement

The authors and the City of Etobicoke acknowledge the contribution and support of: J. Shaw, Great Lakes Cleanup Fund-Environment Canada; D. Henry and M. D'Andrea, Ontario Ministry of Environment and Energy; I. Buchanan, Ontario Ministry of Natural Resources; Staff of the Utility-Engineering Division, City of Etobicoke including: M. Mansfield, Director and J. Tran, Storm Drainage Manager.

25.6 References

MOE. 1991. Stormwater Quality Best Management Practices. Ontario Ministry of the Environment. June 1991.

MOE and MNR. 1991. Interim Stormwater Quality Control Guidelines for New Development. Ontario Ministry of the Environment, and Ontario Ministry of Natural Resources. May 1991.