STORMWATER MANAGEMENT IN BRAMPTON: THINKING OUTSIDE THE BOX WITH RETROFITS

F. Papa[1], G.W. Thoman[1] and J.A. McMahon[2]

[1] Valdor Engineering Inc., 216 Chrislea Road, Suite 501, Woodbridge, Ontario, L4L 8S5
[2] Planning, Design and Development Department, City of Brampton, Brampton, Ontario, L6Y 4R2

Abstract

This paper discusses the outcome of an engineering analysis of existing storm drainage infrastructure with the view to identify synergies between environmental objectives and land development interests. Prompted by a development application for 9.55 hectares of prime commercial retail lands, and the need to provide a stormwater management (SWM) strategy which maximized the usable land while meeting environmental needs, an extraordinary arrangement was reached between the developer and the municipality which yields environmental and economic benefits well beyond those which could be obtained by developing the site in isolation. The final outcome will include the diversion of storm drainage from approximately 125 ha of commercial and industrial lands to a new wetland-type treatment facility located on publicly owned valleylands prior to discharge to Fletchers Creek. Development of these lands occurred before the widespread implementation of SWM controls and, under current conditions, runoff therefrom discharges uncontrolled directly to Fletchers Creek. The engineering analysis was coupled with a financial analysis in order to simultaneously address the needs of the various stakeholders (i.e., developer, municipality, conservation authority and the environment). In the end, an implementation strategy was developed and included provision for financial contributions to be paid by the development community. This project provides a good example of how thinking in a non-traditional way can result in a win-win solution where the best interests of all stakeholders can be satisfied.

Introduction

Upon consideration of a land development application for a 9.55 ha parcel of land ("Site A", see Figure 1), it was identified by the Credit Valley Conservation Authority (CVC) and the City of Brampton that Ontario Ministry of the Environment (MOE) Level 1 treatment, defined as at least 80% total suspended solids (TSS) removal, would be required. Furthermore, a SWM pond facility would be required to achieve this degree of quality control since the site was deemed too large for the implementation of oil-grit separators. A commonly employed threshold to determine the suitability of oil-grit separation technology alone versus the implementation of a SWM facility is 5 ha, considerably less than the size of the subject development. In addition, the provision of erosion and flood controls for this site was also required.

As the subject lands are ideally situated for prime commercial development, the imposition of a SWM facility meant the loss of developable land and compromised the economic viability of the development.

The proposed development lies in a 121± ha sewershed which drains to Fletchers Creek. The sewershed is almost fully developed and within which limited on-site SWM controls have been implemented. Furthermore, CVC has studied Fletchers Creek in considerable detail and has found that the watershed is suffering from water quality, erosion and flooding problems.

The study area also included an additional 4 ha commercial development ("Site B") in which the developer also held an interest. This additional parcel is located immedately adjacent to "Site A", and through its inclusion in the study area, additional benefits were derived. "Site B" belongs to the City of Brampton's Fletchers Meadow Secondary Plan Area and, as such, was originally intended to provide quality controls through on-site oil-grit separators. It was identified by the study team that the funds that would otherwise go towards the installation of the oil-grit separators and their appurtenant long-term maintenance costs could otherwise be used toward implementation of the preferred alternative. Also, since "Site B" was controlled by the same developer as "Site A", construction coordination was facilitated and multi-developer negotiations were not required. A back-up stormwater management plan for "Site B" was prepared which incorporated oil-grit separators, in the event that approvals for the preferred alternative caused delays beyond which the developer could bear, based on its commitments to its tenants and/or end users. Including these additional lands, the total study area became 125 ha.

The critical element of the study was the identification of the opportunity to locate a SWM facility in empty valleylands adjacent to the creek. A relatively large, flat area devoid of trees was ideally situated to collect runoff generated from the 125 ha study area and provide treatment thereof.

This paper closely follows the report submitted in support of the development application (Valdor Engineering Inc., 2001).

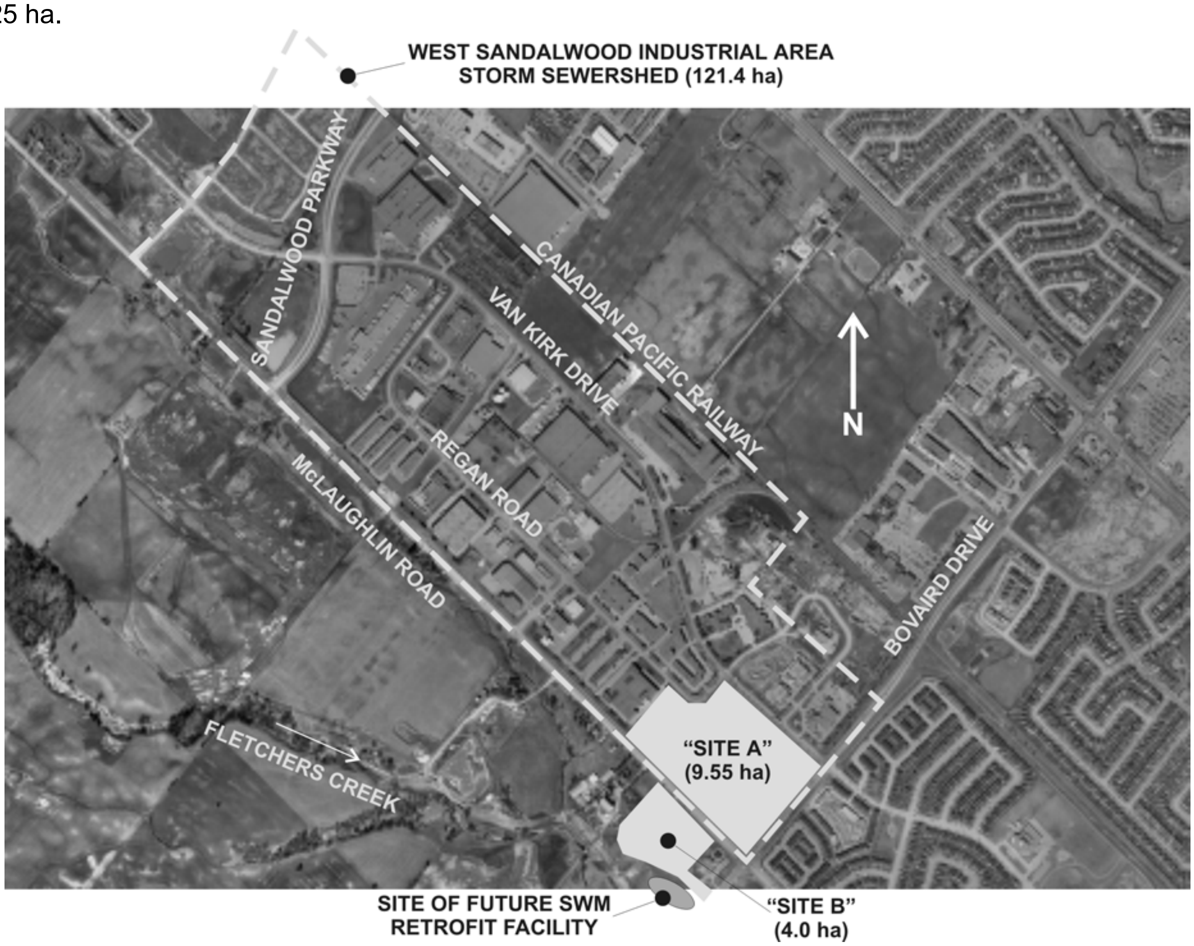

Figure 1
Study Area

Fletchers Creek Subwatershed

The Fletchers Creek Subwatershed Plan was completed in 1995, the purpose of which is to provide direction to regulatory agencies on how to maintain and enhance its features, functions and linkages in anticipation of future growth.

The plan recommended the consideration of low function units of the creek's greenspace system as candidate areas for rehabilitation and enhancement. The valley lands located between the active channel of the creek and the developable lands fit this description.

Additionally, the plan made recommendations relating to SWM objectives to be implemented which included the attenuation of post-development flow rates to pre-development levels for all storms up to and including the Regional storm (Hurricane Hazel).

Fletchers Creek is a perennial stream at Bovaird Drive, exhibiting characteristics of a warmwater fishery (Type 2) habitat upstream of this point while, downstream, is a potential coldwater (Type 1) fishery.

Water quality data has been collected for Fletchers Creek, with long-term data available for its crossing at Steeles Avenue as part of the Provincial Water Quality Monitoring Network (PWQMN) coordinated by the Ministry of the Environment (MOE). More recently, short-term data has been collected (1998 to present) as part of the Fletchers Creek Monitoring Study. Four sites are being monitored between Brampton and Mississauga. The long-term data suggests that Fletchers Creek is in poor condition, particularly with respect to total phosphorus, metals, bacteria and chlorides. The recent monitoring study has confirmed the poor water quality, but has also revealed that the water temperature, dissolved oxygen, flow regimes and levels of suspended solids are also of concern.

In addition to the water quality issues, the Credit Valley Conservation Authority has also indicated that many reaches of Fletchers Creek are susceptible to erosion due to increased peak flows from urbanization within the watershed. Most of the existing developed areas do not have SWM facilities that provide an erosion control function. It is anticipated that erosion problems will continue to propagate unless existing SWM facilities and outfalls are retrofit with erosion control capabilities.

West Sandalwood Industrial Area Storm Sewershed

The 9.55 ha development ("Site A") lies within a larger 121± ha sewershed where the land use is predominantly industrial with some commercial uses. Several vacant parcels also exist which have the potential to provide funds that could be used to partially recover the cost of implementing the solution discussed at length later in this paper.

Local storm sewers have been designed to convey the 2-year post-development flow and, at present, discharge directly to Fletchers Creek via an 1800 mm diameter storm sewer. Development of this sewershed occurred (c. 1979) prior to the widespread implementation of any SWM controls and, as such, there are no quantity or quality controls in place.

Recognizing that individual site developments may have implemented on-site SWM controls (i.e., oil/grit separators), a large supplier was contacted for historical data relating to sites within the sewershed.. From the information obtained, it was estimated that approximately 8.40 ha, consisting of 8 sites, utilize these type of on-site controls.

Based on this, and considering the inclusion of "Site B" into the study area for a total catchment area of 125 ha, the "effective" sewershed area contributing TSS to the runoff is calculated as follows, assuming MOE Level 1 treatment from those sites which have on-site controls:

$$A_e = 125 - 8.40 \times 80\% = 118.3\,\text{ha}$$

This figure was used in calculating the average annual pollutant loading rates from the entire study area.

SWM Alternatives

A total of four (4) technically feasible alternatives were developed and for which preliminary designs were completed. Both on-site and off-site alternatives were investigated, including the opportunity to divert stormwater runoff from the existing 1800 mm diameter storm sewer on McLaughlin Road to a permanent water quality and erosion control facility.

Design criteria used in the preparation of the alternatives were derived from the following sources: City standards; discussions with CVC; the Fletchers Creek Subwatershed Study (Paragon, 1995); and the Fletchers Meadow Secondary Planning Area Environmental Implmentation Report (MMM,1997).

For the analysis, wetland-type facilities were used rather than wet ponds, largely due to their enhanced ability to reduce nutrient levels.

For alternatives contemplating a SWM facility in the valley lands, hydraulic analyses were conducted using the U.S. Army Corps of Engineers' HEC-2 model to compute the associated impact on the Regulatory Flood Line. The HEC-2 model for Fletchers Creek was obtained from CVC, and modifications thereto were made to account for topographical changes required for the proposed SWM facility. Results of the analysis indicate that changes to the flood plain would be very minor and local in nature. Considering that the potential benefits derived from the project would far outweigh any minor impacts to the flood plain, the proposals were found to be acceptable to CVC.

The following discussion presents the pertinent characteristics of each alternative considered. Additional discussion and data relating to facility performance is provided in the next section. Table 1 presents the relevant design parameters used for each of the alternatives.

Alternative 1:
SWM Facility on Subject Lands
treating drainage from "Site A"

This alternative presents the condition the developer would face without considering opportunities beyond the site's boundaries. The resultant SWM facility size for this alternative is estimated to be approximately 0.75 ha (1.9 acres) or 8% of the developable land area.

Alternative 2:
SWM Facility in Valley Lands
treating drainage from "Site A" and "Site B"

This alternative presents the condition where only the development sites are included and is largely presented for illustrative purposes as the City would not likely have approved the use of City-owned lands for such a restricted purpose.

It is noted that both Alternatives 1 and 2 provide for Level 1 water quality control (i.e., ≥80% TSS removal) for their respective drainage areas.

Alternative 3:
SWM Facility in Valley Lands
treating drainage from Entire 125 ha Study Area
1.2m Active Storage Zone for Erosion Control

This alternative considers the conveyance of drainage from the entire 125 ha study area, requiring the diversion of storm drainage from an existing 1800mm diameter storm sewer and installation of a large flow splitting maintenance hole to effect same.

The SWM facility is designed to maximize the available valley lands available, respecting a trunk sanitary sewer easement under the jurisdiction of the Regional Municipality of Peel.

An active storage zone of 1.2m is proposed under this alternative to provide erosion control benefits to the receiver. It is noted that the facility's ability to provide erosion control is traded off by its ability to provide runoff water quality control. That is, as the active storage depth for erosion control is increased, there is an associated decrease in the water quality control performance of the facility. This is primarily due to side-sloping requirements.

Due to the size of the tributary drainage area, the degree of quality control for this alternative is calculated to be 66.1% which qualifies as somewhere between Level 2 and 3 control, according to MOE convention.

Alternative 4:
SWM Facility in Valley Lands
treating drainage from Entire 125 ha Study Area
1.7m Active Storage Zone for Erosion Control

This alternative is fundamentally the same as the previous, however, considers an active storage extended detention zone of 1.7m in depth. As a result, the erosion control performance of the facility is improved while the quality control performance is somewhat less than under the previous alternative (i.e., 61.4%).

Table 1 Design Parameters for Alternatives Considered

Parameter	Alt. 1	Alt. 2	Alt. 3	Alt. 4
Drainage Area (ha)	9.6	13.5	125.0	125.0
Imperviousness[1] (%)	90	90	75	75
Level of Water Quality Control	Level 1	Level 1	Level 2/3	Level 3+
Permanent Pool Volume (m^3/ha)	100	100	30	22
Permanent Pool Volume (m^3)	960	1,350	3,750	2,750
Pond Area at Normal Water Level (m^2)	3,800	2,850	6,350	5,550
Level of Erosion Control Provided[2] (mm)	30	30	15	21
Required Active Storage Volume (m^3)	1,800	2,500	9,000	12,500
Drawdown Time (h)	33.5	35.0	36.5	37.0

[1]Imperviousness for new developments assumed to be 90%. For the entire sewershed, a value of 75% is used and is based on interpretation of aerial photography of the existing conditions.
[2]Degree of erosion control provided measured as equivalent depth of rainfall whose runoff if captured and detained in the facility.

Evaluation of Alternatives

Several quantitative measures of effectiveness were used to understand the degree of benefit afforded by the various alternatives as well as trade-offs between the alternatives. These measures accounted for both the engineering performance and cost of each of the alternatives considered.

Preliminary cost estimates were prepared based on the designs generated for each alternative, the results of which are summarized as follows:

Alternative 1	$ 187,000
Alternative 2	$ 473,000
Alternative 3	$ 767,000
Alternative 4	$ 785,000

The engineering performance of the facility was assessed using the following measures:

Average Annual Volume of Runoff Treated
This measure is calculated using analytical probabilistic modelling methodology (Adams and Papa, 2000) and employs statistics of long-term rainfall data for the nearby Lester B. Pearson International Airport (Toronto), coupled with hydrologic parameter estimates for the catchment in question.

Total Suspended Solids (TSS) Removal
In order to maintain consistency with industry standard design and review practices, estimates of TSS removal rates are derived from provincial guidelines (MOEE, 1994).

Nutrient Removal
Estimates of the removal of nitrogen and phosphorus are calculated combining the results of the analytical probabilistic models for estimating runoff characteristics, and pollutant removal models presented by Reckhow (1988). Annual nitrogen and phosphorus loading rates were derived from the literature (NVPDC, 1979), as was the phosphorus concentration influent to each facility (Adams and Papa, 2000). Although nutrient removal is not typically addressed in development applications of this variety, the study team deemed analysis thereof to yield meaningful comparative results since oil-grit separation units are generally very less effective at removing these constituents when compared to their wet pond or wetland SWM facility counterparts.

Erosion Control
For purposes of comparing alternatives, the degree of erosion control provided by each is measured as the equivalent rainfall depth whose runoff would fill the extended detention active storage zone of the SWM facility. This approach is consistent with the specification of design criteria. It is recognized that this is a somewhat arbitrary approach and more scientifically-based methods which consider flow-duration and channel bed shear strength characteristics of a watercourse are available, however, such detailed analysis falls beyond the scope of the work presented herein.

Table 2 presents the results from the modelling of the engineering performance of each of the alternatives. It is important to note that the results are based on the effect of each alternative across the entire 125 ha study area, in order to provide a meaningful basis for comparison.

Table 2 Comparative Performance of SWM Alternatives

Performance Measure	Alt. 1	Alt. 2	Alt. 3	Alt. 4
Annual Volume of Runoff Treated ($\times 10^3$ m^3)	29.5	39.7	355.0	362.7
TSS Removal (tonnes)	28.1	39.8	303.3	281.9
TSS Removal Efficiency	6.1%	8.7%	66.1%	61.4%
Nitrogen Removal (kg)	31.1	41.7	299.2	278.6
Nitrogen Removal Efficiency	1.8%	2.5%	17.7%	16.5%
Phosphorus Removal (kg)	6.1	8.2	61.1	57.3
Phosphorus Removal Efficiency	2.7%	3.7%	27.1%	25.5%
Erosion Control (equivalent rainfall depth, mm)	2.3	3.3	15	21

As can be seen from the table, a significant improvement in the quality of runoff discharged to Fletchers Creek is afforded by Alternatives 3 and 4, that is, locating the SWM facility in the creek valley and treating drainage from the entire study area. These results are presented graphically in Figure 2.

It is also useful to analyze the cost-effectiveness of each of the alternatives. Results of this exercise are presented in Table 3 and Figures 3 to 5.

Table 3 Cost-Effectiveness of SWM Alternatives

Measure	Alt. 1	Alt. 2	Alt. 3	Alt. 4
Area Tributary to SWM Facility (ha)	9.55	13.53	125	125
Cost per Tributary Area (/ha)	$19,580	$34,960	$6,140	$6,280
Cost per Mass of TSS Removed (/tonne/yr)	$6,660	$11,880	$2,530	$2,570
Cost per Mass of Nitrogen Removed (/kg/yr)	$6,010	$11,340	$2,560	$2,820
Cost per Mass of Phosphorus Removed (/kg/yr)	$30,650	$57,380	$12,560	$13,700
Cost per Erosion Control (/mm eq. rainfall depth)	$81,590	$145,450	$51,130	$37,380

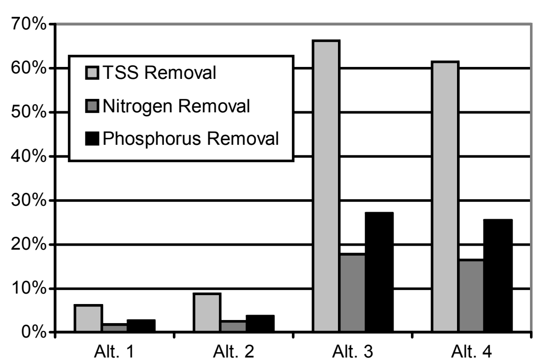

Figure 2
Performance of SWM Alternatives

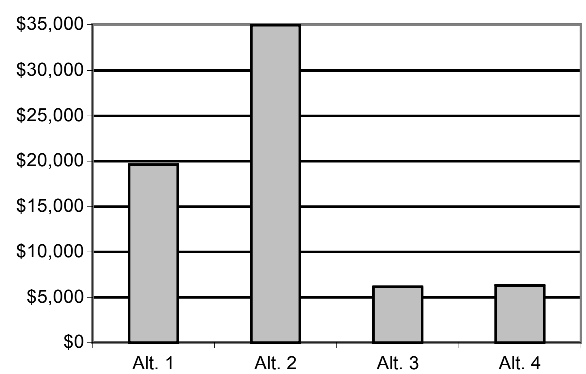

Figure 3
Costs per Tributary Area

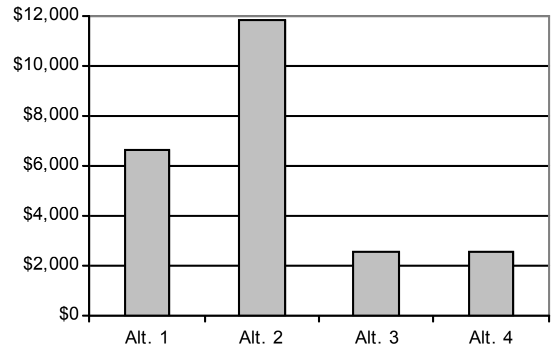

Figure 4
Costs per Tonne of Annual TSS Removal

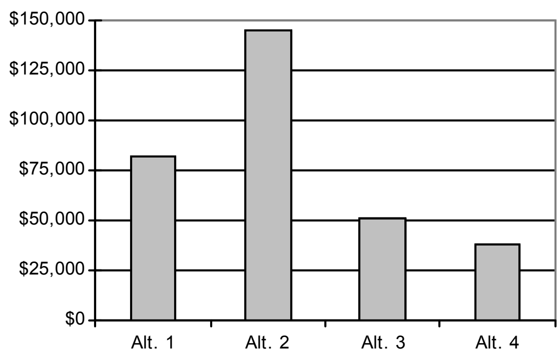

Figure 5
Costs per Equivalent Rainfall Depth for Erosion Control Extended Detention

Beyond the obvious environmental benefits of water quality and erosion control enhancement, other qualitative benefits can be realized by construction of a permanent SWM facility in the valley corridor. The facility will be a visual enhancement over the existing barren flood plain area and provide an opportunity to re-vegetate the area. The pond will be located in a high pedestrian traffic area for residents walking to the adjacent commercial complex; therefore, the facility could be used as an interpretive project to inform local residents about the benefits of stormwater management. Additionally, the City and CVC are planning a trail system through the valley which will be weaved into the design of the facility. Local schools could visit the facility on field trips and use it as a learning tool and possibly for science projects.

Preferred Alternative

The results of the analysis clearly indicate that vast economies of scale can be afforded by implementing a facility that treats drainage from the entire sewershed, albeit at a lower efficiency than an on-site solution for any smaller, individual development. From the perspective of TSS removal, the average annual reduction in pollutant loading to Fletchers Creek would be improved by approximately one order of magnitude.

Based on the analytical work conducted by the study team, it was deemed that Alternative 4 was preferred. Although this alternative compares very closely with, and is marginally more expensive than, Alternative 3, the study team justified this decision based on the significantly increased degree of erosion control afforded by Alternative 4.

It is noted that the division of pond volume between its permanent pool and extended detention active storage zones may be analyzed in greater detail at the detailed design stage to further optimize the balance between environmental objectives and SWM facility performance capabilities.

Implementation and Project Funding

The responsibility for construction of the SWM facility, which would require a Class EA process, has been accepted by the City of Brampton. This element was critical in securing approval from CVC. In the interim, the City has collected funds from the developer of “Site A” and “Site B”, and will collect funds from other development and re-development applications within the study area.

Since “Site B” would have been able to proceed with the implementation of oil-grit separation units, its financial contribution was fixed at the estimated cost of installing said units.

At the time of the study, the City of Brampton was in the process of establishing a Cash-in-Lieu policy for stormwater management, however, at the time no tangible information was available to establish a figure for the financial contribution. The study team undertook a review of cash-in-lieu of stormwater management policies implemented in various jurisdictions within the Greater Toronto Area and a charge of $30,000 per developable hectare was agreed upon between the developer and the City. The cash outlay by the developer was offset by not having to construct a facility on its lands and suffer from the associated loss of development lands.

Part of the process within this project was a review of the amount of smaller infill lands remaining in the sewershed. Using the agreed upon cash-in-lieu value and the total infill area remaining, an estimate was made of the potential funding available as these smaller areas develop. It was found that a large percentage (90-95%) of the estimated cost to construct the facility was potentially available within the sewershed. The remaining funding was expected to be provided by other means including municipal capital funds, potential grants from senior levels of government and the cash-in-lieu policy that was under development. Subsequent to the completion of the project identified in this paper, the City of Brampton has now finalized and council has approved a Cash-in-Lieu Policy for use throughout Brampton.

In addition to this, a citywide retrofit study is nearing completion which identifies and ranks potential retrofit sites throughout the city. While the study is not yet complete, of the 36 potential sites identified to date, preliminary findings indicate that the site discussed in this paper is expected to rank high in the top five.

Conclusions

This paper presents a case study of a stormwater management retrofit project which was born out of a land development proposal in a well established sewershed.

Recognizing the state of existing infrastructure and its performance in relation to current development standards is critical in assessing the needs of the environment, as represented by local municipalities and conservation authorities, and matching these needs with those of developers. In this case, a 9.55 ha development proposal resulted in the provision for treatment of runoff generated from 125 ha of industrial and commercial lands. Additionally, by maximizing the developable area, the municipality's tax base is larger than it would otherwise be, resulting in additional economic benefit to the public.

This is an excellent example of how developers and municipalities can work together for the greater benefit of all concerned. It is hoped that this sort of innovative thinking will continue and evolve in practice.

Acknowledgements

The authors hereby acknowledge the Credit Valley Conservation Authority, the Regional Municipality of Peel and North American Acquisitions Corp./CentreCorp Management Services Limited for their cooperation in this project, representing the successful marriage of economic and environmental needs in a land development application.

Literature Cited

Adams, B.J., and Papa, F. 2000. Urban Stormwater Management Planning with Analytical Probabilistic Models. Wiley, New York.

Marshall Macklin Monaghan Ltd. 1997. Environmental Implementation Report and Sanitary Sewer and Water Servicing Study for the Fletchers Meadow Secondary Planning Area.

MOEE (Ontario Ministry of the Environment and Energy). 1994. Stormwater Management Practices Planning and Design Manual.

NVPDC (Northern Virginia Planning District Commission). 1979. Guidebook for Screening Urban Nonpoint Pollution Management Strategies.

Paragon Engineering Limited. 1995. Fletchers Creek Subwatershed Plan.

Reckhow, K.H. 1988. Empirical models for trophic state in southeastern U.S. lakes and reservoirs. Water Resources Bulletin, Vol. 24, No. 4: 723-734.

Valdor Engineering Inc. 2001. Stormwater Management Alternatives Study, Proposed Commercial Development, Paer of Lot 11, Concession 1, West of Hurontario Street, City of Brampton.