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The Kingston Pond: a case study of stormwater Pound upgrading

By:
W. Watt, J. Marsalek, B. Anderson

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Abstract

The Kingston Pond is typical of thousands of stormwater ponds built during the pre-stormwater quality management era. Retrofit designs for water quality improvement are based on extensive science-based laboratory and field studies of the Pond. Six retrofits are presented to rectify inadequacies. (i) Remove the decorative fountain to eliminate resuspension and export of bottom sediment. (ii) Add a sediment forebay to remove sand particles before they enter the pond. (iii) Dredge the bottom sediment to restore flood storage volume. (iv) Divert the creek passing through the pond to take the pond offline so that clean creek water does not displace dirty pond water during baseflow periods. (v) Add internal baffles to increase pond length/width ratio and reduce wind-driven currents and turbulence, and modify the outlet to increase hydraulic retention times. (vi) Add a constructed wetland or a biofilter downstream of the pond to improve the pond effluent quality by removal of fine suspended solids and dissolved chemical constituents. Actual implementation of these measures faces two challenges – (a) the facility owner/operator must deem the stormwater pollution as a priority problem, and (b) any pond changes must allow future adaptation if conditions change and further modifications are required.

Le bassin de Kingston : une étude de cas sur les travaux de modernisation d'un bassin d'eaux pluviales

Watt, W.E., J. Marsalek et B.C. Anderson

Résumé

Le bassin de Kingston est représentatif de milliers de bassins d'eaux pluviales construits avant qu'on se préoccupe de la gestion de la qualité de l'eau. Les plans de modernisation des installations, visant l'amélioration de la qualité de l'eau, sont fondés sur des études scientifiques de grande envergure réalisées en laboratoire et sur le terrain. On a présenté six mesures destinées à corriger les lacunes : i) enlever la fontaine décorative pour éviter que les sédiments du fond du bassin ne soient remis en suspension et transportés hors du bassin; ii) installer un bassin d'admission des sédiments pour retirer les particules de sable avant qu'elles n'entrent dans le bassin; iii) draguer le fond pour enlever les sédiments et ainsi rétablir le volume de stockage des eaux de crue; iv) dévier le crique passant par le bassin afin d'isoler ce dernier pour que, au cours des périodes où l'écoulement est équivalent au débit de base, l'eau propre du crique ne chasse pas l'eau sale du bassin; v) installer des chicanes dans le bassin afin d'augmenter le rapport longueur/largeur du bassin et de réduire les courants et la turbulence créés par le vent, et modifier la déversion pour accroître la durée de rétention hydraulique; vi) en aval du bassin, aménager des terres humides ou un biofiltre afin de retirer les solides fins en suspension et les constituants chimiques dissous et ainsi améliorer la qualité de l'effluent du bassin. Il existe deux difficultés liées à l'instauration effective de ces mesures – a) le propriétaire-exploitant des installations doit considérer la pollution des eaux pluviales comme un problème prioritaire; b) toute modification du bassin doit permettre des mesures futures d'adaptation dans le cas où les conditions changeraient et où d'autres modifications seraient nécessaires.

NWRI RESEARCH SUMMARY

Plain language title

The Kingston Pond: a case study of stormwater pond upgrading

What is the problem and what do sicentists already know about it?

Early stormwater management ponds were designed just for flow control, without any considerations given to the changes in the quality of stormwater stored at, or passing through, such ponds. The Kingston Pond, built in 1982, is typical of these ponds. However, as a better understanding of, and needs for control of, the stormwater pollution have evolved, there is a need to revisit these older ponds and retrofit them for stormwater quality enhancement. A methodology for undertaking such an analysis is presented in this paper.

Why did NWRI do this study?

NWRI has been working on improving best management practices (BMPs) for controlling urban stormwater pollution. Many such studies focused on the on-stream stormwater pond in Kingston, which offered an ideal case for analysing its performance and proposing ways of improving it. This information will contribute to addressing the stormwater pollution in the Areas of Concern in the Great Lakes Basin.

What were the results?

Six retrofit measures, rectifying Kingston Pond design and operation inadequacies, were proposed and analyzed: (i) Remove the decorative fountain to eliminate resuspension and export of bottom sediment. (ii) Add a sediment forebay to remove sand particles before they enter the pond. (iii) Dredge the bottom sediment to restore flood storage volume. (iv) Divert the creek passing through the pond to take the pond offline so that clean creek water does not displace dirty pond water during baseflow periods. (v) Add internal baffles to increase pond length/width ratio and reduce wind-driven currents and turbulence, and modify the outlet to increase hydraulic retention times. (vi) Add a constructed wetland or a biofilter downstream of the pond to remove the pond effluent quality by removal of fine suspended solids and dissolved chemical constituents.

How will these results be used?

Three of the six proposed measures have been either implemented by the City of Kingston or are in the implementation stage. The methodology proposed is applicable in many other locations, where outdated stormwater ponds need to be upgraded.

Who were our main partners in the study?

This study was conducted in co-operation with Queen's University in Kingston, the City of Kingston, and the Great Lakes Sustainability Fund.

Sommaire des recherches de l'INRE

Titre en langage clair

Le bassin « Kingston Pond » : une étude de cas portant sur la modernisation du bassin des eaux pluviales.

Quel est le problème et que savent les chercheurs à ce sujet?

Les anciens bassins de gestion des eaux pluviales ont été conçus uniquement pour assurer la régulation du débit, sans égard aux changements relatifs à la qualité des eaux pluviales emmagasinées ou acheminées dans de tels bassins. Le bassin « Kingston Pond », construit en 1982, en est un exemple typique. Cependant, avec l'évolution des connaissances sur la pollution des eaux pluviales et des besoins de la maîtriser, il est important de revoir ces vieux bassins et de les moderniser afin d'améliorer la qualité de ces eaux. La méthodologie pour entreprendre une telle analyse est présentée dans ce résumé.

Pourquoi l'INRE a-t-il effectué cette étude?

L'INRE travaille à améliorer les meilleures pratiques de gestion pour contrôler la pollution des eaux pluviales en milieu urbain. De nombreuses études ont porté sur le bassin des eaux pluviales en opération à Kingston, qui constitue un excellent cas pour en analyser les performances et proposer des améliorations. Ces renseignements contribueront à lutter contre le problème de la pollution associée aux eaux pluviales dans les secteurs préoccupants du bassin des Grands Lacs.

Quels sont les résultats?

Six mesures de modernisation, qui permettront de corriger les lacunes de la conception et de l'exploitation du bassin « Kingston Pond », ont été proposées et analysées : (i) Retirer la fontaine décorative dans le but d'éliminer la remise en suspension et l'exportation des sédiments qui se trouvent au fond du bassin. (ii) Ajouter un bassin d'admission des sédiments afin d'en retirer les particules de sable avant qu'elles n'entrent dans le bassin. (iii) Draguer les sédiments du fond afin de restaurer le volume de réserve du bassin. (iv) Dévier le trajet de l'affluent qui passe dans le bassin de manière à ce que l'eau propre de celui-ci ne déplace pas l'eau sale du bassin au moment des périodes d'écoulement de base. (v) Ajouter des déflecteurs internes afin d'augmenter le ratio longueur/largeur du bassin et de réduire les courants dûs au vent ainsi que la turbulence, et modifier l'exutoire de manière à augmenter les temps de rétention hydraulique. (vi) Ajouter un marais artificiel ou un lit bactérien en aval du bassin afin d'améliorer la qualité de l'effluent du bassin en éliminant les matières fines en suspension et les constituants chimiques dissous.

Comment ces résultats seront-ils utilisés?

Trois des six mesures proposées ont déjà été mises en œuvre par la ville de Kingston ou sont en voie de l'être. La méthodologie proposée peut s'appliquer à de nombreux autres emplacements où des bassins d'eaux pluviales désuets ont besoin d'être modernisés.

Quels étaient nos principaux partenaires dans cette étude?

Cette étude a été menée en collaboration avec l'Université Queen's de Kingston, la ville de Kingston et le Fonds de durabilité des Grands Lacs (FDGL).

THE KINGSTON POND: A CASE STUDY OF STORMWATER POND UPGRADING

ED WATT[1], JIRI MARSALEK[2] and BRUCE ANDERSON[1]
[1]*Department of Civil Engineering, Queen's University, Kingston, ON K7L3N6, Canada*
[2]*National Water Research Institute, Environment Canada, Burlington, ON L7R4A6, Canada*

1. Introduction

The use of stormwater ponds in urban drainage systems in Canada and the United States dates back to the 1960s. In Ontario, the first ponds were built in the metropolitan Toronto and Ottawa areas. Flood reduction and drainage cost reduction were identified as the two most important objectives; control of stormwater pollution was ranked fairly low [1]. By 1981, there were almost 13,000 drainage storage facilities in Canada and the US [2].

Although the first publications on the quality of urban runoff and its impact on receiving waters appeared in the 1960s (e.g., Weibel [3]), many more were published during the following two decades and this period of research culminated with the 1983 publication by the US EPA of the "Results of the Nationwide Urban Runoff Program" [4]. At the same time, beginning in late 1970s and into the 1980s, the use of stormwater ponds for water quality enhancement was investigated and pond processes contributing to such an enhancement were studied. For example, Whipple [5] proposed a dual-purpose detention basin, Whipple and Hunter [6] studied the settleability of urban runoff pollution in ponds, and Hvitved-Jacobsen et al. [7] investigated the fate of phosphorous and nitrogen in ponds.

A generally advanced understanding of urban stormwater pollution in the mid to late 1980s and early 1990s led to the promulgation of government policies aimed at the control of stormwater pollution and the development of a wide range of "best management practices", which include extended detention basins. Schueler [8], Hvitved-Jacobsen [9] and Ontario MOEE [10] all contain design guidelines for such basins.

Retrofitting for water quality improvement was first advocated in the early 1990s [11]. Marsalek et al. [12] were among the first to point out that "older ponds needed to be examined in the light of new environmental knowledge and objectives". They also noted that some of the earlier ponds, developed for flood control only and sometimes poorly maintained, may adversely impact on the environment and represent potential liabilities, a warning also made earlier by Jones and Jones [13].

The Kingston Pond, constructed in 1982 to reduce post-development peaks to pre-development levels, is typical of thousands of ponds built in southern Canada and the United States during the pre-stormwater quality management era. As such, it is an excellent candidate for retrofitting. To determine appropriate retrofit designs for water quality improvement and to provide guidance for the design of extended detention ponds, extensive science-based laboratory and field studies of the Kingston Pond performance, stormwater pond processes, and effluent polishing were conducted.

The objectives of this paper are to provide an overview of the Kingston Pond retrofit, to summarize the studies of the Kingston Pond performance and processes, and to describe the Kingston Pond retrofits addressing the identified inadequacies.

2. Kingston Pond: History and Research Program Summary

The Kingston Stormwater Pond, an on-line stormwater management pond on the west branch of the Little Cataraqui Creek in Kingston, Ontario, Canada, was built in 1982 to reduce peak flows from the parking lot of a shopping mall. The two-stage pond consists of a permanent wet pond (area 5,200 m^2 and 1.2 m average depth) and a dry pond (area 5,000 m^2) that floods during larger storm events. Figure 1 shows the pond layout and sites of upstream inflow, parking lot inflow, pond outflow and the location of instrumentation and weirs at the inlets and outlet. The pond currently receives runoff from the upstream suburban/rural area and from the shopping mall parking lot. The upstream catchment, with an area of 4.54 km^2, has developed over time so that a significantly larger area is now paved, and directly or indirectly connected to the drainage system and pond.

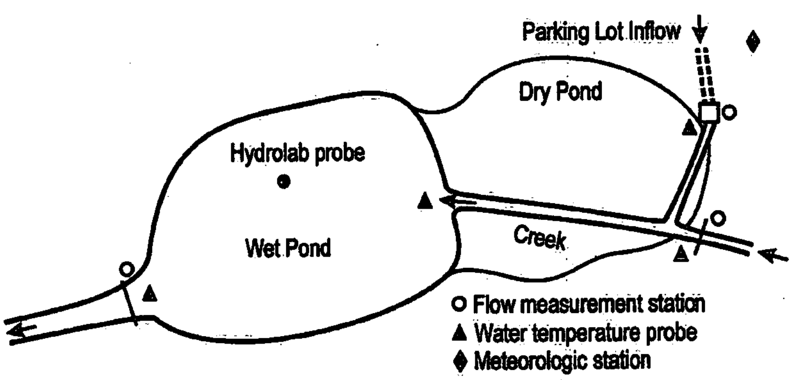

Fig. 1. Kingston Stormwater Management Pond

Long-term interdisciplinary research was conducted at this full-scale stormwater treatment facility for a decade with the objective of understanding how this particular facility functions in terms of quality and quantity control, and with the goal of proposing cost-effective solutions to improve these functions in under-designed and overloaded systems. Research findings on the Kingston Pond performance and processes are summarized in the following paragraphs; detailed results are given in the publications cited.

2.1 PERFORMANCE - FIELD SEASON

Van Buren et al. [14,15] presented a methodology for assessing the pollution control performance of an on-stream pond and applied the methodology to the Kingston Pond. The assessment is based on constituent mass balances for both baseflow and event conditions. Results on pollutant removal rates, which were based on data collected over two field seasons, were provided for selected dissolved constituents, nutrients, suspended solids, metals and organic contaminants. In summary, dissolved constituents exhibit zero removal during baseflow periods and positive removal for events; nutrients and suspended solids exhibit negative removal for baseflow periods and positive removal for events; and metals and organics exhibit positive removal for both baseflow periods and events. In terms of field season performance, contaminant removals during storm events were fair to good, but the pond is now undersized because of significant upstream development after 1982. Moreover, during baseflow periods, the pond exports contaminants.

2.2 PERFORMANCE – WINTER

Marsalek et al. [16,17] characterized the winter operation of the pond based on field studies over two winters. The pond froze over in late November and ice thickness varied from 0.2 - 0.5 m. The measured and modelled velocity field indicated a fast flow region, a small dead zone and a large recirculating zone. During a snowmelt event, near-bottom velocities reached 0.05 m/s, but were not sufficient to scour the fine bottom sediment. Pond water temperature increased with depth, from 0.5 °C to 3.5 °C. High dissolved oxygen (DO) levels (6-12 mg/l), which were generally observed throughout the pond, indicated stable aerobic conditions at the sediment-water interface. In one brief episode, DO fell to zero after a long cold spell. Reduction in DO readings from inlet to outlet indicated an oxygen consumption of about 1.7 kg/day. pH ranged from 7.1 to 8.9. Conductivity readings indicated large amounts of dissolved solids, representing mostly chlorides from de-icing agents. During baseflow, conductivity increased with depth (total dissolved solids concentrations up to 1200 mg/l near the bottom). Average trace metal concentrations were mostly below detection limits. The study of winter performance and processes showed a cycle of chloride accumulation during winter and export during spring and summer.

2.3 SEDIMENT ACCUMULATION

Marsalek et al. [18] reported that pond bottom sediments had accumulated at an average rate of 0.02 m/year and comprised gravel, sand, silt and clay; the gravel and sand accumulated only by the inlet whereas the silt and clay were spread throughout the pond and represented up to 45 % and 54 % of the total sediment respectively. The water content of the sediment (by volume) ranged from 48 % by the inlet to 75 % at the outlet. The assessment of total metals in the sediment against the Ontario Ministry of the Environment (MOEE) sediment quality guidelines indicated a gross pollution by Cr and marginal to significant pollution by Cd, Cu, Fe, Pb, Mn, Ni, and Zn. Sequential analysis of the samples indicated that 40-90% of the retained metals were in potentially mobile forms. The chemistry of the suspended particulate, representing silt and clay, was similar to that of the bottom sediment, except in the case of Cr. They noted, "the results indicate a significant disadvantage of on-stream stormwater ponds built on urbanizing catchments – such ponds tend to accumulate sediment at relatively high rates and will require more frequent sediment removal than off-line facilities".

Marsalek [19] estimated the volume of the inlet sand spit at 150 m^3, and the corresponding sediment mass 160 t, accumulated over 15 years.

Krishnappan et al. [20] conducted three surveys of suspended solids at 17 points in the pond. Observed suspended solids were composed mainly of flocs, with maximum sizes ranging from 30 to 212 µm for winter and summer surveys respectively. Using an empirical relation developed for floc fall velocity, they determined that the highest floc settling velocities were for flocs of size 5 to 15 µm; larger flocs would settle more quickly, but may be broken up by flow turbulence into smaller fragments, which settle readily.

2.4 VELOCITY FIELD

Shaw et al. [21] determined from field measurements and computer simulations that the flow pattern in the pond is very dynamic and complex – the complexity resulting from wind stress on the pond surface. A combination of high wind and low inflow generates a circulation pattern that is pronounced in the vertical, whereas with relatively low wind stress, the velocity field is determined by inflow momentum and pond geometry and is characterized by circulation in the horizontal plane. In general, the velocity field measurements displayed a jet-type flow through the pond with associated dead zones and recirculation zones. Regardless of the magnitude of the inflow, the length to width ratio of the pond (1.5:1) and the inflow momentum promote short-circuiting of the flow and limit the efficiency of the settling.

2.5 INTERNAL BAFFLES

Matthews et al. [22] reported on an interim retrofitting measure whereby installation of strategically placed baffles in the pond increased the length-to-width ratio of the flow path from 1.5:1 to 4.5:1. Results of dye-tracing studies performed after the retrofit demonstrated an increase in retention times with a reduction in the speed and volume of short-circuited flow and a decrease in wind-generated flow patterns due to the baffles. The hydraulic efficiency of the pond (defined as the ratio of measured to volumetric retention times) increased from 0.65 to 0.85. They inferred an increase in pollutant removal through sedimentation processes from a comparison of retention time distributions before and after baffle installation.

2.6 RESUSPENSION AND SEDIMENT EXPORT

Watt [23] investigated the effects of the operation of a decorative fountain on the total suspended sediment (TSS) concentrations in the pond and in the pond outflow. Analysis of continuous measurements of TSS over periods when the fountain pump was on and off showed that outflow concentrations "jumped" by about 100 mg/l when the pump was turned on during baseflow conditions. Currents generated by the operation of the pump were resuspending pond bottom sediment and thereby contributing to sediment export during baseflow.

2.7 EFFLUENT POLISHING BY CONSTRUCTED WETLANDS

Rochfort et al. [24] described the performance of field-scale subsurface flow constructed wetlands that received a portion of the pond effluent. It was generally found that acceptable removal of suspended solids, soluble metals and phosphorus occurred, while organic carbon was not removed effectively (possibly due to low loadings during the test period). The main removal mechanisms appeared to be biological assimilation and, to an unknown extent, physical adsorption within the limestone medium. They concluded that the subsurface flow wetland system could be used in conjunction with extended ponds and surface flow wetlands in a multiple pond design, or by itself provided that adequate treatment of solids occurs.

2.8 EFFLUENT POLISHING BY BIOFILTER

Anderson et al. [25] describe the laboratory and initial field studies associated with the testing of a field-scale submerged aerobic biological filter (SABF) for polishing effluent from the pond. The SABF units demonstrated the ability to remove organic carbon (10-20%), suspended solids (90%), and ammonium nitrogen (60-95%) depending on influent loading and hydraulic residence time (HRT). Phosphorus was removed in the lab experiments, but field results were inconclusive, due mostly to the low loadings. Copper and zinc were removed in both lab and field filters (27-66%).

Mothersill et al. [26] describe tests conducted on the SABF after one and three years of operation to evaluate the impacts of accumulated sediment on its performance and treatment efficiency. They found that the high accumulation of sediment, predominately in the upper 200 mm of the filter, changed the hydraulic properties of the biofilter and decreased the effectiveness of aqueous carbon and phosphorus removal. The backwashing system was not effective in sediment removal, in part because of limited head and also because of higher than usual sediment loadings during the test period because of construction activities in the upstream catchment and the operation of a decorative fountain in the pond.

2.9 THERMAL BALANCE

Van Buren et al. [27] describe the development and assessment of the thermal energy balance for the Kingston Pond. The energy balance method was used successfully to predict average pond temperatures. During dry-weather periods, the pond temperature increased as a result of solar heating, and thermal energy stored in the pond accounted for about the total thermal energy. In contrast, during wet weather periods, pond temperatures decreased as a result of limited solar radiation and replacement of warmer pond water by cooler inflow and thermal energy supplied from the pond accounted for almost 3% of total thermal energy. Lack of tree canopy surrounding the pond and the inlet channel provides little shading and increased opportunity for solar heating. The on-stream nature of the pond promotes increased temperatures of receiving waters during dry-weather periods because the cooler baseflow is continually heated during its residence time in the pond.

3. Kingston Pond: Operation and Maintenance Concerns

During the period of research studies summarized above, it became apparent that operation and maintenance of stormwater management facilities and the perceptions of multiple stakeholders about what these systems are intended to accomplish will play integral roles in the success or failure of stormwater management facilities in fulfilling their primary function of ecosystem protection. These factors are also significant in the development and implementation of retrofit strategies. Watt et al. [28,29] present operation and maintenance concerns for each of three stages: initial design, regular operation & maintenance, and retrofitting with examples drawn from experience at the Kingston Pond. They link these examples to conflicting expectations of key stakeholders. Anderson et al. [30] review both the research results and the overall experience at the Kingston Pond and conclude that there are a number of identifiable factors, termed critical issues that will significantly influence the success, failure and sustainability of stormwater facilities. They group these factors within the categories of initial design, operation and maintenance, performance, and adaptive design, which includes retrofits.

4. Kingston Pond Retrofits to Address Inadequacies

4.1 OVERVIEW

At the beginning of the research program, it was clear that the pond required retrofitting in order to improve water quality control. What was not clear, however, and accordingly required demonstration, were the performance of the existing pond and quantification of problems resulting from its inadequacies. Five principle Kingston Pond inadequacies were identified: (i) it does not have a sediment forebay, (ii) it is on-line, (iii) its small length/width ratio yields HRTs that are too short, (iv) it has a decorative fountain that resuspends sediment and (v) it is not adequately maintained. In addition, it does not remove dissolved contaminants and cannot remove the fine sediment by sedimentation because of wind-generated currents and associated turbulence. In order to rectify or compensate for these inadequacies, six retrofit strategies are presented: (i) remove the fountain to eliminate resuspension by the pump, (ii) add a sediment forebay to remove the sand particles before they enter the pond, (iii) dredge the bottom sediment to maintain the storage volume, (iv) divert the creek to take the pond primarily offline so that clean creek water does not displace dirty pond water, (v) add internal baffles and modify the outlet to increase HRT, and (vi) add a constructed wetland, or a biofilter, downstream of the pond to remove dissolved pollutants and very fine particulates (Fig. 2).

In each of the following sections, the retrofit is identified by the section heading and a common format is followed: (i) reason for the inadequacy, (ii) problems caused by inadequacies, (iii) description and status of the retrofit, and (iv) predicted improvements, primarily water quality, but also flood protection and erosion reduction.

4.2 REMOVAL OF DECORATIVE FOUNTAIN

The decorative fountain was placed in the pond because of a lack of communication between the pond designers and the pond owners who placed responsibility for the pond in the parks and recreation department. As noted above, operation of the fountain resulted in a significant export of sediment from the pond bottom to downstream receiving waters. The retrofit has been accomplished in that the fountain has been removed, partly because of environmental concerns and partly because of financial considerations. The primary benefit of the retrofit is a reduction in total suspended sediment load to receiving waters.

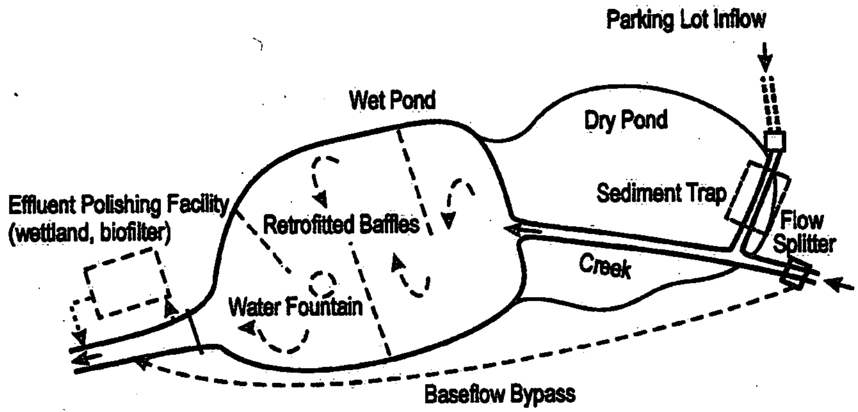

Fig.2. Kingston Stormwater Management Pond: Proposed Retrofit Measures

4.3 ADDITION OF SEDIMENT FOREBAY

As indicated in section 2 above, the pond was constructed as a peak-shaving pond and, as was the case with almost all flood-control ponds of this era, a sediment forebay was not provided. As a result, sand accumulated in a spit at the entrance to the wet pond. As indicated in section 2.3, the volume of this sand was measured as 150 m^3 and the accumulation rate was estimated as 10 m^3/year [19]. There are two problems with this situation. First, the sand is reducing the storage volume of the pond and hence reducing its peak-shaving capability. Second, dredging the sand from this location is much more difficult and expensive than for a sediment forebay.

A sediment forebay, 18 m wide and 30 m long, was added to the pond system in 1998 (see Fig. 2) as the second element of a series of retrofits. The forebay is upstream of the confluence of the outflow channel from the shopping mall and the creek and hence traps sediment originating on the shopping mall, which is placed there primarily during winter sanding operations. The expected clean-out frequency is 7-9 years. The primary benefits of the forebay retrofit are maintenance of the flood control ability of the pond and a lower cost of sediment removal.

4.4 DREDGING OF BOTTOM SEDIMENT TO RESTORE STORAGE

As indicated in section 2.3, sediment is accumulating on the bottom at a rate of 0.02 m/year and the pond has never been dredged. As a result, pond storage for flood control has been reduced. The municipality has now recognized the problem and sediment removal is scheduled for November 2003. The primary benefit will be flood control. However, as long as the pond remains an on-stream pond, there will be an additional benefit in that there will be less bottom sediment to resuspend by wind-generated currents and hence less sediment exported during baseflow periods. Finally, in view of potential mobility of metals adsorbed to bottom sediments, the risk of metal release is reduced by sediment removal.

4.5 CREEK DIVERSION TO TAKE POND OFF-LINE

As indicated in section 2, the pond was constructed in 1982 as a peak-shaving pond to reduce post-development peak flows from a shopping mall parking lot to pre-development levels. It was designed as an on-line pond. Because the upper catchment was largely undeveloped and its future development was not an issue in the design, whether the pond was on-line or off-line was of no significance in the sizing for peak shaving capability. The decision to go on-line was governed by cost considerations, that is, the proximity of the shopping mall outflow conduit to the creek.

The on-line nature results in four problems. First, the upstream catchment has been allowed to develop with only limited stormwater management. As a result, post-development flows from this area are well in excess of pre-development flows. The pond is too small to control the flows from both the shopping mall parking lot and the upstream catchment. Second, sediments originating in the upstream catchment are reducing the storage capacity of the pond faster than would be the case if only sediments from the mall parking lot were depositing. Third, the pond is too small to be an effective, extended detention pond for both the mall and the upstream catchment. Finally, the relatively clean baseflow from the upstream catchment compromises the pond settling process by displacing "dirtier" pond water after storm events.

The proposed retrofit involves a diversion whereby creek flows would be diverted around the pond by way of a constructed, mobile bed, open channel. Two alternatives are considered, depending on the status of upstream stormwater management facilities. If upstream flows will be completely controlled by an extended detention pond, then the diversion would be sized to convey a baseflow of about 0.05 m^3/s. In the event that there is no extended detention pond upstream, then the diversion would be sized to convey peak flows in the range 5 to 10 m^3/s. The first alternative is preferable from an aesthetic viewpoint in that the low flow channel, which would convey a relatively constant flow, would be more attractive than a large channel, mostly empty most of the time, especially in the park setting of this pond. Accordingly, only the low flow channel alternative will be considered in the following paragraph.

The primary benefit of the diversion will be a reduction in TSS exported from the pond and, accordingly, an improvement in receiving water quality. A second important benefit would be a reduction in sediment accumulation in the pond by as much as 25-50 % and hence a corresponding reduction in the annual maintenance cost. A third benefit would be a reduction in downstream flooding due primarily to the provision of upstream control.

The municipality has given no indication that it would consider such a retrofit.

4.6 BAFFLE INSTALLATION TO INCREASE LENGTH/WIDTH RATIO

As noted above, the length-to-width ratio of the existing pond (1.5) does not meet guidelines and results in short-circuiting and dead zones. The likely reason for this inadequacy is that the pond was built in 1982 and the designer had limited knowledge of optimum pond dimensions at this stage of stormwater pond development. We recommend installation of baffles similar to those described in section 2.5 whether or not the pond is taken off-line. The primary benefit would be increased pollutant removal by sedimentation, but another benefit would be a reduction in wind-driven currents and associated sediment resuspension and export.

The municipality has given no indication that it would consider such a retrofit.

4.7 OUTLET MODIFICATION TO INCREASE HYDRAULIC RETENTION TIME

As noted above, even with baffles the HRTs do not meet guidelines and are much too low for effective sediment removal. If the pond is taken off-line, it should be reconfigured as an extended detention pond. Accordingly, the outlet control should be modified to include a low-level outlet as well as an overflow weir. The primary benefit would be increased pollutant removal by sedimentation.

The municipality has given no indication that it would consider such a retrofit.

4.8 EFFLUENT POLISHING BY CONSTRUCTED WETLAND

As noted above, the pond was designed and built as a single stormwater treatment facility. Addition of a sediment forebay has added another element in the treatment train and will remove coarse sediments originating on the mall parking lot before they enter the pond. Taking the pond off-line would eliminate the input of fine sediments from upstream and conversion to an extended detention pond and installation of baffles would enhance removal of suspended sediments originating on the mall parking lot. Addition of a constructed wetland as a polishing device would complete the train for this system. The primary benefit would be enhanced removal of fine sediments and removal of soluble metals and phosphorus.

The municipality has given no indication that it would consider such a retrofit.

5. Concluding Remarks

The results of a decade of interdisciplinary research and our relations with stakeholders at the Kingston Pond stormwater management facility provide an excellent background for recommending retrofits that are likely to be effective in removing the priority pollutants of today. However, there are two challenges to implementation. First, the community, as represented by it elected officials and public employees, may not deem stormwater pollution as a priority problem and will not authorize the required funding. Second, care must be taken to make the retrofitted facility as adaptive as possible so that future retrofits are possible if conditions change.

6. References

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Canada

Canada Centre for Inland Waters
P.O. Box 5050
867 Lakeshore Road
Burlington, Ontario
L7R 4A6 Canada

National Hydrology Research Centre
11 Innovation Boulevard
Saskatoon, Saskatchewan
S7N 3H5 Canada

St. Lawrence Centre
105 McGill Street
Montreal, Quebec
H2Y 2E7 Canada

Place Vincent Massey
351 St. Joseph Boulevard
Gatineau, Quebec
K1A 0H3 Canada

Centre canadien des eaux intérieures
Case postale 5050
867, chemin Lakeshore
Burlington (Ontario)
L7R 4A6 Canada

Centre national de recherche en hydrologie
11, boul. Innovation
Saskatoon (Saskatchewan)
S7N 3H5 Canada

Centre Saint-Laurent
105, rue McGill
Montréal (Québec)
H2Y 2E7 Canada

Place Vincent-Massey
351 boul. St-Joseph
Gatineau (Québec)
K1A 0H3 Canada