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2014

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11th International Conference on Hydroinformatics
HIC 2014, New York City, USA

CITY OF TORONTO'S APPROACH ON ESTIMATING CSO USING A GIS-BASED HYDROLOGIC AND HYDRAULIC MODEL

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Canada releases over 150 billion litres of untreated and undertreated wastewater into the water environment every year. To clean up urban wastewater, new Federal Wastewater Systems Effluent Regulations (the Regulation) on establishing national baseline effluent quality standards that are achievable through secondary wastewater treatment were enacted on July 18, 2012. With respect to the wastewater from the combined sewer overflows (CSO), the Regulations require municipalities to report the annual quantity and frequency of effluent discharges. The City of Toronto currently has about 300 CSO locations within an area of approximately 16,550 hectares. There are about 3,450 km of total sewer length and 51,100 manholes in the CSO area. A system-wide monitoring of all CSO locations has never been undertaken due to the cost and practicality. Instead, the City has relied on estimation methods and modelling approaches in the past to allow funds that would otherwise be used for monitoring to be applied to reduce CSOs' impacts. The City is now undertaking a study by using the approach of GIS-based hydrologic and hydraulic modelling. Results show the usefulness of this for 1) determining the flows contributing to the combined sewer system in local and trunk sewers for dry weather flow and wet weather flow; 2) assessing and predicting hydraulic grade line and surface water depth in all local and trunk sewers under heavy rain events; 3) analyzing local and trunk sewer capacities for future growth; and 4) estimating annual quantity and frequency of CSOs at each CSO locations.. This modelling approach has also allowed funds to be applied toward reducing and ultimately eliminating the adverse impacts of CSOs rather than expending resources on unnecessary and costly monitoring.

INTRODUCTION

Cleaning up the nation's largest source of water pollution is a priority for the Government of Canada. Currently Canada releases over 150 billion litres of untreated and undertreated wastewater into the water environment every year [1]. To clean up urban wastewater, new Federal Wastewater Systems Effluent Regulations (the Regulations) were enacted on July 18,

2012. The objective of the Regulations is to establish national baseline effluent quality standards that can be achieved through secondary treatment, or equivalent, of wastewater before discharge. With respect to the wastewater from combined sewer overflows (CSO), the Regulations require municipalities to report the annual quantity and frequency of effluent discharges, which include: 1) the identification of CSO locations and a description of water use (if any), the name of waterbody, and the water frequented by fish into which the effluent from a point of entry in relation to each CSO location is deposited; and 2) the date, duration, and overflow volume of each occurrence at each CSO location on an annual basis. In the Regulations, the CSO location or the "overflow point" is defined as "a point of a wastewater system via which excess wastewater may be deposited in water or a place and beyond which its owner or operator no longer exercises control over the quality of wastewater before it is deposited as effluent." Moreover, the method of determining the reported information on the CSO is not specified in the Regulations [3].

The City of Toronto (the City) currently has about 300 CSO locations within an area of approximately 16,550 hectares. The total sewer length of the CSO area is about 3,450 km and the number of sewer manholes is about 51,100. The City has been adapting computer modelling as one of the tools to perform hydrologic and hydraulic analyses on the sewer systems since the 1970s [4]. For the CSO area, many computer models with different levels of modelling details using different modelling software packages have been developed for different purposes over time. Thus, an effective model management is essential to the success of planning, decision support, operations and maintenance [4]. Furthermore, the City has been monitoring a few of the CSO locations in the past for different purposes, such as reporting to the Ontario Ministry of Environment and modelling calibration, but the City has never been undertaken a system-wide monitoring of all CSO locations due to the cost and practicality. Instead, the City has relied on estimation methods and modelling approaches in the past to allow funds that would otherwise be used for monitoring to be applied to the reduction of the impacts of the CSOs. A GIS-based hydrologic and hydraulic modelling study is being undertaken, by a team of Ryerson University's civil engineering and geography researchers and the Toronto Water Division of the City, to: 1) determine the flows contributing to the combined sewer system in the local and trunk sewers for dry weather flow (DWF), wet weather flow (WWF), and snowmelt conditions; 2) assess and predict hydraulic grade line and surface water depth in all the local and trunk sewers under heavy rain events; 3) analyze the local and trunk sewer capacities for future growth; and 4) estimate the annual quantity and frequency of CSOs. The objective of this paper is to discuss the approach, challenges, and progress of this on-going model development project.

STUDY AREA

The CSO area of this project is roughly bounded by Eglinton Avenue / Lawrence Avenue to the north, Lake Ontario to the south, the Humber River to the west and Brimley Road to the east [3] (grey polygons in Figure 1). Like many other cities in North America, the City's drainage system started in the late 19th century as a combined sewer system in the downtown area. The expansion of the combined sewer system continued until the 1950s as the quality of receiving waters became a public concern. Since then, the separated sewer system was introduced. In the mid-1960s, the Mid-Toronto Interceptor was developed to provide relief for the existing combined sewer system due to the projected long-term growth of the City. Additionally, the

City started a 25-year (1965-1990) combined sewer separation program by constructing road storm sewers to address flooding and prevents future deterioration of the water quality along the waterfront due to the increase of the CSOs. Most of the streets in the City nowadays are equipped with storm sewers except for locations where construction were not feasible or the combined sewers had sufficient capacity at that time. Furthermore, some of the road storm sewers are connected to the existing combined sewers due to issues of establishing storm sewer outlets. All private drains, foundation drains and roof downspouts were originally connected to the combined sewers. Over time, some of the private storm drainage have been disconnected from the combined sewers and connected to the road storm sewers through re-development. In 2007, the City implemented a 5-year mandatory downspout disconnection program within the study area [4].

Starting in the late 1980s, stormwater was being identified as a major cause of receiving water quality degradation. The pollutant wash-off associated with stormwater runoff, CSOs and sewage treatment plant by-passes were recognized as the degradation of water quality along the waterfront. Although sewer separation will reduce CSOs, it would not achieve the acceptable water quality along the waterfront or the City's water courses. Thus, the former City undertook a Sewer System Master Plan in 1991 which resulted in the construction of the two eastern beaches WWF tanks and the western beaches WWF tunnel within the study area. In 2003, the City completed a WWF Master Plan. Recently, the City completed the Don River and Central Waterfront Environmental Assessment for a WWF tunnel/storage system along the Inner Harbour and Lower Don River to capture and treat CSOs and stormwater discharges. This is a recommendation of the WWF Master Plan to achieve one CSO per year and the implementation phase is starting in 2013 and 2014 [4].

In terms of the model development history of the study area, the former City started sewer network modelling in the mid-1970s using the Hydrograph-Volume Method (HVM) and the Quantity-Quality Simulation (QQS) models developed by Dorsch Consult Limited. The QQS model is a long-term simulation model defining the impacts of urban runoff on receiving waters. The HVM model is an event-based model identifying the hydraulic performance in the sewer systems. It was the first commercially available sewer network model that could deal with conduit surcharge. Both models were used to support water pollution control, sewer capacity management and sewer separation programs for the study area in the former City for about 30 years. As several dynamic sewer network modelling software packages with similar capabilities of the HVM and QQS models are available on the market, Toronto Water has used InfoWorks CS software to analyze the hydraulic behavior of the City's sewer network in the past decade. Several InfoWorks models from version 9 to version 13 have been developed for the City's combined sewer system. The levels of modelling details vary due to different modelling objectives. For instance, the basement flooding investigation studies require detailed network and subcatchment delineations, and input details on the overland flow paths. On the other hand, the trunk sewer capacity analysis and master planning studies for stormwater and combined sewer overflow control involve lumped catchments in a skeletal sewer network [3] [4]. The colored polygons in Figure 1 depict the locations within the study area which have complete detailed urban drainage network models.

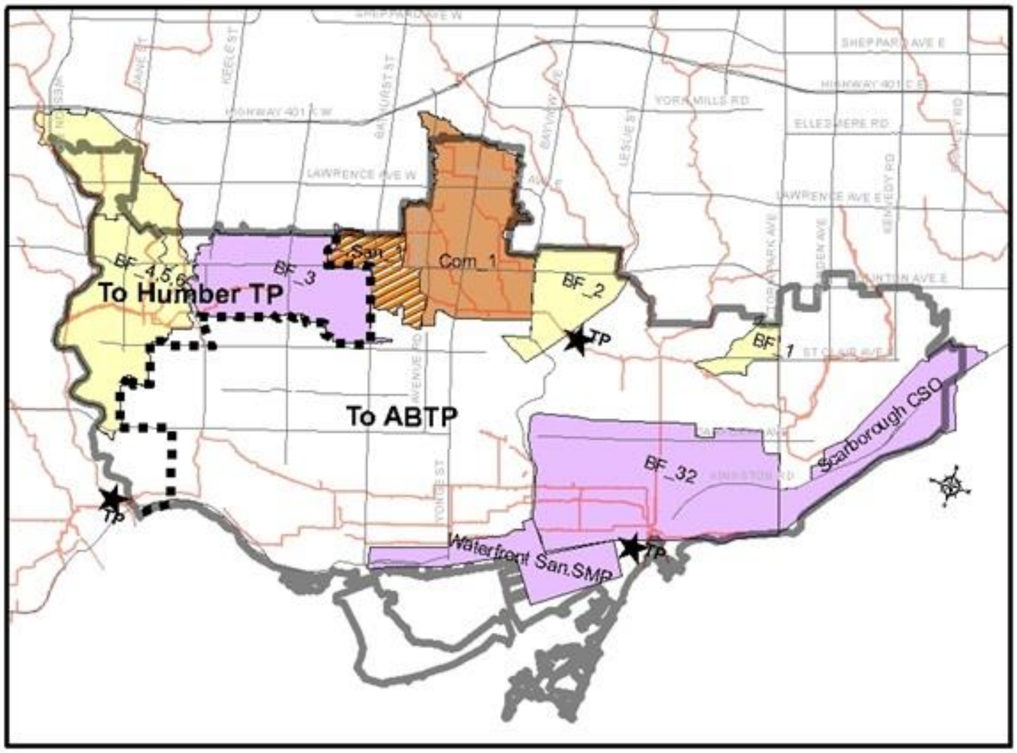

Figure 1. Study Area [3].

MODELLING APPROACH

To develop a GIS-based hydrologic and hydraulic urban drainage detailed model, the following work plan was developed by the project team: 1) data transfer and reconciliation between Toronto Water Asset Geodatabase (TWAG) and InfoWorks CS software; 2) merging the existing models into an “integrated” model; 3) detailed DWF and WWF subcatchment delineation; 4) rainfall data interpolation; and 5) rainfall and snow melting modelling.

Figure 1 (the white area within the grey ABTP polygon) indicates that most of the study area have not been modelled to the level of details in achieving the modelling objectives of this project. Furthermore, catchments in the existing lumped catchment models within the study area are too coarse to identify some of the CSO locations. Thus, developing a pipe-to-pipe based urban drainage model is essential for this project. Since a great effort, particularly on the control structures (i.e. weirs, orifices) perspectives, had been put in the development of the lumped models in the past, the project team decided to incorporate the details of the trunk sewers and their control structures in the lumped models and the current GIS-based network system (TWAG) together in preparing the pipe-to-pipe base urban drainage model. Synchronization between the old lumped models and the current TWAG system was one of the challenges the project team faced in the beginning of this project. The node identification codes in the lumped models are not in the current TWAG system and no common field can join them together. Moreover, the geo-referencing technique cannot be applied in transforming the data in the lumped models as they were not geo-coded. Some manholes and pipes in the lumped models are for the modelling purpose and were not the same as those in the TWAG system.

Challenges were also experienced during integrating the recent detailed models (colored polygons in Figure 1). Although all detailed models were developed using InfoWorks CS software, the set-up of the modelling parameters, land use types, surface runoff profiles are varied as they were prepared by various consultants [4].

For the DWF and WWF delineation, the traditional manual delineation approach was time-consuming especially if the study area is huge. Thus, an automated approach using Arc Hydro Engine was adapted for this project. The automated DWF delineation method uses the infrastructure editor toolbar to utilize the geometric networks, sets of connected edges or lines and junctions or points that are used to model infrastructure from a real world in a GIS environment using the ArcGIS software. This toolbar allows each property parcel to link to the nearest local sanitary or combined pipe and form a DWF subcatchment. The automated WWF delineation approach considers the topography of the urban environment by burning both the roads layer and the storm and combined sewer layer with catch basins attached to them and raises the elevation of the raw digital elevation model (DEM) with the building structures. As a result, one WWF subcatchment for every storm and combined sewer will have at least one catch basin attached to it [9]. The building polygons, the DWF and WWF subcatchments can be then divided into four categories to allow flexibility of adjusting input parameters for future model calibration. The four categories are: 1) DWF (wastewater plus baseflow from groundwater infiltration), 2) connected roof, 3) foundation drain, and 4) surface runoff including runoff from the disconnected roof, paved area, and non-paved area. To simulate the flow in the sewer network, the number of catch basins in a subcatchment is considered so that the inlet capacity to intercept the surface runoff into a sewer can be estimated for the model input [4].

STATUS

This project is still in the on-going process of verifying the data, identifying the errors in the data, modifying the automated GIS-based subcatchments delineation tool, and simulating CSO over rainfall and snowmelt events.

ACKNOWLEDGEMENT

Funded by Toronto Water, this project is being conducted by Toronto Water's staff engineers and professors and graduate students of Ryerson University.

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