APPENDIX G
METHODOLOGY FOR EVALUATING RETROFIT OPTIONS/RETROFIT STUDIES

G.1 Introduction

Retrofitting of existing infrastructure may be required to achieve water balance, water quantity, water quality, and erosion and flood control goals. The objective of this appendix is to outline a methodology that can be used to prepare a stormwater retrofit study which evaluates retrofit options.

The term "retrofit" is used in a general sense and includes retrofitting of:

- existing SWM practices in order to provide multiple benefits (e.g., retrofitting an existing dry pond which presently provides only a flood control function to a multi-purpose facility providing baseflow augmentation, water quality, and erosion and flood control functions);

- infrastructure along a roadway (in order to better reproduce the historical water budget or reduce water quality loadings); and

- an area (from as small as a municipal block to as large as a subwatershed) in order to achieve environmental goals and targets (e.g., reduction of in-stream phosphorus levels to meet Provincial Water Quality Objectives (PWQO)).

G.2 Background

Initially, retrofitting was geared towards water quantity and water quality issues. For example, many municipalities completed Pollution Control Plans which involved retrofitting of infrastructure to address concerns such as: basement flooding, combined sewer overflows, and parameters which exceeded PWQOs. Retrofitting to address environmental concerns, such as loss of aquatic habitat, excessive rates of erosion, diminishing baseflows or loss of natural features, is a more recent occurrence.

Early retrofit studies tended to examine entire watersheds (e.g., Don River); summarize the environmental concerns; and identify a range of SWM practices which if implemented could improve existing environmental conditions. More recently, retrofitting opportunities are being identified within subwatershed studies or environmental studies undertaken by municipalities or regions.

G.3 Methodology for Evaluating Retrofit Options

The following methodology/steps could be used in selecting the preferred retrofit option(s):

Step 1: Define Environmental Goals, Objectives and Targets

Step 2: Identify General Types of Suitable SWM Practices based on Environmental Goals, Objectives and Targets

Step 3: Undertake Technical Assessment

Step 4: Select SWM Practices Based on Evaluation Criteria

Step 5: Develop an Implementation Plan

Step 1: Define Environmental Goals, Objectives and Targets

In order to define the environmental goals, objectives and targets, an understanding of current and potential future environmental conditions is needed. This information may be available from existing studies, or may require interpretation of available information together with a field program.

Following this task, an assessment of the inter-relationships between the environmental resources needs to be made as does the factors characterizing the health of the resources (Table G.1), and the identification of key ecologic constraints and opportunities (see Chapter 2 for further details). Environmental goals, objectives and targets may then be defined.

The environmental goals, objectives and targets provide the framework for Steps 2 to 5. The goals, objectives and targets may vary from relatively straightforward to complex. For instance, a goal of reducing in-stream phosphorus concentrations by an average of 20 percent is fairly straightforward, whereas a goal of improving a degraded ecosystem with one that supports a healthy warm water fishery, provides stable flow regimes and results in minimal exceedences of PWQOs for key water quality constituents is fairly complex.

Step 2: Identify General Types of Suitable SWM Practices (Qualitative Screening Based on Environmental Goals, Objectives and Targets)

An initial qualitative screening of potential SWM practices early in the process (prior to other assessments, e.g., technical feasibility or costs) is useful to identify SWM practices that would likely meet the environmental goals established in Step 1 as well as identifying potential conflicts.

Table G.1: Factors Characterizing the Quality and Quantity of Environmental Resources

	FLOW FACTOR				STREAM QUALITY/ GEOMORPHIC FACTORS				ENVIRONMENTAL QUALITY PARAMETERS							HABITAT BUFFER FACTORS			
ENVIRONMENTAL RESOURCES	Water Balance	Peak Flow	Baseflow	Width/Depth	Stream Gradient	Riparian Cover	In-Stream Cover	Bedload	TSS	Nutrients	Heavy Metals	Organics	Fecal Bacteria	Toxicity Test	Colour	Temperature	Habitat Diversity and Sensitivity	Width of Buffer	Presence of Endangered Species
I. GREAT LAKES ECOSYSTEM																			
Great Lakes Water Quality	×	×	×			×	×	×	×	×	×	×	×	×	×	×			
II. ROUGE RIVER SURFACE WATER SYSTEM																			
Flowing Water	×	×	×																
Surface Water Quality	×	×	×			×	×	×	×	×	×	×	×	×	×	×			
Aquatic Sediments								×		×	×	×		×	×				
Benthic Organisms		×	×		×	×	×	×	×	×							×		
III. PUBLIC HEALTH																			
Drinking Water – Groundwater	×								×	×	×	×	×	×	×	×			
Edible Fish											×	×		×	×				
Contact Recreation	×		×						×				×						
IV. GROUNDWATER																			
Recharge/Discharge Areas	×		×														×	×	
Groundwater Quality			×							×	×	×	×	×	×	×			

Table G.1: Factors Characterizing the Quality and Quantity of Environmental Resources (cont'd)

	FLOW FACTOR			STREAM QUALITY/ GEOMORPHIC FACTORS						ENVIRONMENTAL QUALITY PARAMETERS						HABITAT BUFFER FACTORS			
ENVIRONMENTAL RESOURCES	Water Balance	Peak Flow	Baseflow	Width/Depth	Stream Gradient	Riparian Cover	In-Stream Cover	Bedload	TSS	Nutrients	Heavy Metals	Organics	Fecal Bacteria	Toxicity Test	Colour	Temperature	Habitat Diversity and Sensitivity	Width of Buffer	Presence of Endangered Species
V. PUBLIC SAFETY																			
Flooding	×	×			×														
Erosion	×	×			×	×	×	×	×										
VI. AQUATIC COMMUNITIES																			
Community Diversity	×	×	×	×	×	×	×	×	×	×				×		×	×		
Habitat	×	×	×	×	×	×	×	×	×	×						×	×	×	×
VII. TERRESTRIAL FEATURES																			
Wetlands	×	×	×			×			×	×	×	×					×	×	×
Woodlots	×																×	×	×
Valleylands	×				×	×	×										×	×	×
VIII. WILDLIFE																			
Wildlife Communities	×				×	×											×		
Wildlife Habitats	×				×	×											×	×	×
IX. AESTHETICS	×	×			×	×	×		×										
X. RECREATION		×	×			×	×												

Source: Best Management Practices Environmental Resource Management Project – Town of Markham, 1996.

Table G.2 could be used in an initial screening to qualitatively assess whether or not the SWM Practices/Watershed Management Practices outlined (horizontal axis) would improve a given environmental resource (environmental goals), potentially result in conflict, or would likely have a strong potential for conflict with environmental goals.

This initial screening provides indication of the potential for the various SWM Practices/ Watershed Management Practices to result in the most benefit (as indicated by a large number of potential for improvement "✕") or result in conflicts (as indicated by a large number of potential conflict " F "; and strong potential for conflict "∼") (see Table G.2).

This assists decision-makers in selecting a list of potential SWM practices. It does not, however, directly lead to the inclusion or exclusion of a given SWMP. This type of table format may also be a useful tool in presenting options to the public.

Step 3: Undertake Technical Assessment

Steps 1 and 2 provide key environmental goals/objectives/targets and an initial qualitative indication as to which SWM practices are likely to be the most effective in meeting these goals. Step 3 involves undertaking a technical assessment in order to determine which SWM practices or group of SWM practices, when implemented, would assist in meeting these goals. More than one set of alternatives needs to be identified since further assessment with respect to technical feasibility, cost, etc., is required.

The technical assessment method used will depend on the situation. For example, to retrofit a series of dry ponds in order to meet specific in-stream water quality conditions, a relatively straightforward assessment utilizing water quantity and water quality models may be used. Alternatively, if enhancement of aquatic habitat conditions together with improvements in stream stability are the objectives, then a variety of tools, including habitat, geomorphologic and water resource models, may be required.

Step 4: Select SWM Practices Based on Evaluation Criteria

Step 3 generally identifies several technically feasible SWM options. For example, any combination of ponds in a series of existing dry ponds could be retrofitted in order to meet the required water quality objectives. Various combinations of source control measures, pond retrofits or stream rehabilitation could be undertaken in order to enhance aquatic habitat conditions and stabilize a stream.

Step 4 involves evaluating each of the feasible options against series of criteria and ultimately selecting the preferred option. Examples of evaluation criteria are provided in a number of documents including the Municipal Environmental Assessment which uses natural, social and

Table G.2: Environmental Resources Improved by or Potentially Impacted by SWM Practices/Watershed Management Practices

ENVIRONMENTAL RESOURCES	SWM Practices/Watershed Management Practices						
	Storage Water Quality/ Q Pond	Infiltration Devices	Artificial Wetlands	Urban Retrofit	Riparian Buffer Creation (Valleyland Reforestation)	Aquatic Habitat Restoration	Groundwater Recharge Protection
I. GREAT LAKES ECOSYSTEM							
Great Lakes Water Quality	X	X		X			
II. ROUGE RIVER SURFACE WATER SYSTEM							
Flowing Water		X	X				X
Surface Water Quality	X	X		X			
Aquatic Sediments	X					X	
Benthic Organisms	X		X		X	X	
III. PUBLIC HEALTH							
Drinking Water – Groundwater	F	~					X
Edible Fish	X	X		X			
Contact Recreation							
IV. GROUNDWATER							
Recharge/Discharge Areas		X	X		X		X
Groundwater Quality		~	F				X
V. PUBLIC SAFETY							
Flooding	X	X	X				
Erosion	X	X	X				
VI. AQUATIC COMMUNITIES							
Community Diversity				F	X	X	X
Habitat	X, ~	X			X	X	X
VII. TERRESTRIAL FEATURES							
Wetlands	X		X		X	X	
Woodlots					X		
Valleylands					X	X	
VIII. WILDLIFE							
Wildlife Communities					X		
Wildlife Habitats					X		
IX. AESTHETICS	X	X	X	X	X	X	
X. RECREATION	X	X			X		

X Potential for Improvement F Potential Conflict ~ Strong Potential for Conflict

Source: Best Management Practices Environmental Resource Management Project – Town of Markham, 1996.

economic criteria as the basis for selecting the preferred alternative. Evaluation criteria should generally consider:

- public acceptance;
- cost – capital as well as operation and maintenance;
- land requirements with respect to associated impact on present/future land uses;
- implementability of option; and
- potential for environmental improvement.

Step 5: Develop an Implementation Plan

Once the preferred alternative has been selected, an Implementation Plan needs to be developed. For straightforward initiatives, implementation may only require addressing funding issues and identifying the agency responsible for overseeing construction.

For more involved projects, a series of decisions may need to be made, including:

- deciding whether or not an implementation committee needs to be established and defining the committee's role;

- defining lead and secondary agencies responsible for implementation, funding alternatives, and policy considerations for each of the proposed SWM practices;

- prioritizing proposed SWM practices – generally based on cost-effectiveness, ease of implementation, and on the provision that considerable improvement in environmental conditions be implemented first;

- defining education programs, the role of the public and stewardship opportunities; and

- defining long-term monitoring requirements to define the effectiveness of the measures to meet the environmental goals, objectives and targets.

G.4 Methodology for Evaluating Retrofit Options – Town of Markham Case Study

The previous sections provided general information on a five-step methodology for evaluating retrofit options. The "Town of Markham Stormwater Retrofit Study" was completed by the Toronto and Region Conservation Authority and the Town of Markham in 1999. Provided below is a summary of the Town of Markham findings using the five-step methodology to evaluate its retrofit options.

Background
The objective of the Town of Markham retrofit study was to prioritize the retrofit of eleven stormwater management ponds in terms of water quality and erosion control. The study area is located within the Town of Markham and the ponds are located within urbanizing areas between Highway 404, Highway 48, Steeles Avenue and Major MacKenzie Drive. The ponds are scattered along the upper reaches of the Rouge River and a number of tributaries, including German Mills Creek, Beaver Creek, Burndenette Creek and Robinson Creek. Table G.3 summarizes the pond number, name and type, as well as land use within the catchment area.

During the course of the study, a comprehensive screening and prioritization protocol was developed in order to assess the retrofit potential of the ponds. The protocol incorporated logistical constraints (e.g., adjacent land uses and space for enlargement), as well as the following three environmental components:

- ecological significance of the receiving stream;
- potential erosion control benefit; and
- potential water quality benefit.

The water quality and geomorphologic approaches outlined in Chapter 3 and Appendices B through D were also used to assess options.

Step 1: Define Environmental Goals, Objectives and Targets

The major goal/objective of the Markham study was to determine the potential for maintaining/ restoring the environmental conditions of stream tributaries by retrofitting existing ponds to address water quality and erosion concerns.

Step 2: Identify General Types of Suitable SWM Practices (Qualitative Screening Based on Environmental Goals, Objectives and Targets)

A qualitative screening of different types of SWM practices was not undertaken because the study objective was to assess only one type of SWM practice, i.e., existing stormwater management ponds in the Town of Markham.

Step 3: Undertake Technical Assessment

The technical assessment was geared for meeting the environmental goal/objective described in Step 1 and for providing information that could be used for Step 4. The study was undertaken at a planning level; therefore, certain technical findings needed to be assessed in greater detail. As part of the technical assessment, the following were determined:

A. habitat index for the streams;
B. erosion control benefit of each pond; and
C. water quality benefit of each pond.

A. Habitat Index (HI)

A Habitat Index was determined for each stream based on previous field work studies. HI values range from one (low sensitivity) to five (high sensitivity). Stormwater ponds flowing to a stream highly sensitive to environmental impacts were considered to be a higher retrofit priority than ponds flowing to a stream with a lower sensitivity.

B. Erosion Control Benefit of Each Pond

The erosion control benefit of each pond was estimated by initially comparing the ratio of existing channel cross-sectional area $(R_e)_i$ to the ultimate channel cross-sectional area $(R_e)_{ULT}$. An assessment was then carried out in order to determine the feasibility of providing storage and rate control within the existing pond. Ultimately, the erosion control benefit would be based on a combination of the difference between the existing channel cross-sectional area $(R_e)_i$, the ultimate channel cross-sectional area $(R_e)_{ULT}$ and the channel cross-sectional area $(R_e)_{CONT}$ using the optimal storage and rate control.

C. Potential Water Quality Benefit of Retrofitting Each Pond

Water quality control criteria selected was the Level 1 target **[Editor's Note: now referred to as enhanced protection level]**. A Level 1 target was selected because of the sensitivity of the receiving waters (the Rouge River and associated tributaries). Table 3.1 was then used to determine the required water quality storage volumes.

Step 4: Select SWM Practices Based on Evaluation Criteria

The eleven stormwater management ponds were initially evaluated against five technical criteria. Different priority values (weights) were given to each criteria.

- **Habitat index –** Higher habitat index value indicated a more sensitive stream and resulted in a higher priority for retrofitting the pond.

- **Ratio of catchment area draining to the pond (PCDA) and total catchment drainage area (CDA) –** Ponds with a high PCDA:CDA ratio were considered to be higher in priority for retrofit than those with a lower ratio since stormwater ponds that treat a higher percentage of the total catchment drainage area (CDA) are considered to have greater potential for protecting/restoring downstream erosion and water quality problems.

- **Ultimate stream area enlargement ratio –** Stormwater management ponds which drain to a receiver with a relatively high ultimate enlargement ratio were considered to be higher in priority for retrofit than ponds which discharge to a stream with a small ultimate enlargement ratio.

Table G.3: Summary of Existing Stormwater Management Ponds

Pond No.	Pond Name	Pond Type	Land Use (CDA)*	Land Use (PCDA)**
11.0	SE Quadrant Brown's Corner	On-Line/Dry Pond	11.9% Residential 31.1% Industrial 3.5% Airport 53.5% Undeveloped	20.0% Industrial 80.0% Undeveloped
12.0	Markville Pond	Off-Line/Wet Pond	8.0% Residential 5.9% Industrial 0.4% Airport 85.7% Undeveloped	60.0% Residential 40.0% Undeveloped
80.0	Leitchcroft Farm Pond 2	Off-Line/Dry Pond	14.6% Residential 62.0% Industrial 23.4% Undeveloped	100% Industrial
82.0	Beaver Creek Pond 1	On-Line/Dry Pond	56.2% Industrial 43.8% Undeveloped	n/a
82.1	Beaver Creek Pond 3	Off-Line/Dry Pond	13.6% Residential 33.2% Industrial 4.2% Airport 49.0% Undeveloped	100% Industrial
87.0	Hagerman Estates Subdivision	Off-Line/Dry Pond	7.5% Residential 89.6% Industrial 2.9% Undeveloped	100% Residential
88.0	Bridle Trail Phase 3	Off-Line/Dry Pond	15.2% Residential 84.8% Undeveloped	100% Residential
88.1	Bridle Trail Phase 4	Off-Line/Dry Pond	19.2% Residential 80.8% Undeveloped	80.0% Residential 20.0% Undeveloped
88.2	Bridle Trail Phase 5	Off-Line/Dry Pond	18.4% Residential 81.6% Undeveloped	90.0% Residential 10.0% Undeveloped
90.0	Raymerville Community	On-Line/Dry Pond	11.5% Residential 88.5% Undeveloped	100% Residential
98.0	Unionville B-3 Subdivision	Off-Line/Wet Pond	7.5% Residential 6.1% Industrial 0.4% Airport 86.0% Undeveloped	80.0% Residential 20.0% Undeveloped

* CDA = total catchment drainage area
** PCDA = pond catchment drainage area

Source: Best Management Practices Environmental Resource Management Project – Town of Markham, 1996.

- **Ratio of existing channel cross-sectional area to the ultimate channel cross-sectional area –** Stormwater ponds which drain to a receiving channel which has not yet reached an advanced stage of enlargement were considered to be higher in priority for retrofit than ponds which discharge to streams which have already undergone relatively significant enlargement.

- **Stream order –** Stormwater ponds which drain to a low order (smaller) receiver were considered to be higher in priority than those ponds which discharge to a higher (larger) receiver since low order streams are (all other factors being equal) more sensitive to a change in the flow regime.

Table G.4 summarizes the findings of the evaluation for each pond.

Subsequent evaluations focussed on the feasibility of retrofitting each pond, including the ability to expand storage volume, adjacent land uses, safety, access, etc.

Step 5: Develop an Implementation Plan

Implementation of the selected preferred option is the final step in the evaluation methodology but was not included in the Markham retrofit study. Implementation will involve prioritizing the eleven stormwater management ponds based on further technical evaluation criteria, feasibility, cost and other factors.

Table G.4: Evaluation of SWM Ponds for Retrofit Based on Technical Criteria
Town of Markham and T.R.C.A.

Pond No.	Pond Name	HI		PCDA/CDA		$(R_e)_{ult}$		$1 - \{(R_e)_i / (R_e)_{ult}\}$		SO		Total Weighted Score	Priority
		NPV	Rank	NPV	Rank	NPV	Rank	NPV	Rank	NPV	Rank		
11.0	SE Quadrant Brown's Corner	0.40	7.5	0.25	6	0.05	5	0.25	8	0.05	8.5	7.18	8
12.0	Waldon Pond (Markville)	0.40	5.5	0.25	10	0.05	8	0.25	5	0.05	10.5	6.88	7
80.0	Leitchcroft Farm Pond 2	0.40	10	0.25	2	0.05	2	0.25	2.5	0.05	4	5.43	4
82.0	Beaver Creek Pond 1	0.40	10	0.25	1	0.05	3	0.25	7	0.05	4	6.35	6
82.1	Beaver Creek Pond 3	0.40	7.5	0.25	9	0.05	4	0.25	9	0.05	4	7.90	11
87.0	Hagerman Estates Subdivision	0.40	10	0.25	4	0.05	1	0.25	10	0.05	4	7.75	10
88.0	Bridle Trail Phase 3	0.40	2.5	0.25	8	0.05	10	0.25	2.5	0.05	4	4.33	3
88.1	Bridle Trail Phase 4	0.40	2.5	0.25	7	0.05	6	0.25	2.5	0.05	4	3.88	2
88.2	Bridle Trail Phase 5	0.40	2.5	0.25	3	0.05	7	0.25	2.5	0.05	4	2.93	1
90.0	Raymerville Community	0.40	2.5	0.25	5	0.05	11	0.25	11	0.05	8.5	5.98	5
98.0	Unionville B-3 Subdivision	0.40	5.5	0.25	11	0.05	9	0.25	6	0.05	10.5	7.43	9

Notes:
1. NPV – Normalized Priority Value.
2. HI – Habitat Index.
3. PCDA – Catchment Drainage Area draining to pond.
4. CDA – total Catchment Drainage Area.
5. $(R_e)_{ult}$ – Ultimate Stream Area Enlargement Ratio.
6. $(R_e)_i$ – Existing Stream Area Enlargement Ratio.
7. SO – Stream Order.
8. Rank and Priority Scale – 11 (low priority) to 1 (high priority).

Source: Best Management Practices Environmental Resource Management Project – Town of Markham, 1996.

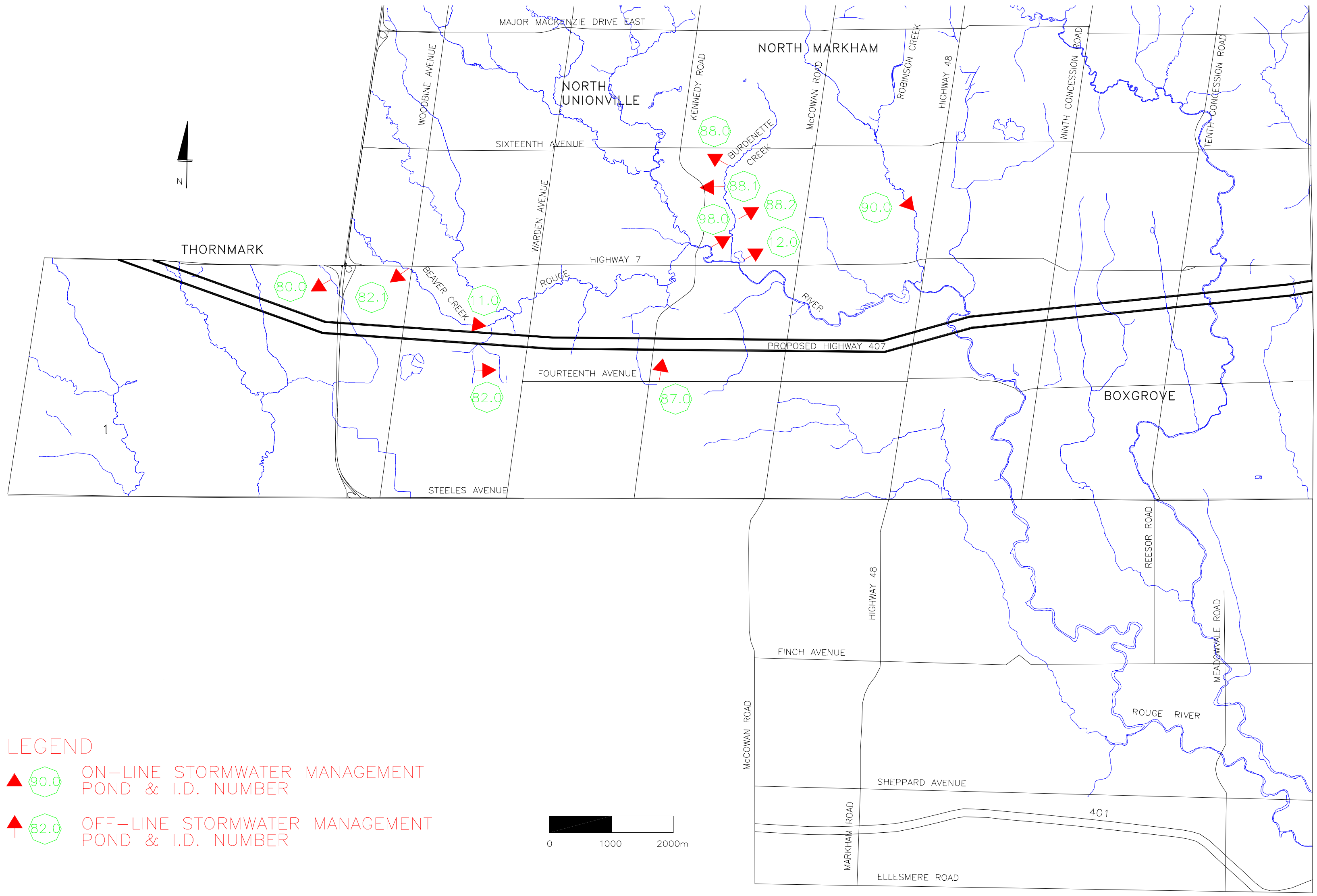

Figure G.1: Location of Stormwater Management Ponds within Study Area – Markham, Ontario

Source: The Toronto and Region Conservation Authority and the Town of Markham, Town of Markham Stormwater Retrofit Study, 1999.