

# **Petticoat Creek Watershed Hydrology Update FINAL REPORT**

Toronto and Region Conservation Authority



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## **1.0 INTRODUCTION**

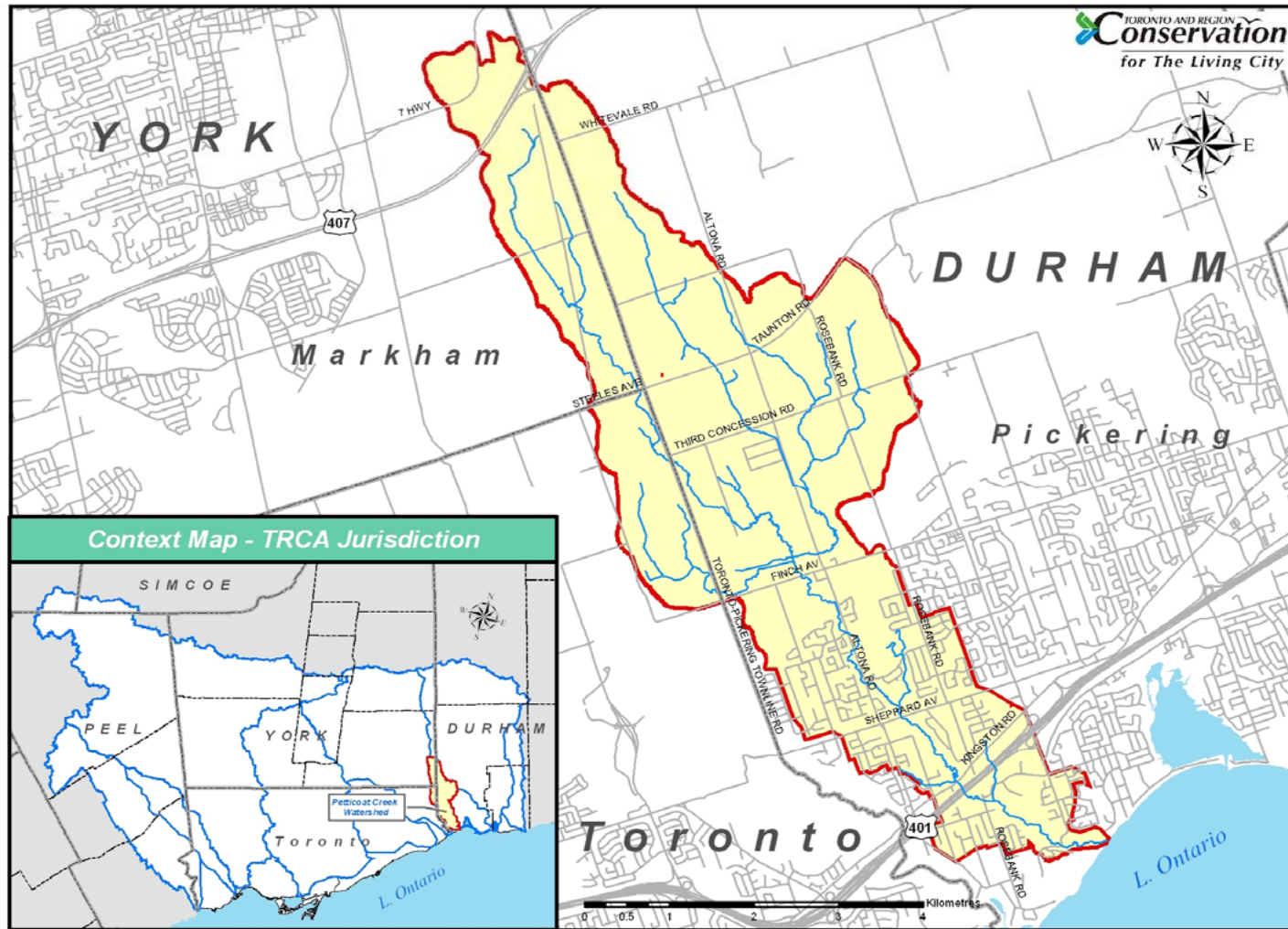
Due to recent development within the Petticoat Creek Watershed and a scheduled update of the TRCA floodline mapping for Petticoat Creek, a need was identified to develop a new watershed hydrology model and to calibrate the model based on recently available flow and rainfall data. Greenland Consulting Ltd. was retained by the TRCA to complete the hydrology update for Petticoat Creek using Visual OTTHYMO (v. 2.0).

The original hydrology model for Petticoat Creek was completed by Cosburn Patterson Wardman Limited using HYMO in the 1990's. A more recent update was completed by XCG Consultants Limited using VO2 in order to complete the Environmental Master Servicing Plan for the Rouge Park Neighbourhood. However, the model was never calibrated nor sufficiently discretized and is not considered suitable for estimating peak flows for floodline mapping.

## **2.0 DESCRIPTION OF STUDY AREA**

The Petticoat Creek Watershed is located within the jurisdiction of the TRCA within the Regional Municipality of Durham (City of Pickering), the Regional Municipality of York (Town of Markham) and the City of Toronto. The watershed has a drainage area of approximately 26 km<sup>2</sup> and is surrounded by the Rouge River, Duffins Creek and the Frenchman's Bay watersheds (see **Figure 2.1**).

The Petticoat Creek Watershed consists of the Main Branch and the East and West Tributaries. The headwaters of Petticoat Creek originate in a till plain. The predominant hydrologic soil groups (HSGs) within the watershed are AB, B and BC (see **Figure 2.2**). The land use within the watershed can be generally divided between rural (agricultural) land use north of approximately Finch Avenue and urban land use south of approximately Finch Avenue (see **Figure 2.3**). Petticoat Creek drains through the Petticoat Creek Conservation Area to Lake Ontario.



**Petticoat Creek Hydrology - Study Area**

Figure 2.1: Study Area of Petticoat Creek Watershed  
(Provided by the TRCA)

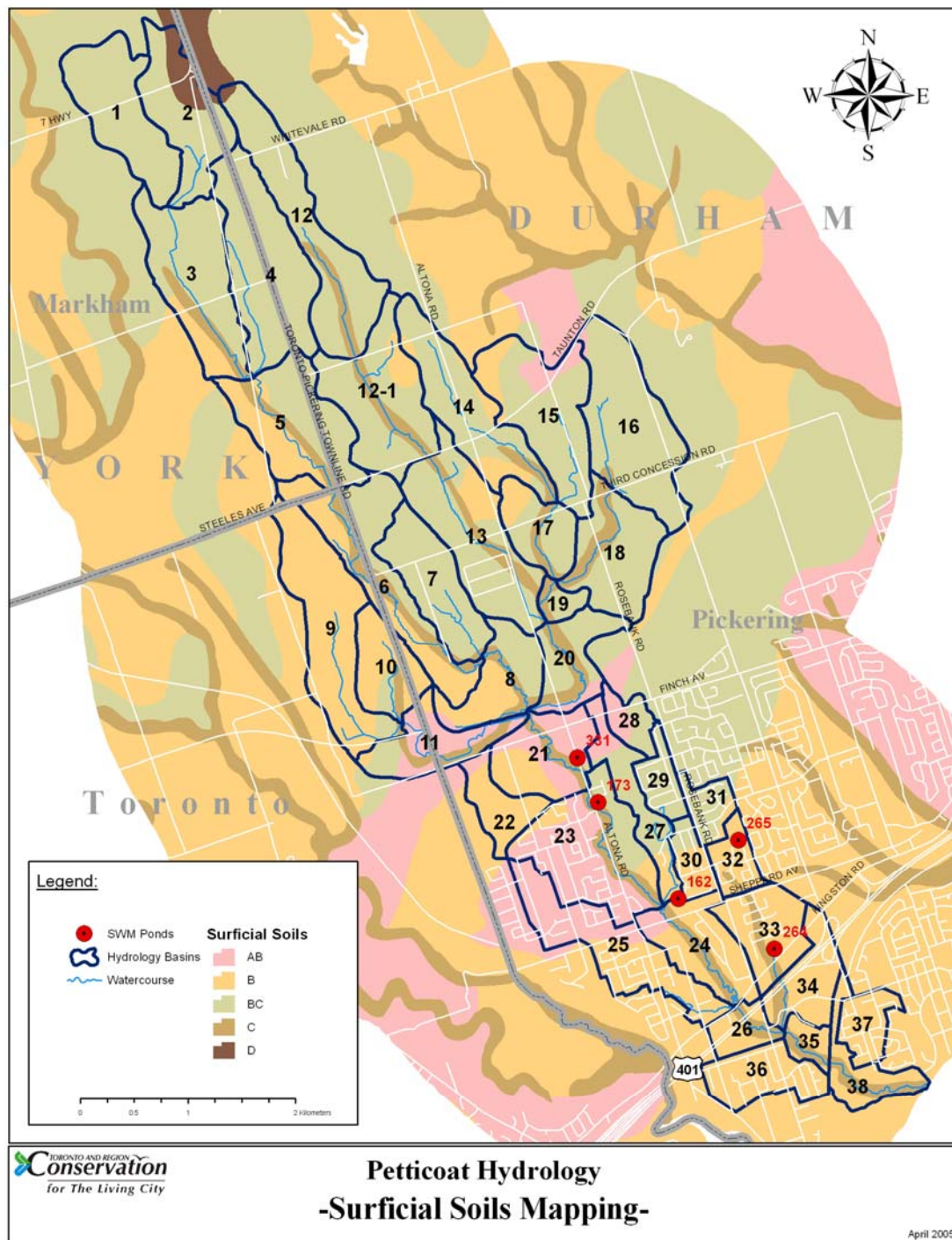


Figure 2.2: Surficial Soils Mapping of Petticoat Creek  
 (Provided by the TRCA)



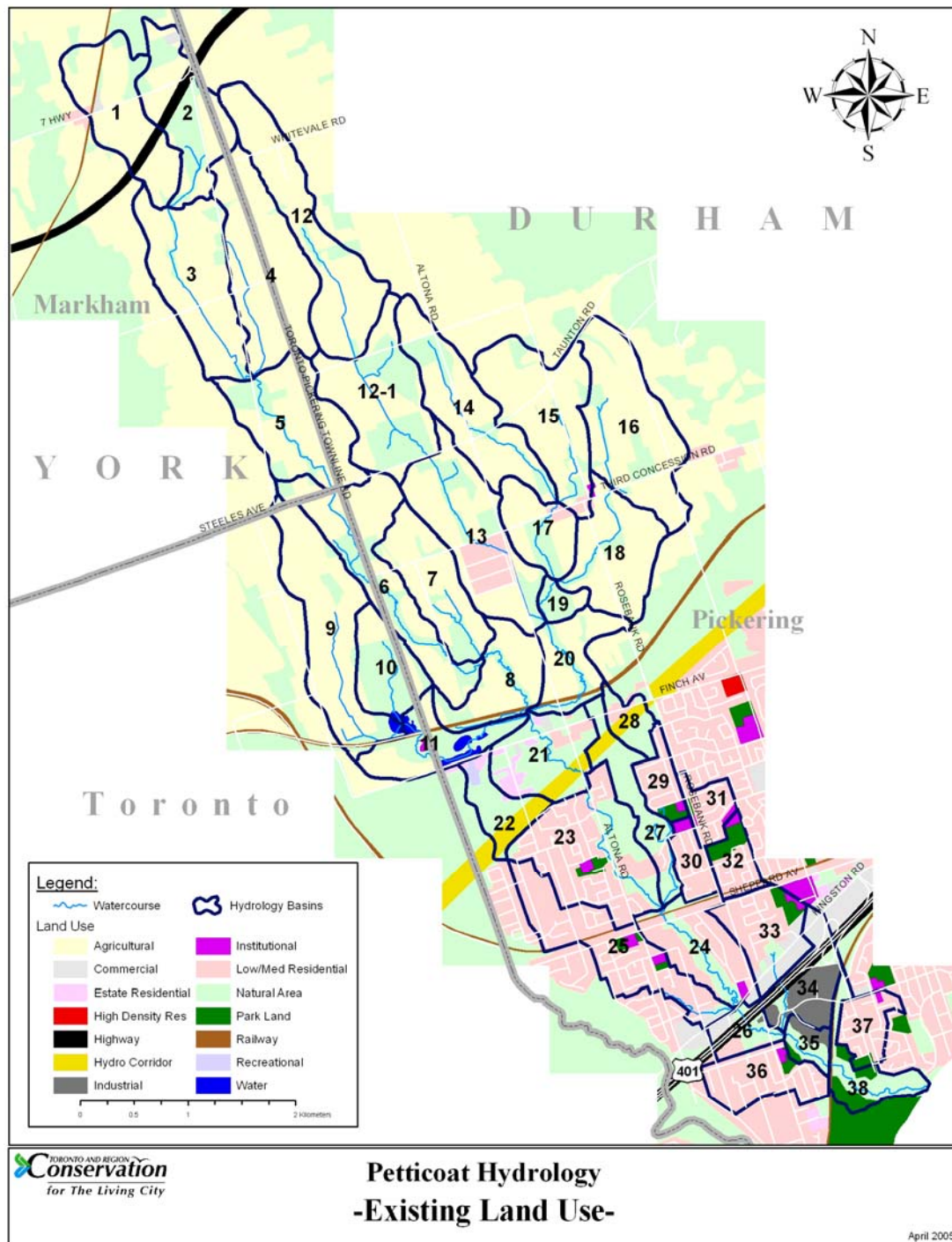


Figure 2.3: Existing land Use of Petticoat Creek  
 (Provided by the TRCA)

### 3.0 VO2 MODEL PREPARATION

#### 3.1 Model Discretization

The Petticoat Creek Watershed was discretized by TRCA staff into 39 separate catchments. Rural catchment watershed boundaries were delineated based on topographic/digital elevation model (DEM) mapping. Urban areas were delineated based on sewershed mapping (storm sewer inventory map). The urban catchment boundaries were delineated upstream of existing SWM ponds.

#### 3.2 Model Set-up

The VO2 hydrology model was set-up to reflect the catchment discretization provided by the TRCA. GIS tools were used to interpret available soils, land use and topographic layers to calculate a number of VO2 parameter values including curve number (CN), total imperviousness (TIMP), directly connected imperviousness (XIMP), average catchment slope, and length and slope of main channel for all catchments and all land use scenarios. Catchments with a TIMP less than 20% were coded using the Nash unit hydrograph (NASHYD) and catchments with a TIMP greater than or equal to 20% were coded using the Standard unit hydrograph (STANDHYD). A table of assumed TIMP and XIMP values used based on the land use can be found in **Appendix A**. CN values provided by the TRCA were converted to CN\* per standard procedure. Hydrographs were routed through channel elements using the Variable Storage Coefficient (VSC) Method. Time-to-peak calculations were completed using the Airport Method and the Bransby Williams Method for determining time of concentration. Additional details and calculations associated with model parameter development are provided in **Appendix A**.

#### 3.3 Stormwater Management Facilities

Based on a review of material provided by the TRCA and further discussions to clarify any discrepancies, available rating curves for significant SWM facilities within the watershed were included in the model to better reflect actual conditions for model calibration and peak flow estimation. The following 5 ponds were included in the VO2 model (see **Figure 2.2**):

- Stroud Pond (#264);
- Bramalea Highbush Pond (#162);
- Amberlea Pond (#265);
- Crystal Forest Pond (#173); and
- Altona Forest Pond (#331).

Stormwater management facilities were incorporated into the watershed model using a lumped pond approach, following the approved technique used in the TRCA Rouge River Watershed Visual OTTHYMO hydrology model. Natural storage areas, reservoirs, and wetlands were not isolated as separate catchments for this model; these have been indirectly accounted for with CN\* values used in the model. Tables showing the rating curves for the ponds utilized in the model and return period storage volumes are provided in **Appendix A**.



### 3.4 Land Use Scenarios

Three land use scenarios were established and included within the VO2 model. The land use scenarios included the following:

- Existing Conditions (2004);
- Future (Committed) Conditions; and
- Future (Ultimate) Conditions.

Existing conditions were established using orthophotography land use data from 2002 and any development plans approved by the TRCA after 2002 to reflect 2004 conditions (see **Figure 2.3**). Future (Committed) conditions reflects land use information based on current municipal and regional OP's and OPA's (see **Figure 3.1**). Future (Ultimate) conditions reflects a land use scenario assuming full urban development within the watershed based on 50% imperviousness for all rural catchments beyond future committed planning. These conditions were used in order to determine the impacts to Regional Storm peak flows. Land use types are outlined in **Appendix A**.

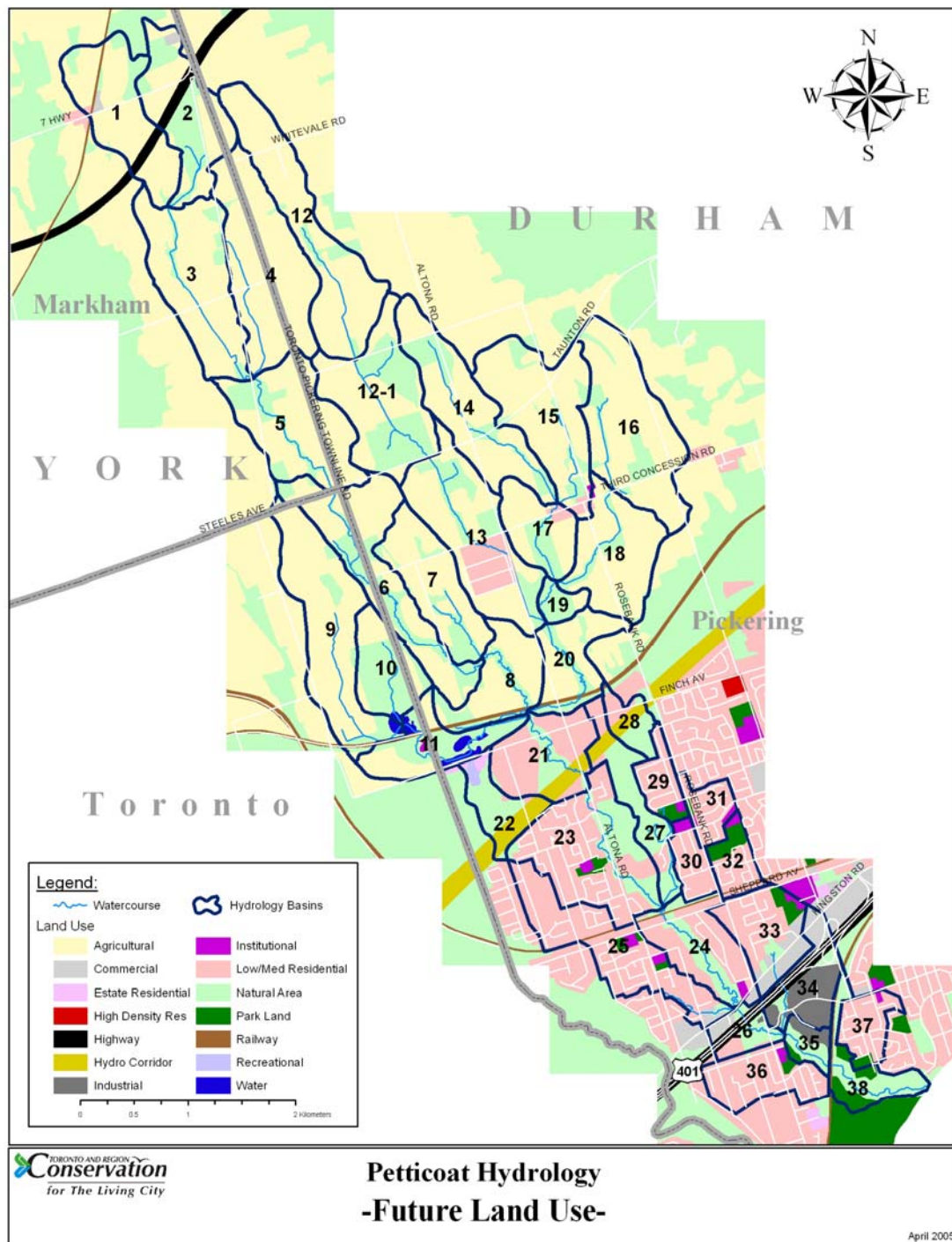


Figure 3.1: Future Committed land Use of Petticoat Creek  
 (Provided by the TRCA)

## 4.0 MODEL CALIBRATION AND VERIFICATION

The Visual OTTHYMO model was calibrated and verified for the existing conditions (2004) land use scenario using available observed flow data and rainfall data. Flow data was provided by the TRCA from the TRCA stream gauge #55 located on Petticoat Creek south of Highway 401 near the bottom of the watershed. The period of record for the flow gauge is 2001 to present. Rainfall data for the corresponding period was also provided by the TRCA for several climate stations including the following:

- # 82 (located just west of the watershed);
- # 95 (located east of the watershed);
- # 107 (located west of the watershed);
- # 106 (located at the south end of the watershed);
- # 83 (located just east of the watershed); and
- # 51 (located just east of the watershed).

Locations of the stream gauge and precipitation gauges can be found in **Figure 4.1**.

Based on a review of the available flow data, a number of events were selected for both model calibration and model verification and these are identified in **Table 4.1**. A total of 5 events were selected for model calibration and 3 events were selected for model verification. The total rainfall depth for the events selected for model calibration and verification ranged between 13.3 mm and 53.3 mm. A detailed description of the model calibration and verification procedure implemented is provided in **Appendix B** along with a series of hydrograph plots depicting the baseflow separation results and gauged vs. predicted flows. The results of the model verification trials are presented in **Table 4.2** for a number of key parameters including peak flow, runoff volume, and time-to-peak. The percent differences in peak flow estimates for the verification events were between -36% and 48%. The results of the model verification are not unreasonable and are in line with verification results for the recent Visual OTTHYMO model prepared for the adjacent Duffins Creek Hydrology Update (Aquafor Beech Ltd., May 2002). There are a number of factors that can contribute to variability (i.e. % difference) between observed and simulated runoff hydrographs for any given event, including the following:

1. Spatial distribution of rainfall (i.e. isolated thunderstorm activity). We have accounted for the spatial distribution of rainfall as best as reasonably feasible with the available data provided by TRCA, however, this is never always perfect.
2. Based on preliminary calibration efforts with the 2001 and 2002 flow data, we have identified that there may be some issues with the flow data during this time. Based on discussions with TRCA, it appears that the rating curve for the Petticoat Creek flow gauge is only verified up to approximately 0.8 m<sup>3</sup>/s (we are calibrating our model for flows up to 23.0 m<sup>3</sup>/s). Efforts have been made by TRCA to check the extrapolation of the rating curve, however, there is quite likely an increasing level of uncertainty (i.e. confidence limits)

with the accuracy of the rating curve extrapolation especially for higher flows which is what we are most interested in for model calibration.

3. Some of the verification events consist of complex hydrographs consisting of off-and-on rain over an extended period. These events can sometimes prove challenging to simulate, especially in terms of runoff volume, as the baseflow separation is more difficult to estimate.

Regarding the 29 August 2004 event specifically, the estimated peak flow is off by 36%. Once again, while we would like to see a closer match, it is not unusual to see variability within this order of magnitude. Based on a review of the Duffins Creek verification events for peak flow, for example, the variability ranged between -22% and 60%. In addition, if we suspect that there could be increasing variability with the Petticoat Creek gauge rating curve above the verified portion (i.e. above approximately 0.8 m<sup>3</sup>/s), then it stands to reason that this could result in more variability observed between predicted and gauged verification events for higher flows (such as the 29 August 2004 event) as well.

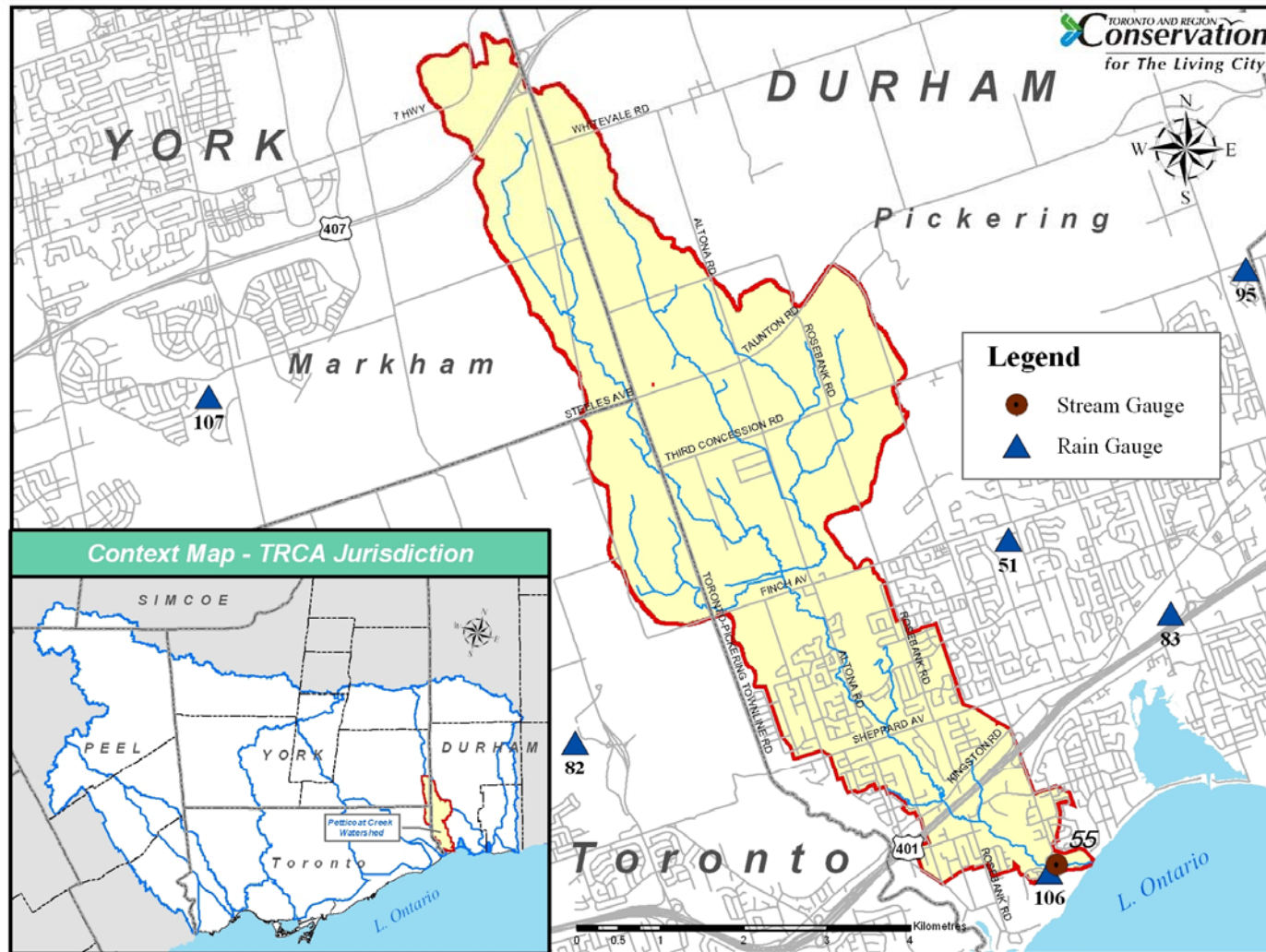
Table 4.1: Summary of Calibration/Verification Storm Events

Rainfall Event (Date)	Rainfall Depth (mm)	Event Type
15 May 2003	53.3	Calibration
23 May 2003	37.9	Calibration
13 June 2003	18.4	Verification
15 July 2003	15.1	Calibration
24 May 2004	22.2	Verification
4 August 2004	13.3	Calibration
29 August 2004	23.7	Verification
9 September 2004	33.1	Calibration

Table 4.2: Comparison of Gauged and Predicted Runoff Peak Flows

Parameter	Event	Gauged	Predicted	% Difference
Peak Flow (m <sup>3</sup> /s)	13 June 2003	2.74	3.07	12%
	24 May 2004	2.62	3.89	48%
	29 August 2004	13.96	9.00	-36%
CN* Adjustment Factor	13 June 2003	n/a	0.91	n/a
	24 May 2004	n/a	0.95	n/a
	29 August 2004	n/a	0.34	n/a
Runoff Volume (mm)	13 June 2003	5.00	2.39	-52%
	24 May 2004	4.29	3.55	-17%
	29 August 2004	4.26	2.06	-52%
T <sub>p</sub> (hrs)	13 June 2003	6.00	6.33	6%
	24 May 2004	11.00	11.25	2%
	29 August 2004	2.00	2.08	4%

Note: 1) Gauged Flows are extrapolated from Petticoat Gauge rating curve  
2) Predicted Flows are the results of the VO2 modelling



**Petticoat Creek Hydrology - Gauge Mapping**

Figure 4.1: Gauge Mapping of Petticoat Creek Watershed  
(Provided by the TRCA)



## 5.0 ESTIMATION AND COMPARISON OF PEAK FLOWS

### 5.1 Return Period and Regional Storm Methods

The CN\* values for return period events (i.e. 2-yr through 100-yr design storms) were set to AMC II conditions. The CN\* values for the Regional Storm (Hurricane Hazel) were set to AMC III conditions per standard procedure. An areal reduction factor of 94.8% was applied to the outlet for the Regional Storm based on the equivalent circular area of 157.2 km<sup>2</sup>. A summary of the areal reduction factors used are provided in **Appendix A**.

### 5.2 Determination of Critical Distribution and Duration

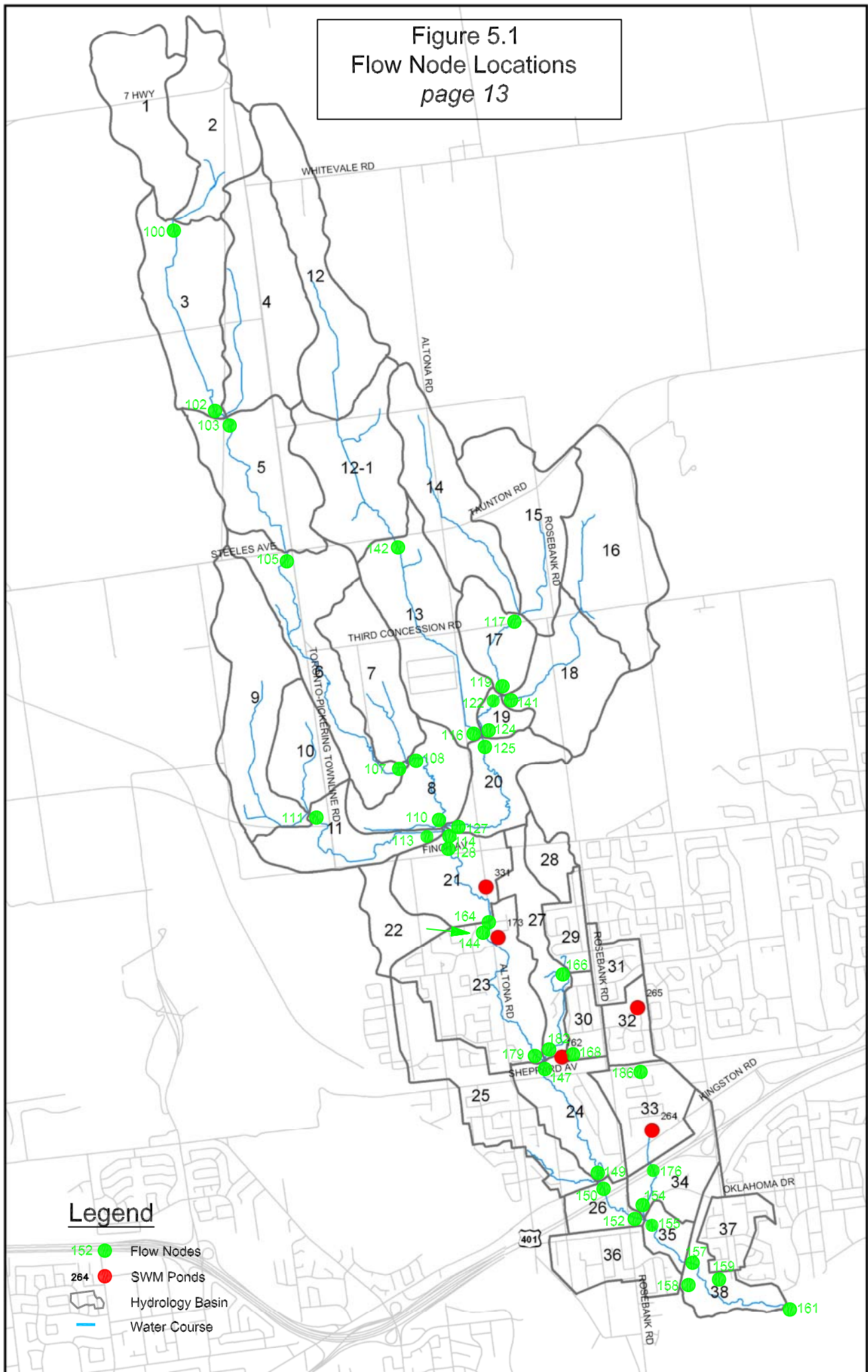
A series of Chicago (3-hr and 4-hr) and AES (6-hr, 12-hr and 24-hr) design storms were assessed to determine the most appropriate duration for use within the watershed. The results of the analysis are provided in **Appendix C**. The analysis showed that the Chicago 3-hr storm distribution had the greatest flow at the watershed outlet but the AES 12-hr storm had the greatest flow at flow node 152. The flow at node 152 seems to reflect the characteristics of the majority of the watershed while the watershed outlet (flow node 161) is greatly influenced by a few urban areas found to the south of node 152. Therefore, it was determined that the 12-hr AES design storms were the most appropriate for use within the Petticoat Creek Watershed.

### 5.3 Existing, Future (Committed) and Future (Ultimate) Peak Flows

Using the calibration factors calculated for existing conditions, two additional scenarios were completed for future (committed) and future (ultimate) land use conditions. A summary of peak flows for the return period events and the Regional Storm is provided in **Appendix C**. Existing SWM facilities were included for all return period peak flow calculations. SWM ponds were excluded for Regional flow calculations per TRCA standard procedure. The location of key flow nodes and associated node identification numbers within the Petticoat Creek Watershed is provided in **Figure 5.1**. Under future (committed) land use scenarios in the upper reaches of the watershed (i.e. approximately north of Finch Avenue) where little development is proposed, increases in peak flow are generally minimal. In the lower reaches of the watershed (i.e. approximately south of Finch Avenue) where some development is proposed under future (committed) conditions, increases in catchment peak flows are significant. However given the timing of runoff hydrographs, in-stream peak flow increases are negligible. Future (ultimate) conditions were included in the comparisons to aid in determining impacts to Regional Storm peak flows. Results showed that under future (ultimate) conditions, increases in peak flows throughout the entire watershed are considerable.

When comparing peak flows for the 3 land use scenarios at the bottom of the watershed (i.e. node 161), peak flow for future (committed) and future (ultimate) scenarios relative to existing conditions for the 100-yr design storm creased 0.8% and 137%, respectively. Please note that the future (ultimate) scenario is without SWM controls and that future SWM requirements must be determined as noted in Section 6.0. On average, the ultimate

Figure 5.1  
Flow Node Locations  
page 13



conditions had a peak flow 27% higher than that of the existing and future conditions for the Regional Storm. A copy of the VO2 summary output is provided in **Appendix C**.

Peak flows from a previous Petticoat Creek Hydrology model obtained from the TRCA has been included for nine (9) of the sub-basins. Although peak flows have generally increased from the previous study, it is difficult to draw comparisons as the previous model was not calibrated and it is unknown if areal reduction factors were accounted for.

## **6.0 FUTURE STORMWATER QUANTITY CONTROL REQUIREMENTS**

Based on discussions with the TRCA it was established that two areas within the Petticoat Creek Watershed are committed for future development and are included in the current Official Plan but are without approved MESP's or approved drainage plans. This includes areas within Catchment 21 and Catchment 27. A summary of peak flows for existing and future (committed) uncontrolled scenarios at key nodes is provided in **Table 6.1**. Although many SWM strategies are required (water quality control, stream bank erosion, safe conveyance, etc.), peak flow control is not necessary for future developments in Catchments 21 and 27 given the negligible in-stream increases.

Development in areas beyond the current Official Plan (i.e. north of Finch Avenue) must demonstrate the level of quantity control required through appropriate hydrologic analysis using the up-to-date Petticoat Creek Watershed model.

Table 6.1: Peak Flow Summary for Catchments 21 and 27  
(12 hour – AES Storm)

	Catchment 21 SW Pond		Downstream Node 164	
Storms	Existing Conditions	Future Committed Uncontrolled	Existing Conditions	Future Committed Uncontrolled
Year	m <sup>3</sup> /s	m <sup>3</sup> /s	m <sup>3</sup> /s	m <sup>3</sup> /s
2	0.10	0.56	8.87	8.90
5	0.23	0.82	14.96	14.94
10	0.34	1.01	19.68	19.67
25	0.48	1.29	26.20	26.20
50	0.60	1.49	31.43	31.43
100	0.72	2.87	37.04	37.03
Regional	5.51	7.79	155.83	154.14

	Catchment 27 SW Pond		Downstream Node 182	
Storms	Existing Conditions	Future Committed Uncontrolled	Existing Conditions	Future Committed Uncontrolled
Year	m <sup>3</sup> /s	m <sup>3</sup> /s	m <sup>3</sup> /s	m <sup>3</sup> /s
2	0.14	0.16	0.14	0.13
5	0.24	0.28	0.24	0.23
10	0.32	0.38	0.32	0.31
25	0.43	0.51	0.57	0.45
50	0.52	0.62	0.83	0.69
100	0.62	0.73	1.10	0.94
Regional	0.34	0.39	6.77	7.04

## 7.0 GUIDELINES FOR FUTURE MODEL USERS

In order to keep the VO2 model current as development proceeds within the Petticoat Creek Watershed, it is useful to have an established protocol for updating the model as the land use continues to change and future SWM facilities are constructed. A lumped pond modelling procedure, similar to that used for the Rouge River, was used to lump ponds within the Petticoat Creek Watershed for existing and future committed conditions and it is recommended that the procedure should continue to be used to update the VO2 model in the future. A copy of the lumped pond modelling procedure for Petticoat Creek is provided in **Appendix D**. It is important to note, however, that this approach works on the assumption that all outflow from SWM facilities and/or the subject catchment is directed to a common outlet (i.e. no flow diversions).

The lumped pond modelling procedure is not recommended in situations where flow diversions from either SWM facilities within the subject catchment or from the subject catchment itself are diverted to an adjacent catchment. In situations where a number of SWM facilities are to be added to a catchment with flow diversions, it is recommended that the subject catchment be further discretized and that all new ponds be included independently to properly account for flow diversions. An example of this type of flow diversion occurs within the Petticoat Creek Watershed Catchment 29 where major flow is diverted to Catchment 27.



## **8.0 SUMMARY**

This report provides the details associated with the development of an updated VO2 hydrology model for the Petticoat Creek Watershed. The following is a summary of key report items:

1. A VO2 model update was completed for the Petticoat Creek Watershed for three land use scenarios including existing conditions, future (committed) conditions, and future (ultimate) conditions.
2. The watershed was discretized into 39 catchments and model parameter values were derived using GIS tools and available data layers for soils, land use and topography.
3. Existing SWM facilities were included in the VO2 model.
4. The VO2 model was calibrated and verified using flow and rainfall data from 5 and 3 events, respectively. The results of the model verification were found to be acceptable and comparable to similar model calibrations such as the recent VO2 model update for the Duffins Creek Watershed.
5. The 12-hr AES design storms were determined to be the most appropriate duration for use within the Petticoat Creek Watershed and were used to estimate return period peak flows for all three land use scenarios. Hurricane Hazel was used to represent the Regional Storm.
6. When comparing peak flows for the three land use scenarios at the bottom of the watershed, the increase in peak flow for future (committed) and future (ultimate) scenarios relative to existing conditions for the 100-yr design storm is 0.8% and 137%, respectively. On average, the ultimate conditions had a peak flow 27% higher than that of the existing and future conditions for the Regional Storm.
7. Areas designated for future development as shown in the current Official Plan but without approved MESP's or drainage studies (i.e. Catchments 21 and 27), do not require peak flow control (i.e. quantity control) given the negligible in-stream increases.
8. Guidelines for future model updates as land use continues to change and SWM facilities are constructed within the watershed were established based on a currently approved methodology for the Rouge River Watershed.

## 9.0 RECOMMENDATIONS

Based on the results of the VO2 hydrology update and other report findings, we offer the following recommendations for consideration:

1. The VO2 model update associated with this report should be utilized to estimate peak flows for the proposed floodline studies for Petticoat Creek.
2. As additional continuous flow data becomes available within the Petticoat Creek Watershed, the VO2 model should continue to be verified and the calibration should be "tweaked" as required.
3. In areas designated for future development as shown in the current Official Plan but without approved MESP's or drainage plans, such as Catchments 21 and 27, SWM strategies are required for water quality, stream bank erosion and safe conveyance of flow. Quantity control, however, is not necessary as this analysis has demonstrated that increases in in-stream flows are negligible. The requirements for SWM strategies that consider water quality control, stream bank erosion control and safe conveyance of flow apply to all future developments both within and beyond the current Official Plan. Quantity control for future development areas beyond the Official Plan (i.e. north of Finch Avenue) may be required and must be assessed with each development proposal. In catchments with approved SWM control strategies, these should continue to be reviewed and applied as development proceeds within the watershed.
4. As land use continues to change and SWM facilities are constructed associated with future development within the Petticoat Creek Watershed, the VO2 model should continue to be updated using the methodology provided in Appendix D. Special consideration, however, should be given in cases where flow diversions exist between catchments.

Respectfully Submitted,

GREENLAND INTERNATIONAL CONSULTING LTD.



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A handwritten signature in black ink, likely belonging to Chaodong Sheng.