HIGHLAND CREEK

HYDROLOGY UPDATE

FINAL REPORT

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1.0 INTRODUCTION

Aquafor Beech Limited was retained by the Toronto and Region Conservation Authority (TRCA) to complete an update of the hydrologic model for Highland Creek and to develop a flood management strategy to minimize the impact of future urban development. The watershed is approximately 105 square kilometres and is situated within the southeastern limits of the City of Toronto (Scarborough), as illustrated in Figure 1.1.

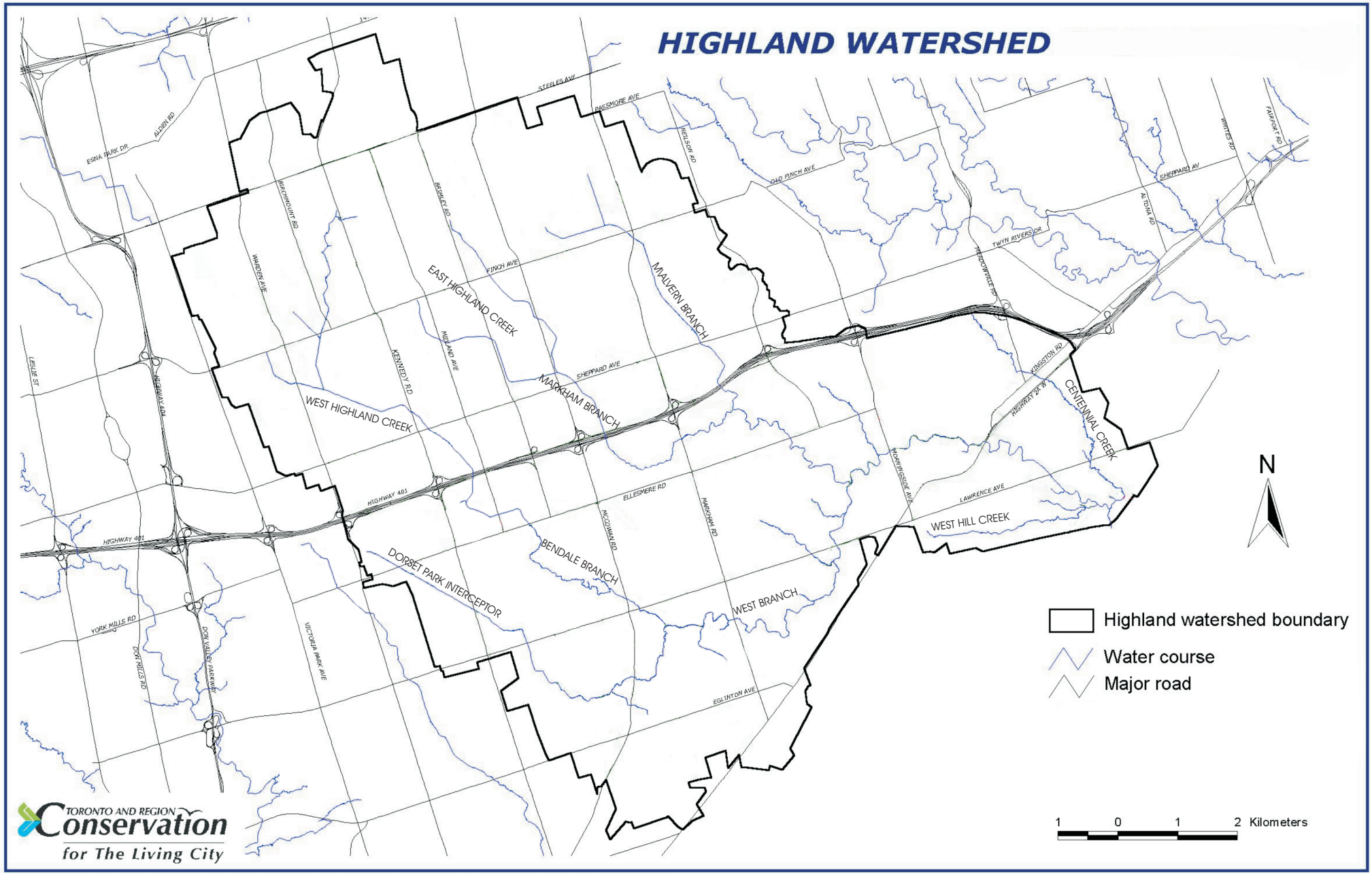


Figure 1.1 *Highland Creek Watershed*

2.0 HYDROLOGIC MODEL SETUP

2.1 Model Selection

The hydrologic model selected for application in this study was VISUAL OTTHYMO, version 2.0. This is a HYMO-based model, similar to the previous OTTHYMO/INTERHYMO model, and is used in a "Windows" operating system environment.

2.2 Model Discretization

As illustrated in Figure 2.1, the Highland Creek Watershed was divided into over 40 subcatchments in order to provide peak flow estimates at key locations throughout the watershed. For consistency, the subcatchment discretization and numbering is the same as that used to model Highland Creek in the recent Toronto Wet Weather Flow Management Master Plan (TWWFMMP) study.

2.3 Model Parameters

The following techniques and model parameters were applied with the VISUAL OTTHYMO model to simulate rural and urban rainfall-runoff responses:

- the CN* approach was used to determine direct runoff from pervious areas;
- the *Standard* unit hydrograph was applied to simulated runoff response from the majority of this urban watershed;
- the *Nash* unit hydrograph was applied to simulate runoff response from rural areas;
- hydrographs were routed through channel elements using the "*Route Channel*" command which uses the *Variable Storage Coefficient* method. Representative channel cross-sections were taken from a HEC-2 hydraulic model of the creek, together with channel slopes derived from the GIS database.

Some model parameters, such as catchment drainage areas, CN* values and percent impervious values, were originally derived from the City of Toronto's GIS database as part of the TWWFMMP study. These values have been updated to reflect existing landuse conditions using information from TRCA's database as per 2002 air photography. Table 2.1 summarizes the assumed CN values based on soil types and land cover. These were used to derive an initial estimate of the CN* values for each catchment in the VISUAL OTTHYMO model. Table 2.2 summarizes the assumed percent

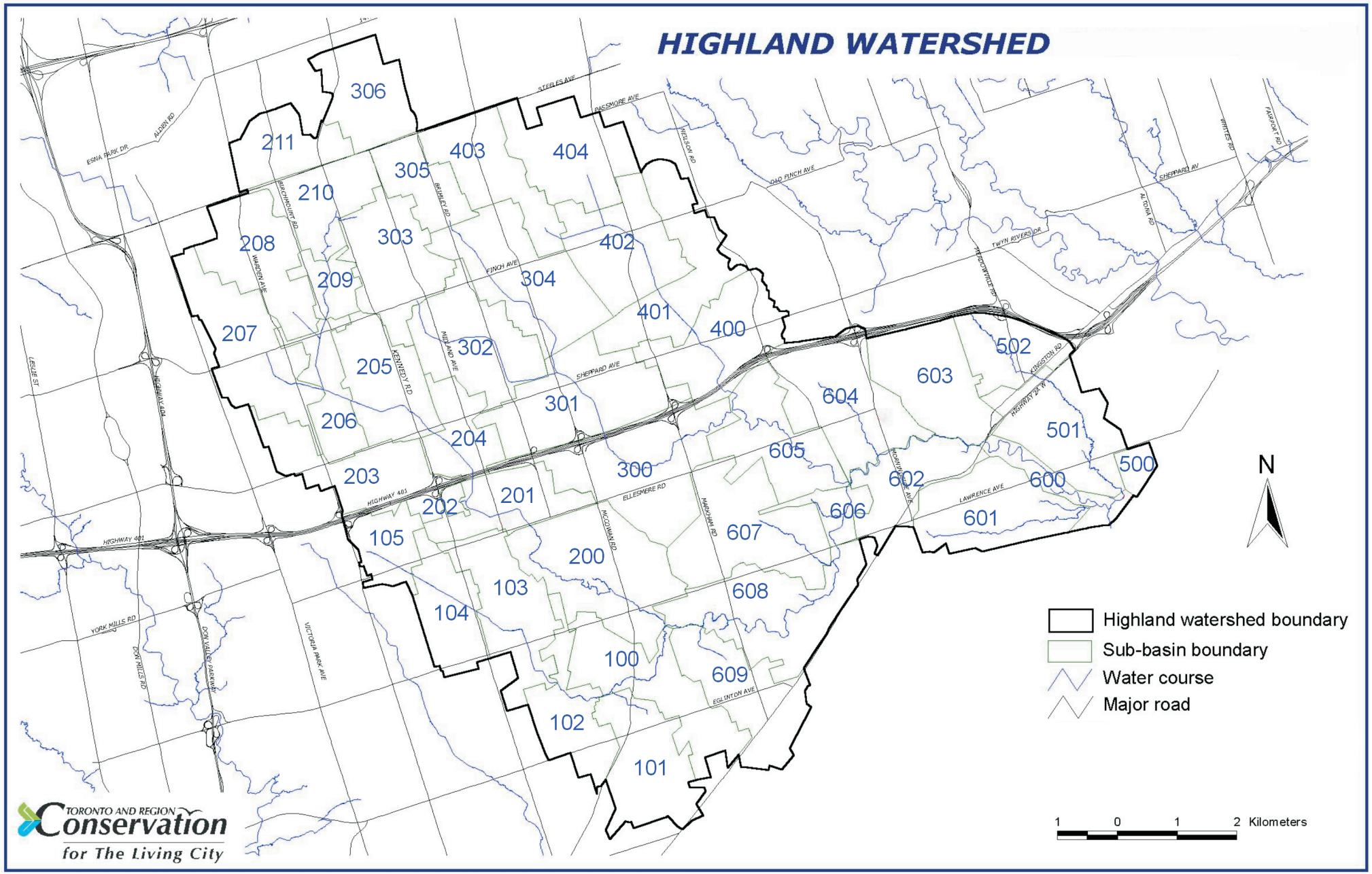


Figure 2.1 *Highland Creek Hydrologic Model - Subcatchment Boundaries*

Table 2.1
Summary of Estimated CN Values by Soil Type and Land Cover

Land Cover	CN*						
	A Soils	AB	B Soils	BC	C Soils	CD	D Soils
Forest	36	48	60	67	73	76	79
Agricultural	64	70	75	79	82	84	85
Urban (lawns)	49	59	69	74	79	82	84

Source: J.F. Sabourin and Associates, 1999.

Table 2.2
Summary of Estimated Percent Impervious Values by Landuse

Land Use Classification	Percent Impervious
Residential	Low Density - 30% Medium Density - 50% High Density - 65% Hi Rise - 50%
Commercial	Strip Mall, Big Box - 98%
Industrial	Prestige - 80% Big Box - 93%
Institutional	32%
Transportation	70%
Open Space	Parks - 10% Valleys - 3%
Agriculture / Forest	0%

impervious values based on landuse. The TRCA database was also used to derive other model parameters including basin slopes and channel slopes. A summary of subcatchment parameters is provided in Appendix A. Soils and landuse mapping used to derive the model parameters are also provided in Appendix A.

3.0 MODEL CALIBRATION

The hydrologic model was checked through calibration to ensure that the model was representative of the study area. Outlined below are the main steps which were undertaken:

1. Streamflow data was collected from three streamflow gauges within the Highland Creek watershed and used in the model calibration. The locations of the streamflow gauges are illustrated in Figure 3.1 and summarized in Table 3.1. The Water Survey of Canada (WSC) gauge was installed in the 1950's, however, reliable data is not available after 1998 due to unstable conditions at the controlling weir. Two gauges on West Highland Creek were operational for portions of 1999 and 2000 (CH2MHill, 2002).

2. Seven rainfall-runoff events that occurred between 1995 and 2000, as recorded at nearby rain gauges, were used for model calibration and verification. The locations of the rain gauges are illustrated in Figure 3.1, and rainfall depths for the events are summarized in Table 3.2. Rainfall depths from the gauges were supplied by TRCA and were averaged over the watershed using the Thiessen Polygon technique. Preference was given to the use of frontal storm events to reflect basin-wide rainfall/runoff response. If data for a selected event was missing at a single gauge, the rainfall was re-distributed over the watershed using a revised Thiessen polygon based on the remaining active gauges.

3. Observed runoff hydrographs were derived from streamflow gauge data by separating baseflows using a procedure provided in Linsley *et al* (1982). Data from the WSC gauge was used for calibration events in 1995 and 1996, and data from the West Highland Creek gauges was used for calibration events in 1999 and 2000.

4. In the calibration process, emphasis was placed first on minimizing the differences between observed and simulated runoff volumes. This involved adjustment of the CN* parameter to match the observed runoff volumes. Given the urban nature of the watershed, the impervious components tend to define the rainfall-runoff response, and the model is less sensitive to adjustments in CN* value than typical rural watersheds.

5. Following calibration of runoff volumes, emphasis was placed on minimizing the differences between observed and simulated peak flow rates, and matching the general hydrograph timing and shape. This involved adjustment to the roughness coefficients used in the channel routing

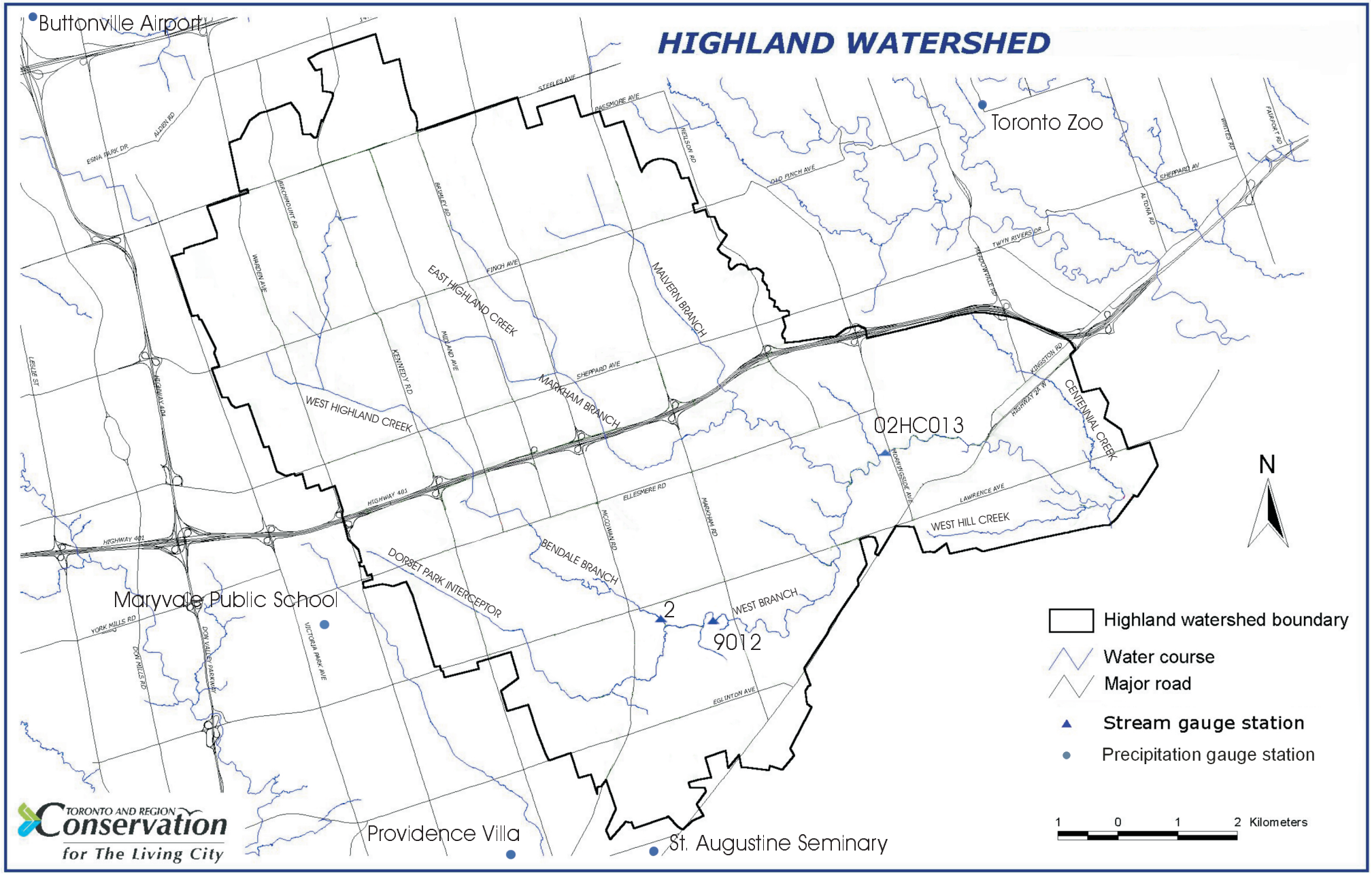


Figure 3.1 *Stream/Precipitation Gauge Locations*

Table 3.1
Summary of Streamflow Gauges

Streamflow Gauge Name	Gauge Number	Drainage Area
Highland Creek near West Hill	WSC 02HC013	93.79 km^2
West Highland Creek above Bendale Creek**	2	25.34 km^2
West Highland Creek below Bendale Creek**	9012	35.12 km^2

** West Highland Creek gauges operated intermittently from April 1999 to August 2000

Table 3.2
Summary of Calibration/Verification Storm Events

Rainfall Event	Rainfall Depth*	Calibration / Verification
13 Jul '95	14.3 mm	verification event
28 Jul '95	15.1 mm	verification event
5 Oct '95	54.4 mm	calibration event
10 Nov '95	54.4 mm	calibration event
7 Sep '96	73.0 mm	calibration event
29 Sep '99	40.9 mm	calibration event
24 June '00	34.8 mm	calibration event

* Average rainfall depths over the watershed were estimated using hourly data from the following rainfall gauge stations: Buttonville Airport, Providence Villa, Toronto Zoo, St. Augustine and/or Maryvale.

elements of the model.

6. Results from the calibration process were then used to derive a relationship between the CN* adjustments (step 4 above) and the amount of precipitation recorded at the rain gauges in the days preceding the storm events. A 10-day antecedent precipitation index (API) was used for each storm (Bruce *et al*). The CN* adjustment for the verification events was then predicted from this relationship.

Illustrated in Figure 3.2 are typical results from the model calibration (5 October 1995 event). Provided in Appendix B are the results from all calibration events, and a plot of the CN* adjustment vs. API relationship. Table 3.3 and Figure 3.3 provide a summary of the observed vs. simulated runoff depths and peak flow rates. Several observations from the calibration results follow:

- good results were obtained, particularly for the larger "frontal" storm events at the Water Survey of Canada gauge location;
- peak flow rates were calibrated to within approximately +/- 10% at the Water Survey of Canada gauge;
- there was slightly more variability in the model results at the West Highland Creek gauges, however, the results appear acceptable, particularly those from the 2000 storm event;
- runoff volumes for smaller July '95 thunderstorm events were moderately over-estimated by the model in terms of percentage. However, in terms of runoff depth, these events are relatively small and the model estimates are within 1-2mm of the observed runoff depths.

In general, the simulated hydrograph characteristics (i.e. volume, peak flows, shape) are reasonable given the variability associated with rainfall data and uncertainty associated with the measurement of streamflow and rainfall. Therefore the calibrated hydrologic model can be considered representative of the watershed.

Figure 3.2: Calibration Results - 5 October 1995 Storm Event

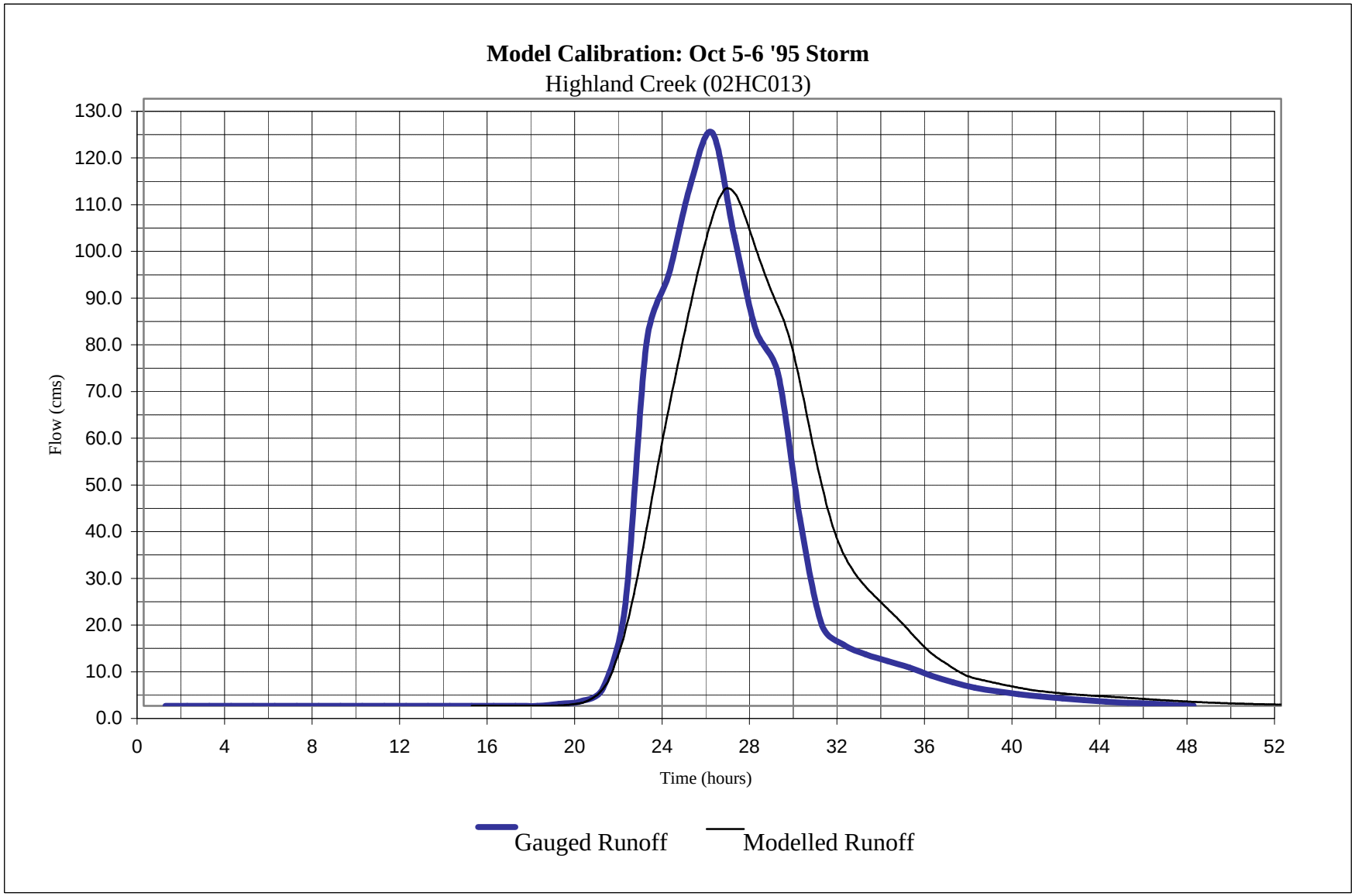
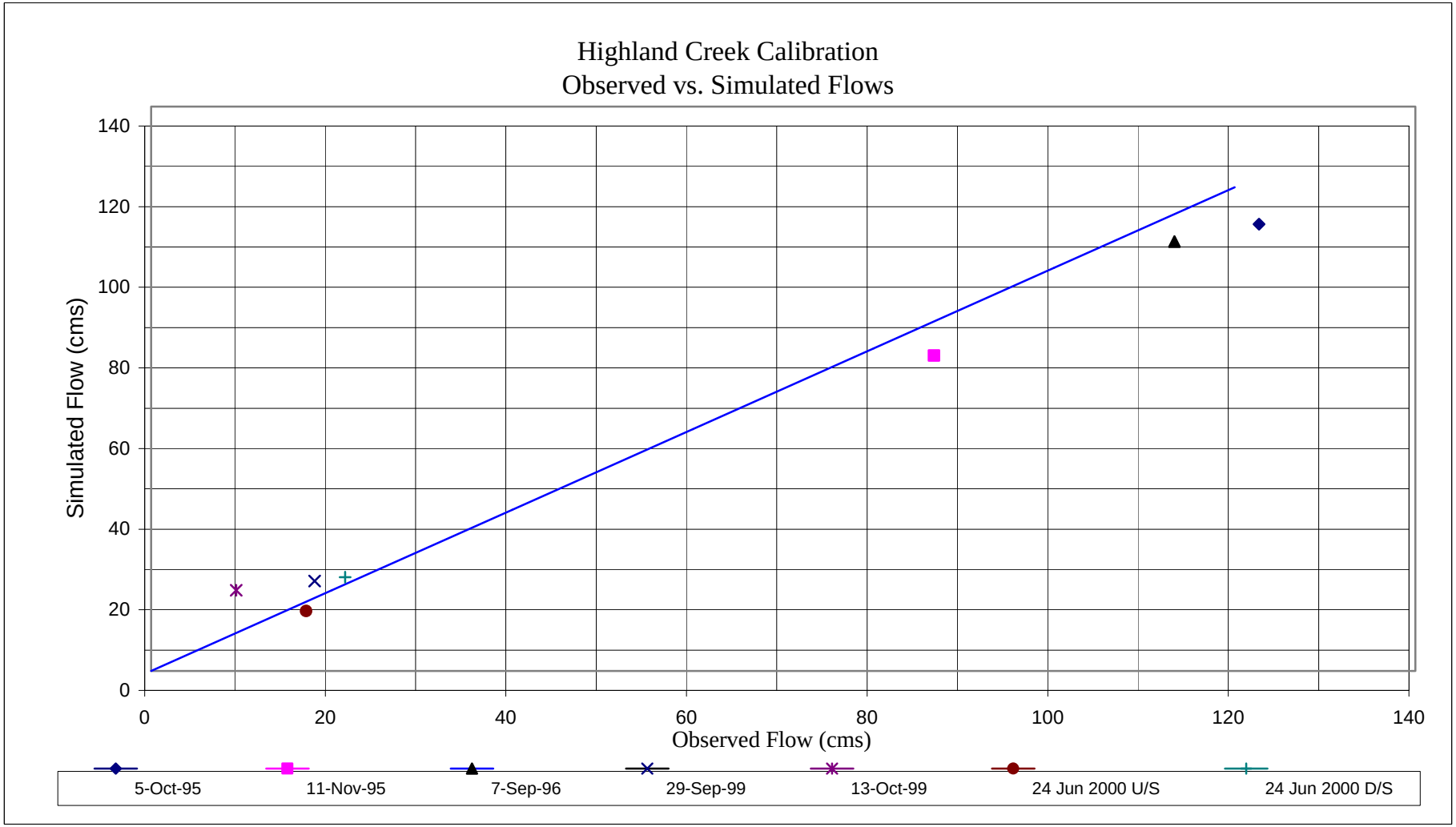


Table 3.3
Summary of Model Calibration/Verification Results

	5 Oct 1995			11 Nov 1995			7 Sep 1996			29 Sep 1999 Upstream			24 Jun 2000 Upstream			13 Jul 1995*			28 Jul 1995*		
	Observed	Simulated	Difference	Observed	Simulated	Difference	Observed	Simulated	Difference	Observed	Simulated	Difference	Observed	Simulated	Difference	Observed	Simulated	Difference	Observed	Simulated	Difference
Rainfall Depth (mm)	54.4	54.4		54.4	54.4		73.3	73.3		40.9	40.9		34.8	34.8		14.3	14.3		15.1	15.1	
Runoff Depth (mm)																					
Highland Creek (gauge 02HC013):	34.38	33.35	-3.0%	29.92	30.54	2.1%	36.93	39.54	7.1%	---	---	---	---	---	---	4.22	5.12	21.3%	5.28	7.41	40.3%
West Highland Creek Upstream of Bendale Creek (gauge #2):	---	---	---	---	---	---	---	---	---	17.45	19.36	10.9%	17.49	17.84	2.0%	---	---	---	---	---	---
West Highland Creek Downstream of Bendale Creek (gauge #9012):	---	---	---	---	---	---	---	---	---	---	---	---	16.26	17.79	9.4%	---	---	---	---	---	---
Peak Flow (cms)																					
Highland Creek (gauge 02HC013):	122.7	110.82	-9.7%	86.71	78.2	-9.8%	113.31	106.5	-6.0%	---	---	---	---	---	---	29.8	32.89	10.4%	46.89	43.49	-7.3%
West Highland Creek Upstream of Bendale Creek (gauge #2):	---	---	---	---	---	---	---	---	---	18.11	22.31	23.2%	17.17	14.87	-13.4%	---	---	---	---	---	---
West Highland Creek Downstream of Bendale Creek (gauge #9012):	---	---	---	---	---	---	---	---	---	---	---	---	21.48	23.24	8.2%	---	---	---	---	---	---

* Verification Event

Figure 3.3:
Summary of Observed vs. Simulated Flows



4.0 HYDROLOGIC ASSESSMENT AND DESIGN STORM FLOW ESTIMATES

Peak flows were established at key locations in the study area for the existing and projected future landuse scenarios. A design storm approach was used to estimate the 2, 5, 10, 25, 50, and 100-year peak flows, and the Regulatory Storm. The Regulatory Storm in the study area for floodplain management purposes is based on Hurricane Hazel.

With a design storm approach, a rainfall input (i.e. duration, return period depth, and temporal distribution) is selected and design flows are determined using specified antecedent moisture conditions and a computational technique such as a hydrologic model. It is assumed with this approach that peak flows which are generated are of approximately the same return period as the applied design storm.

4.1 Design Storm Selection

The 6-hour and 12-hour AES design storm distributions were selected for application to the Highland Creek watershed. The AES distribution was selected over both the U.S. Soil Conservation Service (SCS) and Chicago distributions, as it is more suitable for the study area. Past investigations have indicated that the Chicago distribution is inappropriate for some parts of Canada, and is less than ideal for the rest of the country (Pugsely, 1981). The SCS distribution is based on rainfall data from mountainous regions of the United States, and thus, not considered suitable for the study area.
Of the two storm durations tested in the model, the 6-hour duration produced the highest peak flow rates and was therefore selected over the 12-hour duration to define the flood flow rates throughout the watershed. The shorter, more intense 6-hour duration storm is representative of the predominant type of storm which will cause flooding on this primarily urban watershed.

Return period rainfall depths were obtained from Toronto Bloor Street Intensity-Duration-Frequency (IDF) data. Hyetographs for the 2-year through 100-year and Regulatory Storm events are provided in Appendix C.

4.2 Design Storm Flow Estimates - Existing Landuses

The calibrated hydrologic model for Highland Creek was applied to estimate flood flow rates. The calibrated CN* values were assumed to represent AMC II conditions for the purposes of estimating 2-year through 100-year design storm flow rates. A chart comparing the resulting predicted

(modeled) flood frequency curve to observed flows at the WSC streamflow gauge location is provided in Figure 4.1. As shown, the shapes of the simulated and observed flood frequency curves are similar and the modeled results can be considered representative of the hydrologic response. Insufficient historical data was available to produce flood frequency curves for the other two gauges used in this study.

Regional Storm flow estimates were then obtained by converting CN* values from AMC II to AMC III, and application of areal reduction factors to the rainfall depth using the "equivalent circular area method". The routing effects associated with existing stormwater management facilities were not considered for the regional flood estimates.

Peak flow estimates for the existing landuse scenario were obtained at key locations throughout the Highland Creek Watershed. Summarized in Table D.1 (Appendix D) are the estimated existing design flows at the "flow node" locations illustrated in Figure 4.2.

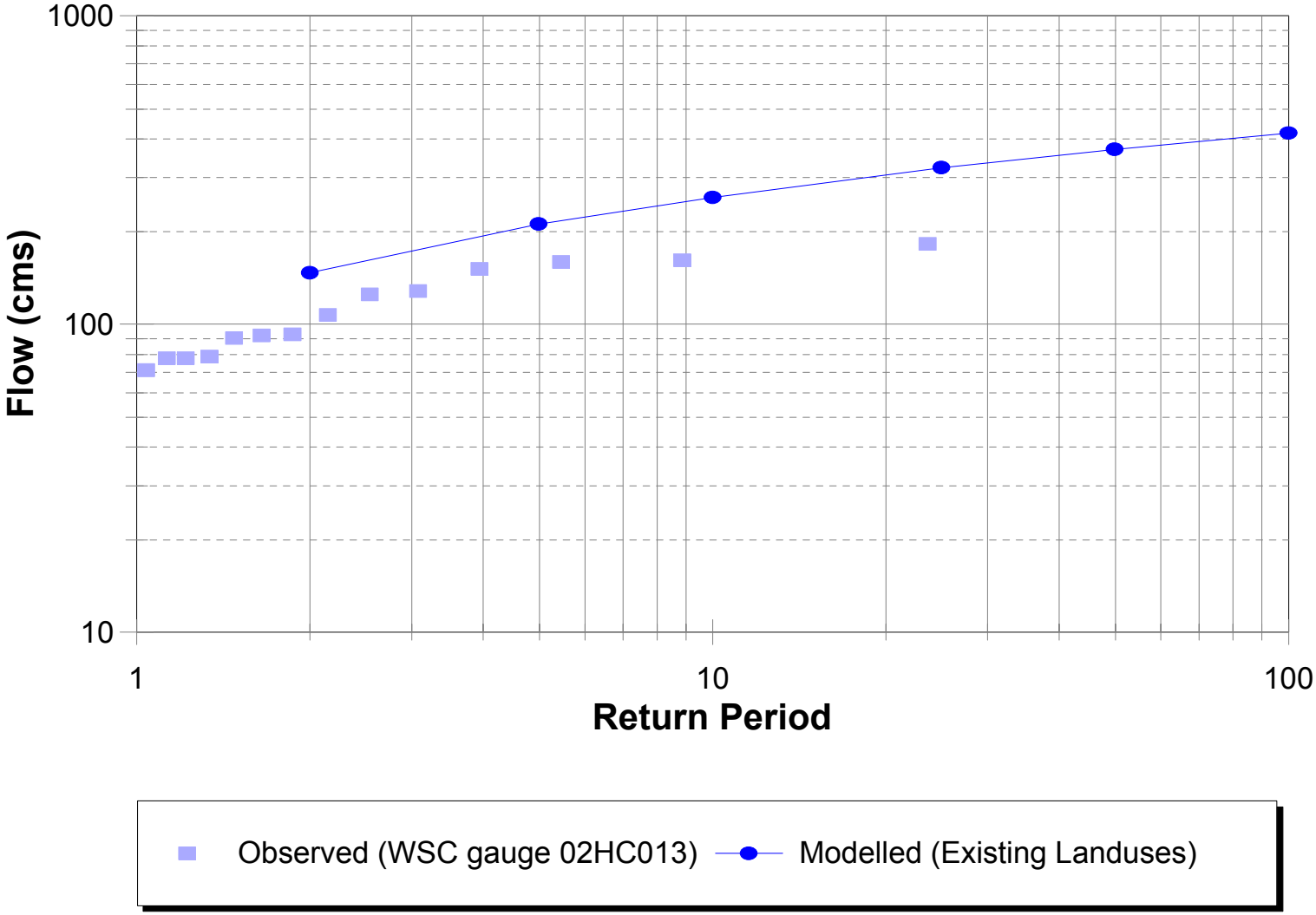
4.3 Design Storm Flow Estimates - Future Landuses

The hydrologic model was then setup to model a landuse scenario associated with future urban development. The Highland Creek watershed is already urban in nature and essentially fully developed. Therefore, future urban development is characterized mainly by "infill" developments or "intensification" of existing urban areas. For example, large clusters of new employment and mixed use areas are being proposed through re-development at various locations. Figure A.3 (Appendix A) illustrates the areas subject to intensification over a 25 year timeframe as defined in the Toronto Wet Weather Flow Management Master Plan (TWWFMMP) study (Aquafor, 2003).

Therefore, the future landuse scenario was defined by "overlaying" the areas of intensification onto the existing landuse pattern. The TRCA GIS database was again used to derive the hydrologic model parameters associated with the future landuse scenario. A value of 90% impervious was assigned to all areas identified for potential intensification. Model parameters associated with future landuses are provided in Appendix A.

Table D.1 (Appendix D) summarizes the estimated future design flows at the "flow node" locations illustrated in Figure 4.2. A summary of the estimated changes in peak flow rates is provided in Table D.2 (Appendix D). Comparison of the estimated peak flow rates indicates that uncontrolled future

Figure 4.1 Highland Creek (WSC02HC013)
Observed vs. Predicted Flows



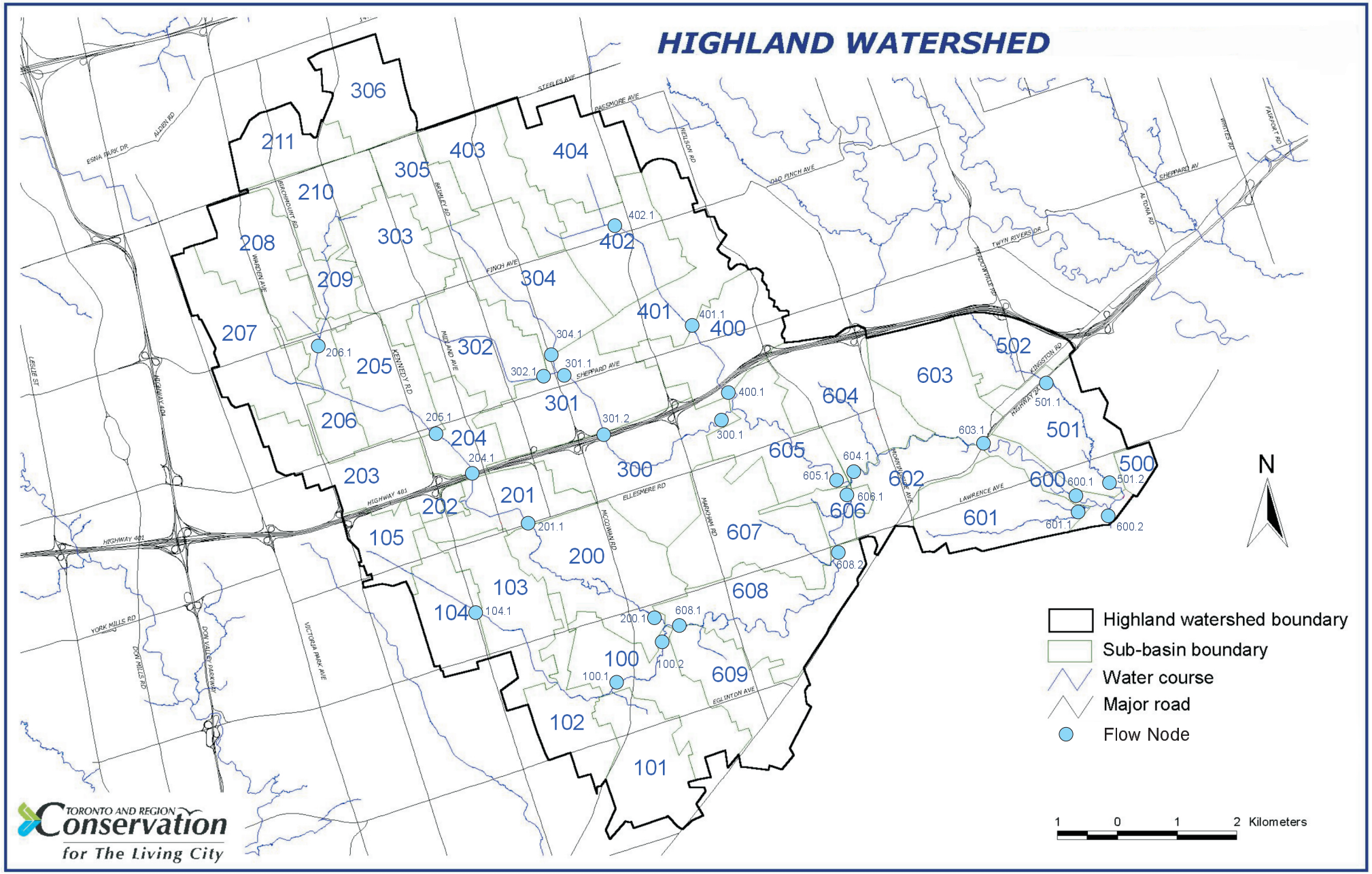


Figure 4.2 *Location of Peak Flow Estimates*

urban intensification within the Highland Creek watershed would result in the following increases:

Dorset Park Interceptor:

- increases of approximately 9% to 14% for the 2-year to 100-year storms; and
- increase of approximately 1% to 2% for the Regional Storm.

Bendale Branch:

- increases of approximately 2% to 6% for the 2-year to 100-year storms; and
- increase of less than 1% for the Regional Storm.

West Branch (d/s Bendale Branch and Dorset Park Interceptor):

- increases of approximately 5% to 9% for the 2-year to 100-year storms; and
- increase of less than 1% for the Regional Storm.

Markham Branch:

- increases of approximately 4% to 23% for the 2-year to 100-year storms; and
- increase of less than 1% to approximately 2% for the Regional Storm.

Malvern Branch:

- decreases of approximately 2% to increases of approximately 26% for the 2-year to 100-year storms; and
- increase of approximately 2% to 3% for the Regional Storm.

West Hill Creek:

- increases of approximately 6% to 10% for the 2-year to 100-year storms; and
- an increase of less than 1% for the Regional Storm.

Centennial Creek:

- an increase of approximately 0% to 1% for the 2-year to 100-year storms; and
- virtually no change for the Regional Storm.

Highland Creek Main Branch (d/s of West Branch and Malvern Branch):

- increases of approximately 4% to 11% for the 2-year to 100-year storms; and
- an increase of less than 1% for the Regional Storm.

As expected, the largest predicted increases in flow rates tend to occur within the tributary reaches where the future landuse intensification (Figure A.3, Appendix A) is concentrated.

5.0 FLOOD MANAGEMENT STRATEGY

The Toronto Wet Weather Flow Management Master Plan Study (TWWFMMPS) (Aquafor, 2003) evaluated a set of alternative stormwater strategies for the Highland Creek and Rouge River watersheds. Within each strategy, a suite of stormwater "best management practices" (BMPs) was proposed. The preferred strategy which was selected in the TWWFMMPS for application in the Highland and Rouge watersheds included "enhanced" levels of source controls and conveyance controls. The following BMPs were included as part of the TWWFMMPS Strategy:

- roof gardens to promote additional interception of rainfall and evapotranspiration;
- routing parking lot runoff to grassed areas and biofilters to promote infiltration;
- use of pervious pavement in parking lots to promote infiltration;
- planting additional trees and shrubs to promote additional interception of rainfall and evapotranspiration; and
- use of exfiltration systems within storm sewers to promote infiltration of road runoff.

The above BMPs and the values applied in the TWWFMMPS are summarized in Table 5.1. As shown, the potential benefits of applying the above BMPs to future development (intensification) areas are the removal of approximately 4.8mm of rainfall volume over the impervious surfaces, and approximately 1.2mm of rainfall volume over the pervious surfaces.

Based on the above, three future control strategies were modeled for the Highland Creek watershed:

Control Strategy 1 - source controls and conveyance controls as per TWWFMMPS;

Control Strategy 2 - source controls and conveyance controls as per TWWFMMPS *and* on-site attenuation controls such as roof top restrictors and catchbasin restrictors to control back to existing peak flows within each subcatchment; and

Control Strategy 3 - as per Strategy No.2, with the removal of attenuation controls within select Bendale Branch subcatchments.

The resulting peak flow rates associated with the above control strategies are summarized in Table D.1 (Appendix D), with comparison of increases/decreases of flows in Table D.2. The above control strategies were assumed to be ineffective in controlling Regional Strom flows.

Table 5.1
Summary of Potential Source & Conveyance Controls

Proposed BMP	Surface to be used for BMP	% of surface area within the landuse*	% of available surface to be utilized*	% of voluntary participation/uptake*	potential control volume (mm) *		Resulting Adjustment Applied in Model (mm)
High Rise Residential							
Impervious Components:							
roof top gardens	roof	9%	0%	0%	150		0.00
route parking lot to grass/biofilter	parking lot	27%	5%	55%	60	(ie. 10mm/hr over 6 hr)	0.45
pervious pavement for parking lots	parking lot	27%	60%	15%	60	(ie. 10mm/hr over 6 hr)	1.46
exfiltrate road runoff	roadways	9%	100%	100%	15		1.35
						TOTAL =	**3.25**
Pervious Component:							
additional trees	lawns	50%	100%	75%	8.75	(ie. 5mm base +75%)	3.28
						TOTAL =	**3.28**
Commercial / Strip Malls							
Impervious Components:							
roof top gardens	roof	17%	25%	10%	150		0.64
route parking lot to grass/biofilter	parking lot	62%	5%	50%	60	(ie. 10mm/hr over 6 hr)	0.93
pervious pavement for parking lots	parking lot	62%	60%	10%	60	(ie. 10mm/hr over 6 hr)	2.23
exfiltrate road runoff	roadways	19%	100%	100%	15		2.85
						TOTAL =	**6.65**
Pervious Component:							
additional trees	lawns	2%	0%	0%	8.75	(ie. 5mm base +75%)	0.00
						TOTAL =	**0.00**
Industrial							
Impervious Components:							
roof top gardens	roof	45%	25%	10%	150		1.69
route parking lot to grass/biofilter	parking lot	42%	5%	25%	60	(ie. 10mm/hr over 6 hr)	0.32
pervious pavement for parking lots	parking lot	42%	60%	10%	60	(ie. 10mm/hr over 6 hr)	1.51
exfiltrate road runoff	roadways	6%	100%	100%	15		0.90
						TOTAL =	**4.41**
Pervious Component:							
additional trees	lawns	7%	100%	70%	6.25	(ie. 5mm base +25%)	0.31
						TOTAL =	**0.31**

Average Volume Adjustments Applied in Hydrologic Model:

Impervious Components, expressed as increased depression storage (DSI): 4.8 mm

Pervious Components, expressed as increase initial abstraction (IA): 1.2 mm

* Values from Toronto Wet Weather Flow Management Master Plan Study (Aquafor, 2003)

5.1 Model Results - Control Strategy No.1

With respect to Control Strategy No.1 , the model results indicate that peak flows will be reduced below uncontrolled rates, but will still exceed existing *instream* peak flow rates. Depending upon the location within the watershed, with this strategy, peak flow increases may be up to 6% less than the increases anticipated under the future uncontrolled scenario for the 2-year event, and up to2% less than the increases anticipated under the future uncontrolled scenario for the 100-year storm.

5.2 Model Results - Control Strategy No.2

For Control Strategy No.2, reservoir routing elements were added to the hydrologic model to simulate attenuation from rooftop and parking lot storage or any other "end-of-pipe" controls within the future re-developed/intensified areas. On average, approximately 60 m^3/ha and 150 m^3/ha of storage were required to control the 2-year and 100-year peak flows, respectively, back to the existing rates within those catchments expected to experience intensified future development. Model results for Control Strategy No.2 indicate that *instream* 2-year through 100-year peak flows will be reduced to existing rates or less in many locations. At most other locations, peak flows are reduced below uncontrolled rates, but will still slightly exceed existing in-stream peak flow rates. However, at some locations on the Bendale Branch, Strategy No.2 actually results in higher in-stream peak flows than Strategy No.1 due to altered hydrograph timing.

5.3 Model Results - Control Strategy No.3

Control Strategy No.3 is identical to Strategy No.2 with the exception of the Bendale Branch. For Strategy No.3, attenuation controls were removed from subcatchments 200 to 204 of the Bendale Branch to avoid the hydrograph timing problems discussed above. Model results for Control Strategy No.3 indicate that 2-year through 100-year peak flows will be reduced to existing rates or less in many locations. At all other locations, peak flows are reduced below uncontrolled rates, but will still exceed existing in-stream peak flow rates. For this strategy, the maximum predicted increases in instream peak flow rates are relatively small, at approximately 8% or less.

6.0 CONCLUSIONS AND RECOMMENDATIONS

Aquafor Beech Limited was retained by the Toronto and Region Conservation Authority (TRCA) to create an updated hydrologic model for the Highland Creek watershed and to develop a flood management strategy to minimize the impact of future urban development. Conclusions and recommendations are summarized in the following sections.

6.1 Conclusions

1. A hydrologic model was created for Highland Creek using the Visual Otthymo model, version 2.0. For consistency, the subcatchment discretization and numbering was setup to match those used to model Highland Creek in the recent Toronto Wet Weather Flow Management Master Plan (TWWFMMP) study.

2. The model was calibrated and verified using a series of rainfall events which occurred in 1995, 1996, 1999, and 2000.

3. Design flows for the 2-year to 100-year return periods and the Regional Storm were estimated for two landuse scenarios:
   - existing landuses; and
   - a future landuse scenario which includes significant intensification of existing urban development areas through"infill" developments, etc.

4. Based on the uncontrolled future landuse scenario, increases in peak flows are anticipated, particularly within the tributary reaches where the future landuse intensification is concentrated. Peak flow rates for the 2-year to 100-year storms could increase by up to 26%, while Regional Storm peak flow rates could increase by up to 3%.

5. Three future control strategies were derived from the recommendations of the TWWFMMPS to assess their potential to mitigate future peak flow increases in the Highland Creek watershed:
   - Control Strategy 1 - source controls and conveyance controls as per the

TWWFMMPS;

- Control Strategy 2 - source controls and conveyance controls as per the TWWFMMPS *and* on-site attenuation controls such as roof top restrictors and catchbasin restrictors to control back to existing peak flows within each subcatchment; and
- Control Strategy 3 - as per Strategy No.2, with the removal of attenuation controls within select Bendale Branch subcatchments (200 to 204).

The control strategies were assumed to be ineffective in controlling Regional Strom flows.

6. Model results for Control Strategy No.1 indicate that peak flows will be reduced below uncontrolled rates, but will still exceed existing *instream* peak flow rates.

7. For Control Strategy No.2, approximately 60 m^3/ha and 150 m^3/ha of storage were required, on average, to control the 2-year and 100-year peak flows, respectively, back to the existing rates within those catchments expected to experience intensified future development. Model results for Control Strategy No.2 indicate that *instream* 2-year through 100-year peak flows will be reduced to existing rates or less in many locations. At most other locations, peak flows are reduced below uncontrolled rates, but will still slightly exceed existing in-stream peak flow rates. However, at some locations on the Bendale Branch, Strategy No.2 actually results in higher in-stream peak flows than Strategy No.1 due to altered hydrograph timing.

8. For Control Strategy No.3, attenuation controls were removed from the Bendale Branch (subcatchments 200 to 204) to avoid the hydrograph timing problems encountered in Strategy No.2. Model results for Strategy No.3 indicate that 2-year through 100-year peak flows will be reduced to existing rates or less in many locations. At all other locations, peak flows are reduced below uncontrolled rates, but will still exceed existing in-stream peak flow rates. However, any such increases are relatively small, at approximately 8% or less.

6.2 Recommendations

Based on a comparison of model results for existing and future landuse scenarios, stormwater controls will be required for future "intensified" development areas to prevent significant increases in peak flow rates. The Toronto Wet Weather Flow Management Master Plan (TWWFMMP) study recommended a suite of stormwater "best management practices" (BMPs) be applied. Based on these proposed BMPs, three future control strategies were assessed for the Highland Creek watershed, with Control Strategy No.3 producing the best all-around results of the three. The recommended strategy includes the following BMP controls from the TWWFMMPS for future intensified developments:

- roof gardens to promote additional interception of rainfall and evapotranspiration (150mm);
- routing parking lot runoff to grassed areas and biofilters to promote infiltration (10mm/hr);
- use of pervious pavement in parking lots to promote infiltration (10mm/hr);
- planting additional trees and shrubs to promote additional interception of rainfall and evapotranspiration (increase by 25%-75%); and
- use of exfiltration systems within storm sewers to promote infiltration of road runoff (15mm).
- "end-of-pipe" attenuation controls, including roof top restrictors and catchbasin restrictors, within all subcatchments except #200 to #204 (Bendale Branch) to control on-site flows back to existing levels. Approximately 60 m^3/ha and 150 m^3/ha of storage is required, on average, for the 2-year and 100-year storms, respectively.

Given that some minor increases in peak flow rates may still occur at various locations, even with the above controls, it is recommended that further investigation be undertaken in order to:

- assess the potential changes in flood levels which may occur at these locations; and
- confirm that no existing flood-susceptible sites will be negatively impacted.

A hydraulic (Hec-Ras) model for Highland Creek should be used to assess the effects of any flow increases on flood levels.

Should the minor flow increases not result in any significant increased water levels, then Control Strategy No.3, as outlined above, is recommended. However, should any of the potential minor peak

flow increases result in increased flood risk, further hydrologic modelling will be required to assess further control requirements. This would likely require increased storage volumes in attenuation BMPs to effectively "over-control" runoff from individual catchments so that instream flows are reduced to existing levels, and/or increased source and conveyance control targets.

Respectfully submitted,

AQUAFOR BEECH LIMITED

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Greg R. Frew, P.Eng.

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APPENDIX A:
Hydrologic Model Parameters, Soils and Landuse Mapping

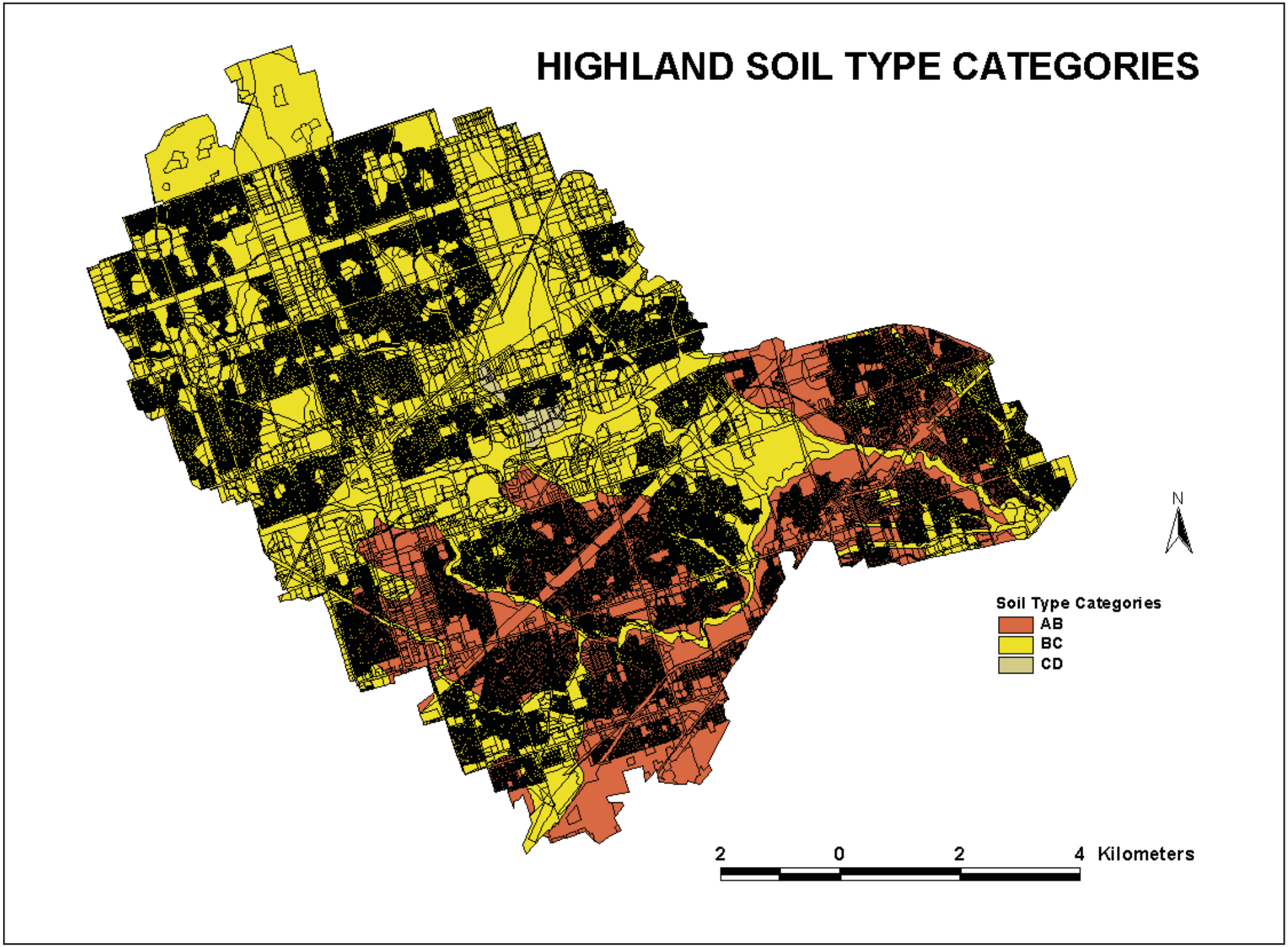


Figure A.1 *Soils Mapping*

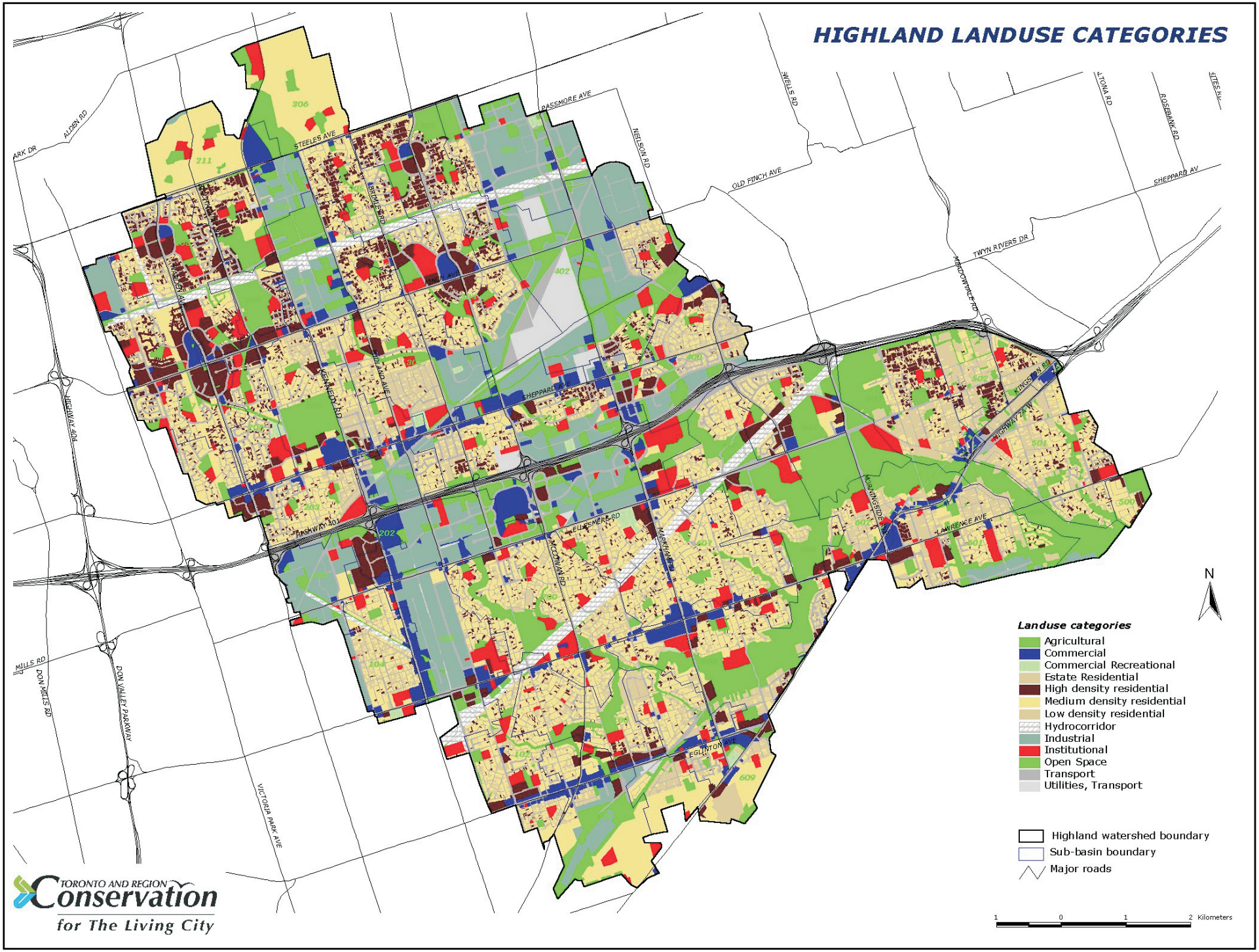
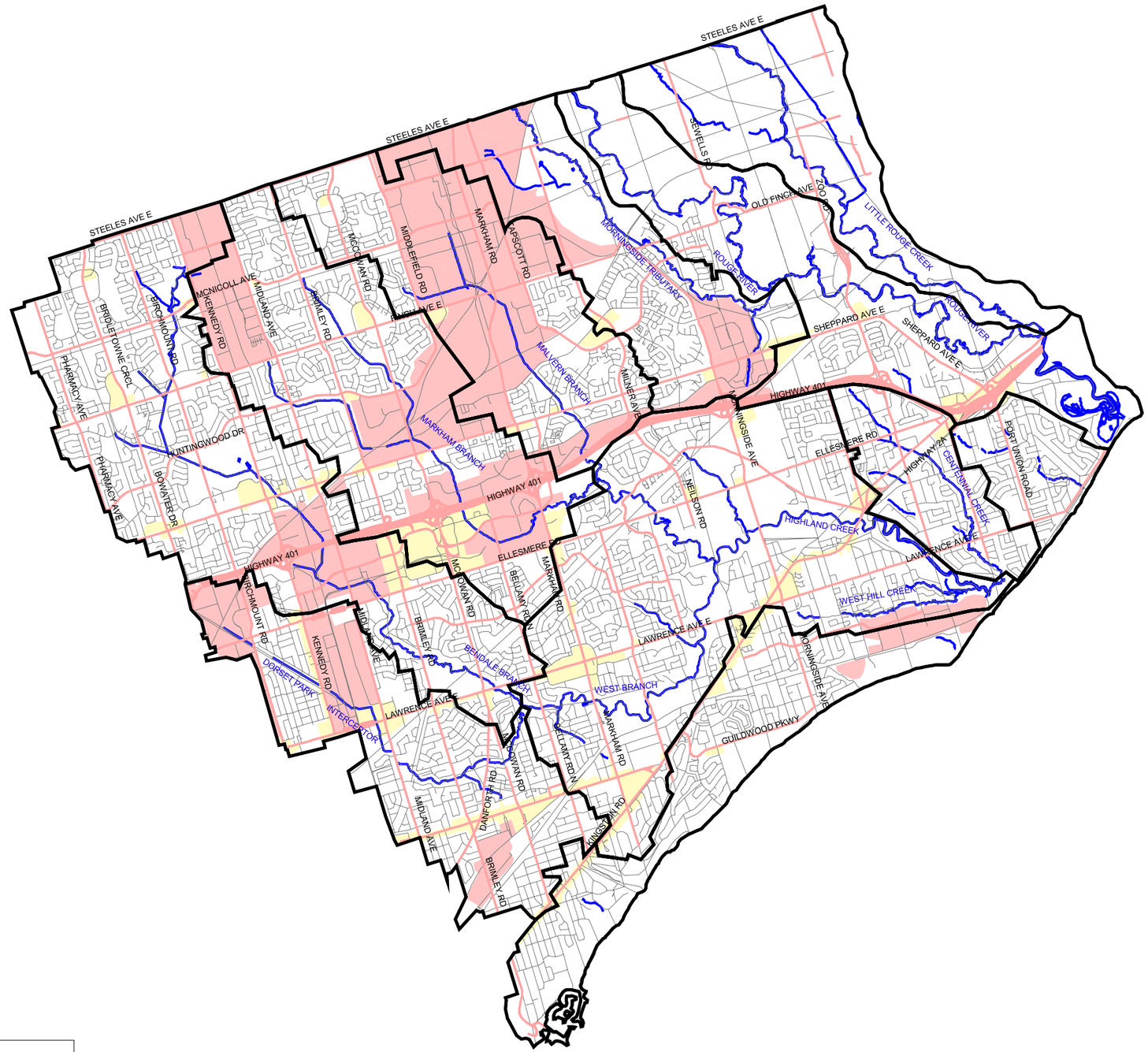


Figure A.2 *Existing Landuses*



SOURCE:
Toronto Wet Weather Flow Management
Master Plan Study (Aquafor Beech Limited, 2003)

N
W E
S

Key Plan

Legend

Tributary Boundary

Areas of Intensification

Mixed Use Areas

Employment Areas

NOTES.....

0.5 0 0.5 1 1.5 2 Kilometers

Aquafor Beech Limited

Highland Creek Hydrology Update

Areas of Future Intensification

Figure A.3

Table A.1

EXISTING LANDUSE SCENARIO

URBAN COMPONENT PARAMETERS

CATCHMENT ID	TOTAL AREA (hectares)	CATCHEMNT SLOPE (mean)	STREAM SLOPE (%)	MAX STREAM LENGTH (metres)	UNADJUSTED CN*_URBAN (from GIS)	DESIGN CN*_URBAN AMC II	DESIGN CN*_URBAN AMC III	IA_perv (mm)	DPI (IA_imp) (mm)	% IMPERVIOUS (%)	IMPERIVOUS LENGTH (m)	PERVIOUS LENGTH (m)	IMPERIVOUS n	PERVIOUS n
100	305.27	5.12	0.55	2310	61	61	78	5.0	2.0	47.7%	1427	40	0.013	0.250
101	274.20	3.00	0.68	2780	65	65	82	5.0	2.0	49.4%	1352	40	0.013	0.250
102	203.50	3.61	0.53	990	68	68	84	5.0	2.0	49.9%	1165	40	0.013	0.250
103	274.79	3.71	0.60	2090	62	62	79	5.0	2.0	63.7%	1354	40	0.013	0.250
104	194.23	3.13	0.49	1250	67	67	84	5.0	2.0	54.6%	1138	40	0.013	0.250
105	130.21	3.56	0.77	1030	73	73	88	5.0	2.0	68.3%	932	40	0.013	0.250
200	417.39	6.42	0.42	3790	62	62	79	5.0	2.0	44.1%	1668	40	0.013	0.250
201	195.99	5.79	0.46	1800	69	69	84	5.0	2.0	66.5%	1143	40	0.013	0.250
202	16.78	3.41	0.38	440	72	72	86	5.0	2.0	93.8%	335	40	0.013	0.250
203	284.36	3.32	0.67	1880	73	73	87	5.0	2.0	53.2%	1377	40	0.013	0.250
204	154.74	4.02	0.52	1040	73	73	87	5.0	2.0	59.2%	1016	40	0.013	0.250
205	251.87	3.47	0.35	1640	72	72	86	5.0	2.0	46.9%	1296	40	0.013	0.250
206	151.79	2.68	0.51	1720	73	73	87	5.0	2.0	53.4%	1006	40	0.013	0.250
207	332.28	2.10	0.51	2290	74	74	88	5.0	2.0	56.4%	1735	40	0.013	0.250
208	273.36	2.02	0.46	2360	73	73	87	5.0	2.0	50.9%	1350	40	0.013	0.250
209	85.82	3.22	0.21	1080	70	70	85	5.0	2.0	33.8%	756	40	0.013	0.250
210	198.36	2.51	1.26	1720	73	73	87	5.0	2.0	54.0%	1150	40	0.013	0.250
211	170.84	2.60	0.85	1270	73	73	87	5.0	2.0	49.9%	1067	40	0.013	0.250
300	429.52	6.45	0.70	3220	62	62	79	5.0	2.0	56.3%	1692	40	0.013	0.250
301	369.48	4.34	1.12	1710	74	74	88	5.0	2.0	61.2%	1570	40	0.013	0.250
302	308.50	3.45	0.69	3150	73	73	87	5.0	2.0	51.9%	1434	40	0.013	0.250
303	280.20	2.47	0.87	1860	73	73	87	5.0	2.0	49.5%	1367	40	0.013	0.250
304	367.59	3.05	0.76	2970	73	73	87	5.0	2.0	55.3%	1565	40	0.013	0.250
305	151.87	1.96	0.81	1770	73	73	87	5.0	2.0	50.2%	1006	40	0.013	0.250
306	217.53	2.41	0.98	1810	72	72	86	5.0	2.0	40.2%	1204	40	0.013	0.250
400	289.75	5.03	0.78	1450	73	73	87	5.0	2.0	53.2%	1390	40	0.013	0.250
401	298.37	3.64	0.95	900	73	73	86	5.0	2.0	55.3%	1410	40	0.013	0.250
402	293.65	3.05	0.56	2170	73	73	88	5.0	2.0	61.8%	1399	40	0.013	0.250
403	243.43	2.88	0.85	3120	72	72	86	5.0	2.0	49.8%	1274	40	0.013	0.250
404	285.65	2.82	0.51	1610	72	72	86	5.0	2.0	60.1%	1380	40	0.013	0.250
500	39.95	2.74	1.11	900	72	72	86	5.0	2.0	42.1%	516	40	0.013	0.250
501	306.25	5.04	0.97	3000	65	65	85	5.0	2.0	44.9%	1429	40	0.013	0.250
502	172.77	3.26	0.95	1750	61	61	78	5.0	2.0	45.2%	1073	40	0.013	0.250
600	97.65	10.72	0.27	3480	60	60	78	5.0	2.0	17.6%	807	40	0.013	0.250
601	297.76	4.86	1.28	3590	63	63	80	5.0	2.0	43.9%	1409	40	0.013	0.250
602	201.44	7.53	0.52	3090	56	56	74	5.0	2.0	41.0%	1512	40	0.013	0.250
603	280.82	3.76	0.44	830	58	58	76	5.0	2.0	39.5%	1368	40	0.013	0.250
604	351.99	8.18	2.45	2480	49	49	68	5.0	2.0	33.8%	1532	40	0.013	0.250
605	266.95	10.32	0.63	3410	70	70	85	5.0	2.0	35.1%	1334	40	0.013	0.250
606	75.33	12.93	0.43	1280	63	63	80	5.0	2.0	28.4%	709	40	0.013	0.250
607	377.11	3.91	1.37	3640	65	65	82	5.0	2.0	51.7%	1586	40	0.013	0.250
608	373.88	9.58	0.44	5390	57	57	75	5.0	2.0	38.5%	1579	40	0.013	0.250
609	281.25	4.35	0.58	2480	59	59	77	5.0	2.0	50.5%	1369	40	0.013	0.250
TOTALS =	10574.47													

Table A.2

FUTURE LANDUSE SCENARIO

URBAN COMPONENT PARAMETERS

CATCHMENT ID	TOTAL AREA (hectares)	CATCHEMNT SLOPE (mean)	STREAM SLOPE (%)	MAX STREAM LENGTH (metres)	UNADJUSTED CN*_URBAN (from GIS)	DESIGN CN*_URBAN AMC II	DESIGN CN*_URBAN AMC III	IA_perv (mm)	DPI (IA_imp) (mm)	% IMPERVIOUS (%)	IMPERIVOUS LENGTH (m)	PERVIOUS LENGTH (m)	IMPERIVOUS n	PERVIOUS n
100	287.2	5.12	0.55	2310	61	61	78	5.0	2.0	46.0%	1384	40	0.013	0.250
100.1	18.18	5.12	0.55	2310	59	59	77	5.0	2.0	90.0%	348	40	0.013	0.250
101	185.26	3.00	0.68	2780	65	65	82	5.0	2.0	43.8%	1111	40	0.013	0.250
101.1	88.92	3.00	0.68	2780	70	70	85	5.0	2.0	90.0%	770	40	0.013	0.250
102	185.31	3.61	0.53	990	68	68	84	5.0	2.0	46.9%	1111	40	0.013	0.250
102.1	18.07	3.61	0.53	990	69	69	84	5.0	2.0	90.0%	347	40	0.013	0.250
103	115.05	3.71	0.60	2090	62	62	79	5.0	2.0	44.5%	876	40	0.013	0.250
103.1	159.8	3.71	0.60	2090	62	62	79	5.0	2.0	90.0%	1032	40	0.013	0.250
104	150.9	3.13	0.49	1250	68	68	84	5.0	2.0	47.9%	1003	40	0.013	0.250
104.1	43.37	3.13	0.49	1250	66	66	82	5.0	2.0	90.0%	538	40	0.013	0.250
105	20.5	3.56	0.77	1030	74	74	88	5.0	2.0	55.9%	370	40	0.013	0.250
105.1	109.71	3.56	0.77	1030	73	73	87	5.0	2.0	90.0%	855	40	0.013	0.250
200	409.83	6.42	0.42	3790	62	62	79	5.0	2.0	43.5%	1653	40	0.013	0.250
200.1	7.6	6.42	0.42	3790	59	59	77	5.0	2.0	90.0%	225	40	0.013	0.250
201	34.94	5.79	0.46	1800	68	68	84	5.0	2.0	59.9%	483	40	0.013	0.250
201.1	161.1	5.79	0.46	1800	70	70	85	5.0	2.0	90.0%	1036	40	0.013	0.250
202	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
202.1	16.78	3.41	0.38	440	72	72	86	5.0	2.0	90.0%	334	40	0.013	0.250
203	244.09	3.32	0.67	1880	73	73	87	5.0	2.0	51.9%	1276	40	0.013	0.250
203.1	40.2	3.32	0.67	1880	73	73	87	5.0	2.0	90.0%	518	40	0.013	0.250
204	80.55	4.02	0.52	1040	73	73	87	5.0	2.0	46.5%	733	40	0.013	0.250
204.1	74.4	4.02	0.52	1040	73	73	87	5.0	2.0	90.0%	704	40	0.013	0.250
205	229.05	3.47	0.35	1640	72	72	86	5.0	2.0	42.8%	1236	40	0.013	0.250
205.1	22.9	3.47	0.35	1640	74	74	88	5.0	2.0	90.0%	391	40	0.013	0.250
206	143.78	2.68	0.51	1720	73	73	87	5.0	2.0	51.8%	979	40	0.013	0.250
206.1	8	2.68	0.51	1720	74	74	88	5.0	2.0	90.0%	231	40	0.013	0.250
207	321.11	2.10	0.51	2290	74	74	88	5.0	2.0	55.3%	1463	40	0.013	0.250
207.1	11	2.10	0.51	2290	74	74	88	5.0	2.0	90.0%	271	40	0.013	0.250
208	268.6	2.02	0.46	2360	73	73	87	5.0	2.0	50.3%	1338	40	0.013	0.250
208.1	4.7	2.02	0.46	2360	74	74	88	5.0	2.0	90.0%	177	40	0.013	0.250
209	84.81	3.22	0.21	1080	70	70	85	5.0	2.0	33.4%	752	40	0.013	0.250
209.1	1	3.22	0.21	1080	74	74	88	5.0	2.0	90.0%	82	40	0.013	0.250
210	128.92	2.51	1.26	1720	73	73	87	5.0	2.0	47.8%	927	40	0.013	0.250
210.1	69.5	2.51	1.26	1720	73	73	87	5.0	2.0	90.0%	681	40	0.013	0.250
211	170.81	2.60	0.85	1270	73	73	87	5.0	2.0	49.9%	1067	40	0.013	0.250
211.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
300	168.58	6.45	0.70	3220	62	62	79	5.0	2.0	41.5%	1060	40	0.013	0.250
300.1	261.06	6.45	0.70	3220	70	70	85	5.0	2.0	90.0%	1319	40	0.013	0.250
301	172.46	4.34	1.12	1710	74	74	88	5.0	2.0	50.6%	1072	40	0.013	0.250
301.1	197	4.34	1.12	1710	75	75	88	5.0	2.0	90.0%	1146	40	0.013	0.250
302	247.48	3.45	0.69	3150	73	73	87	5.0	2.0	46.6%	1284	40	0.013	0.250
302.1	61	3.45	0.69	3150	73	73	87	5.0	2.0	90.0%	638	40	0.013	0.250
303	132.15	2.47	0.87	1860	73	73	87	5.0	2.0	52.6%	939	40	0.013	0.250
303.1	148.00	2.47	0.87	1860	72	72	86	5.0	2.0	90.0%	993	40	0.013	0.250

Table A.2 (Continued …)

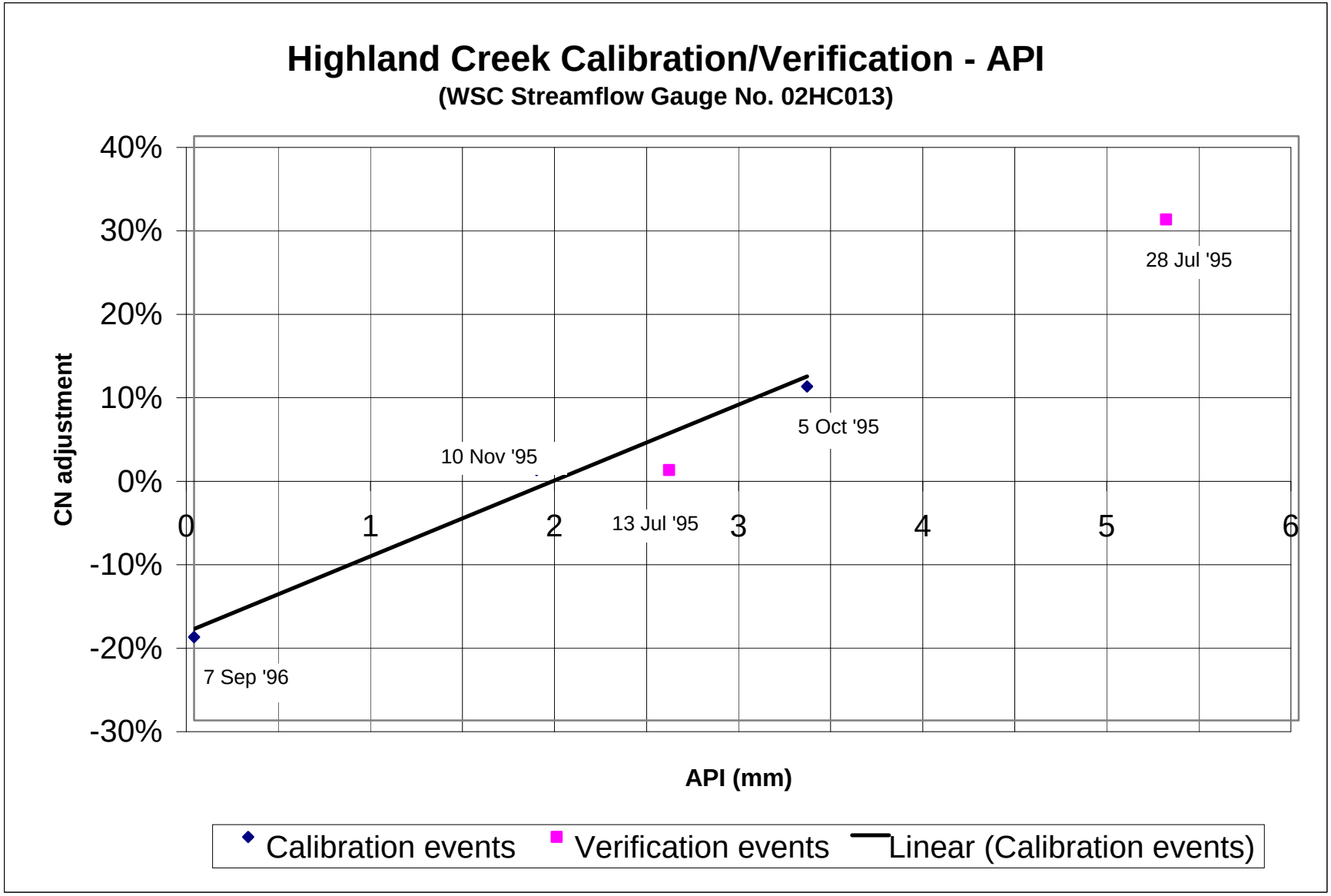
FUTURE LANDUSE SCENARIO

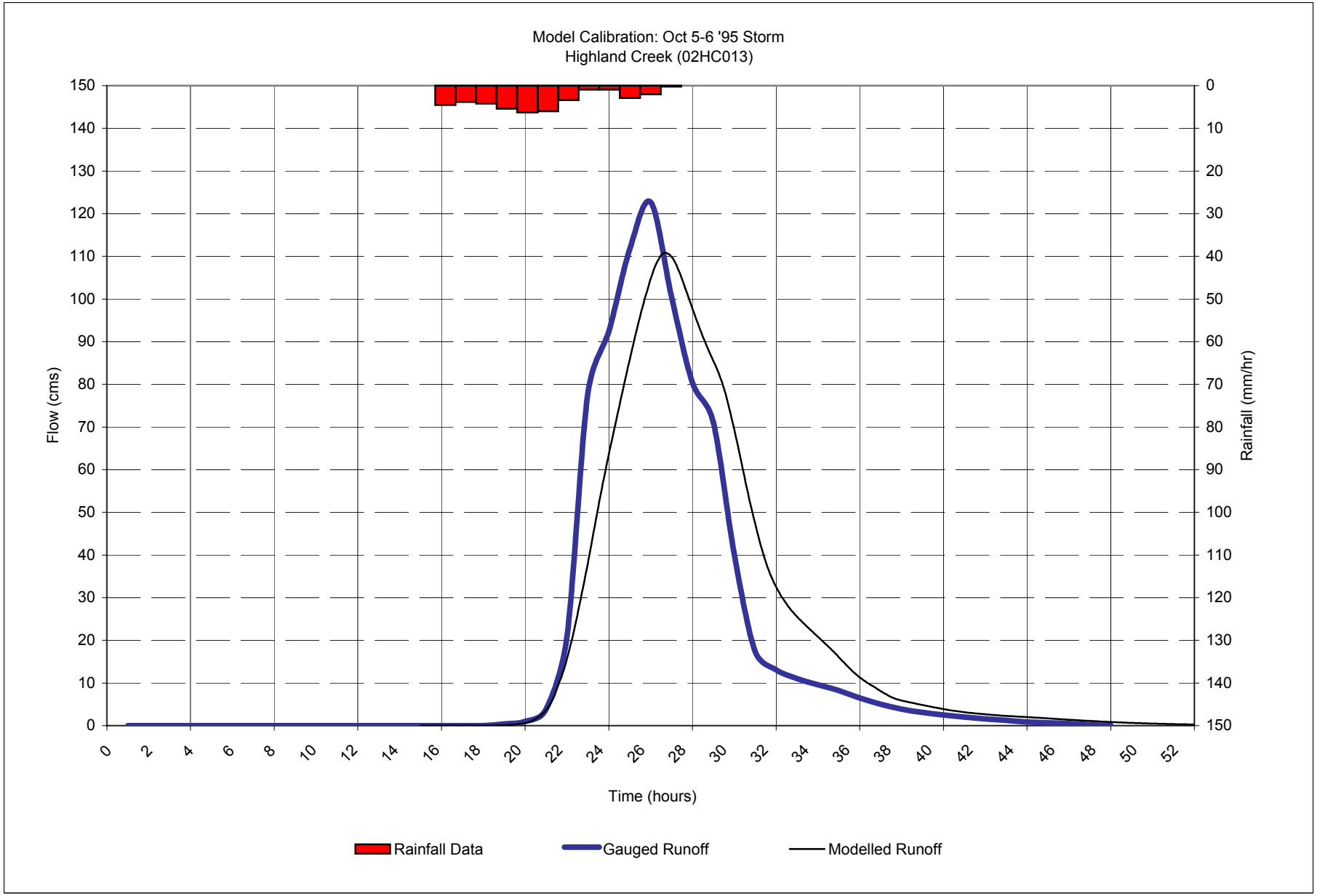
URBAN COMPONENT PARAMETERS

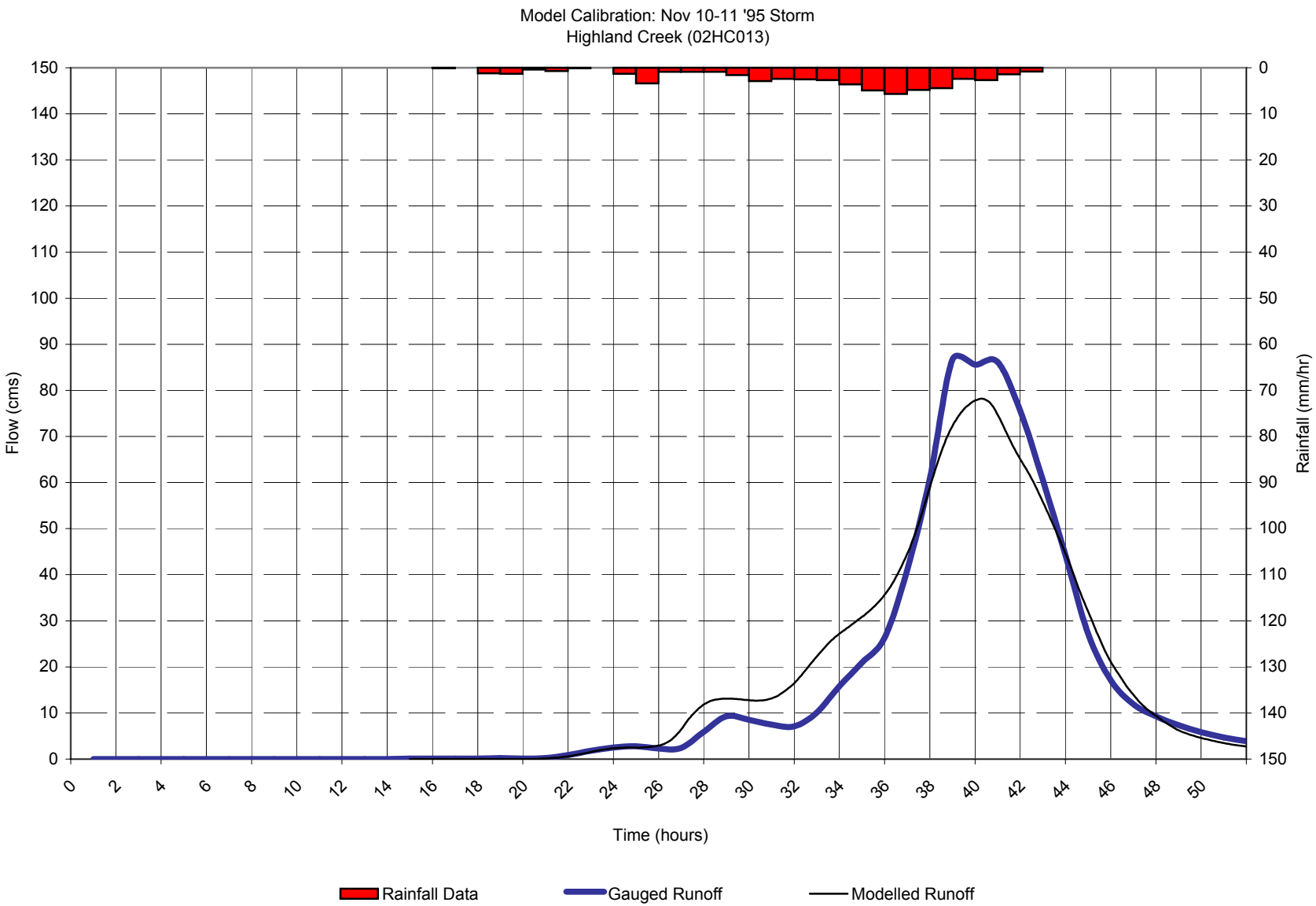
CATCHMENT ID	TOTAL AREA (hectares)	CATCHEMNT SLOPE (mean)	STREAM SLOPE (%)	MAX STREAM LENGTH (metres)	UNADJUSTED CN*_URBAN (from GIS)	DESIGN CN*_URBAN AMC II	DESIGN CN*_URBAN AMC III	IA_perv (mm)	DPI (IA_imp) (mm)	% IMPERVIOUS (%)	IMPERIVOUS LENGTH (m)	PERVIOUS LENGTH (m)	IMPERIVOUS n	PERVIOUS n
304	267.82	3.05	0.76	2970	73	73	87	5.0	2.0	50.2%	1336	40	0.013	0.250
304.1	99.70	3.05	0.76	2970	73	73	87	5.0	2.0	90.0%	815	40	0.013	0.250
305	151.86	1.96	0.81	1770	73	73	87	5.0	2.0	50.2%	1006	40	0.013	0.250
305.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
306	217.54	2.41	0.98	1810	72	72	86	5.0	2.0	40.2%	1204	40	0.013	0.250
306.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
400	214.73	5.03	0.78	1450	73	73	87	5.0	2.0	48.8%	1196	40	0.013	0.250
400.1	75.00	5.03	0.78	1450	73	73	87	5.0	2.0	90.0%	707	40	0.013	0.250
401	148.17	3.64	0.95	900	72	72	86	5.0	2.0	42.2%	994	40	0.013	0.250
401.1	150.30	3.64	0.95	900	73	73	87	5.0	2.0	90.0%	1001	40	0.013	0.250
402	8.20	3.05	0.56	2170	74	74	88	5.0	2.0	48.7%	234	40	0.013	0.250
402.1	285.40	3.05	0.56	2170	73	73	87	5.0	2.0	90.0%	1379	40	0.013	0.250
403	230.37	2.88	0.85	3120	72	72	86	5.0	2.0	48.5%	1239	40	0.013	0.250
403.1	13.00	2.88	0.85	3120	74	74	88	5.0	2.0	90.0%	294	40	0.013	0.250
404	36.92	2.82	0.51	1610	71	71	86	5.0	2.0	39.0%	496	40	0.013	0.250
404.1	248.80	2.82	0.51	1610	73	73	87	5.0	2.0	90.0%	1288	40	0.013	0.250
500	39.95	2.74	1.11	900	72	72	86	5.0	2.0	42.1%	516	40	0.013	0.250
500.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
501	303.55	5.04	0.97	3000	65	65	85	5.0	2.0	44.6%	1423	40	0.013	0.250
501.1	2.90	5.04	0.97	3000	64	64	81	5.0	2.0	90.0%	139	40	0.013	0.250
502	167.51	3.26	0.95	1750	61	61	78	5.0	2.0	44.2%	1057	40	0.013	0.250
502.1	5.10	3.26	0.95	1750	73	73	87	5.0	2.0	90.0%	184	40	0.013	0.250
600	85.41	10.72	0.27	3480	60	60	78	5.0	2.0	13.8%	755	40	0.013	0.250
600.1	12.20	10.72	0.27	3480	62	62	79	5.0	2.0	90.0%	285	40	0.013	0.250
601	256.63	4.86	1.28	3590	63	63	80	5.0	2.0	40.6%	1308	40	0.013	0.250
601.1	41.10	4.86	1.28	3590	65	65	82	5.0	2.0	90.0%	523	40	0.013	0.250
602	162.48	7.53	0.52	3090	55	55	74	5.0	2.0	31.6%	1041	40	0.013	0.250
602.1	38.80	7.53	0.52	3090	59	59	77	5.0	2.0	90.0%	509	40	0.013	0.250
603	258.36	3.76	0.44	830	58	58	76	5.0	2.0	38.3%	1312	40	0.013	0.250
603.1	22.56	3.76	0.44	830	55	55	74	5.0	2.0	90.0%	388	40	0.013	0.250
604	323.23	8.18	2.45	2480	48	48	68	5.0	2.0	30.5%	1468	40	0.013	0.250
604.1	28.70	8.18	2.45	2480	66	66	82	5.0	2.0	90.0%	437	40	0.013	0.250
605	266.92	10.32	0.63	3410	70	70	85	5.0	2.0	35.1%	1334	40	0.013	0.250
605.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
606	75.28	12.93	0.43	1280	63	63	80	5.0	2.0	28.4%	708	40	0.013	0.250
606.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
607	354.52	3.91	1.37	3640	65	65	82	5.0	2.0	49.8%	1537	40	0.013	0.250
607.1	22.52	3.91	1.37	3640	62	62	79	5.0	2.0	90.0%	387	40	0.013	0.250
608	338.98	9.58	0.44	5390	57	57	75	5.0	2.0	33.9%	1503	40	0.013	0.250
608.1	35.00	9.58	0.44	5390	59	59	77	5.0	2.0	90.0%	483	40	0.013	0.250
609	231.26	4.35	0.58	2480	59	59	77	5.0	2.0	46.1%	1242	40	0.013	0.250
609.1	49.9	4.35	0.58	2480	58	58	76	5.0	2.0	90.0%	577	40	0.013	0.250

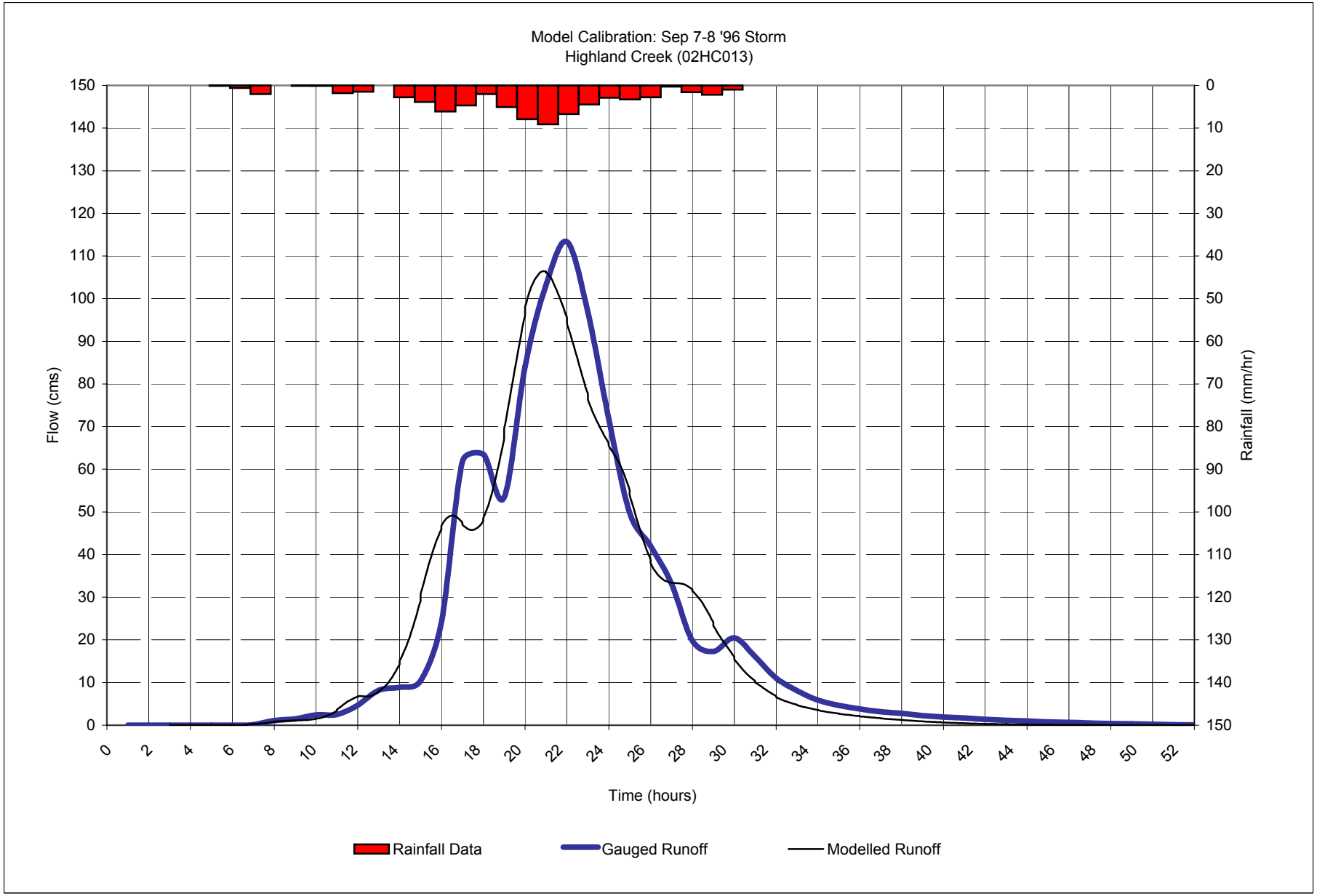
TOTALS = 10574.34

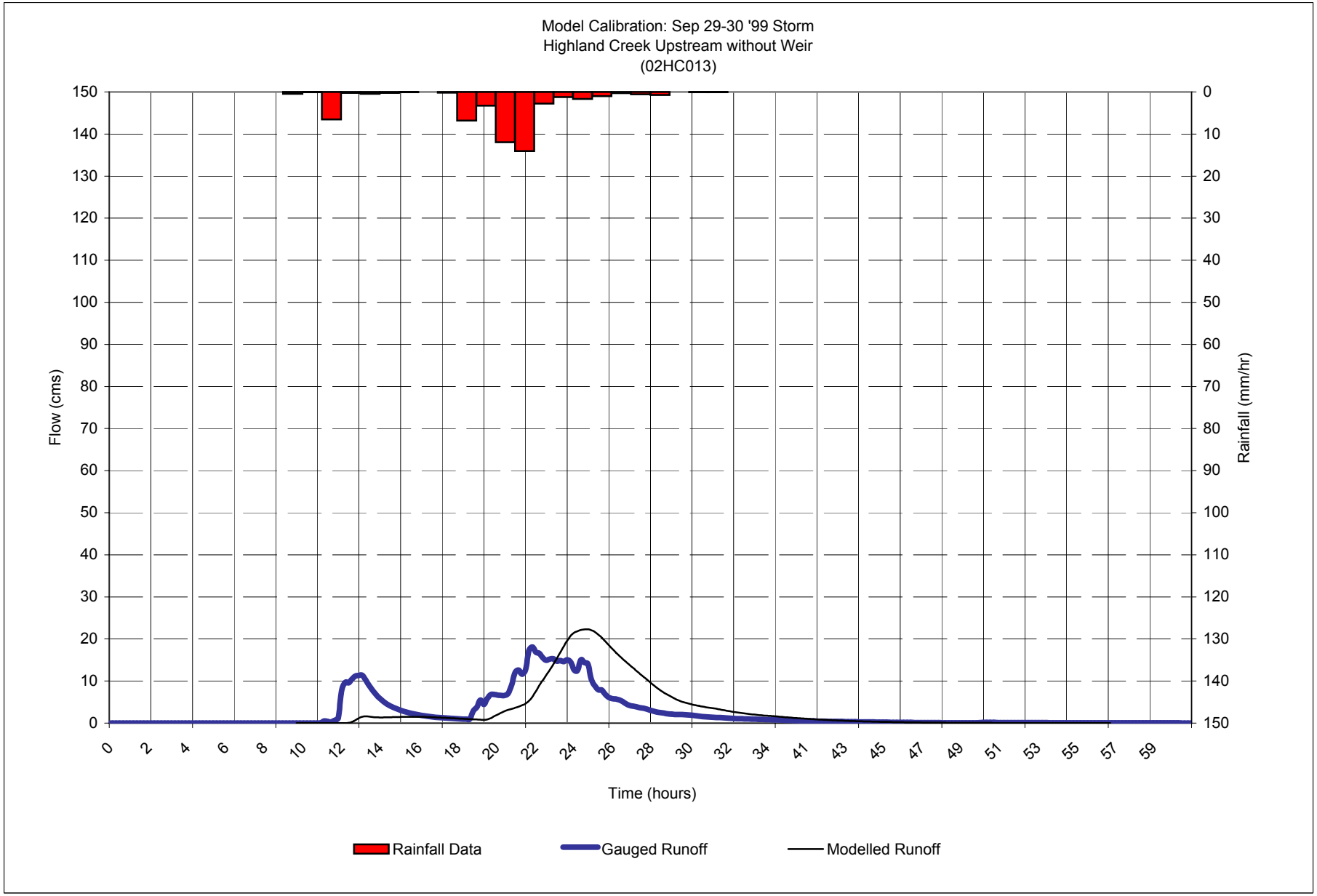
APPENDIX B:
Hydrologic Model Calibration Results

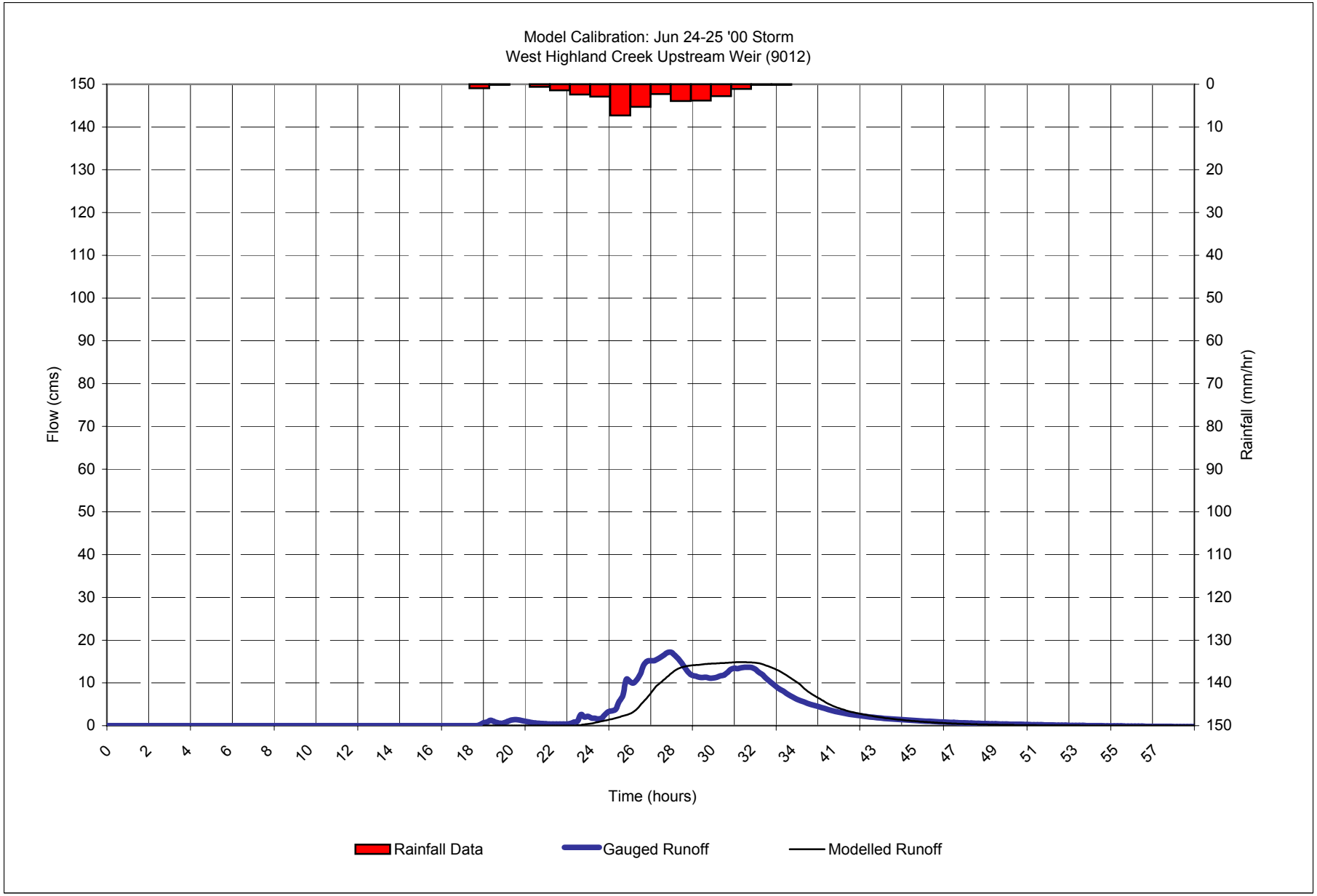

Highland Creek Calibration/Verification - API
(WSC Streamflow Gauge No. 02HC013)
40%
30%
20%
10%
0%
-10%
-20%
-30%
CN adjustment
0
1
2
3
4
5
6
API (mm)
28 Jul '95
5 Oct '95
10 Nov '95
13 Jul '95
7 Sep '96
Calibration events
Verification events
Linear (Calibration events)

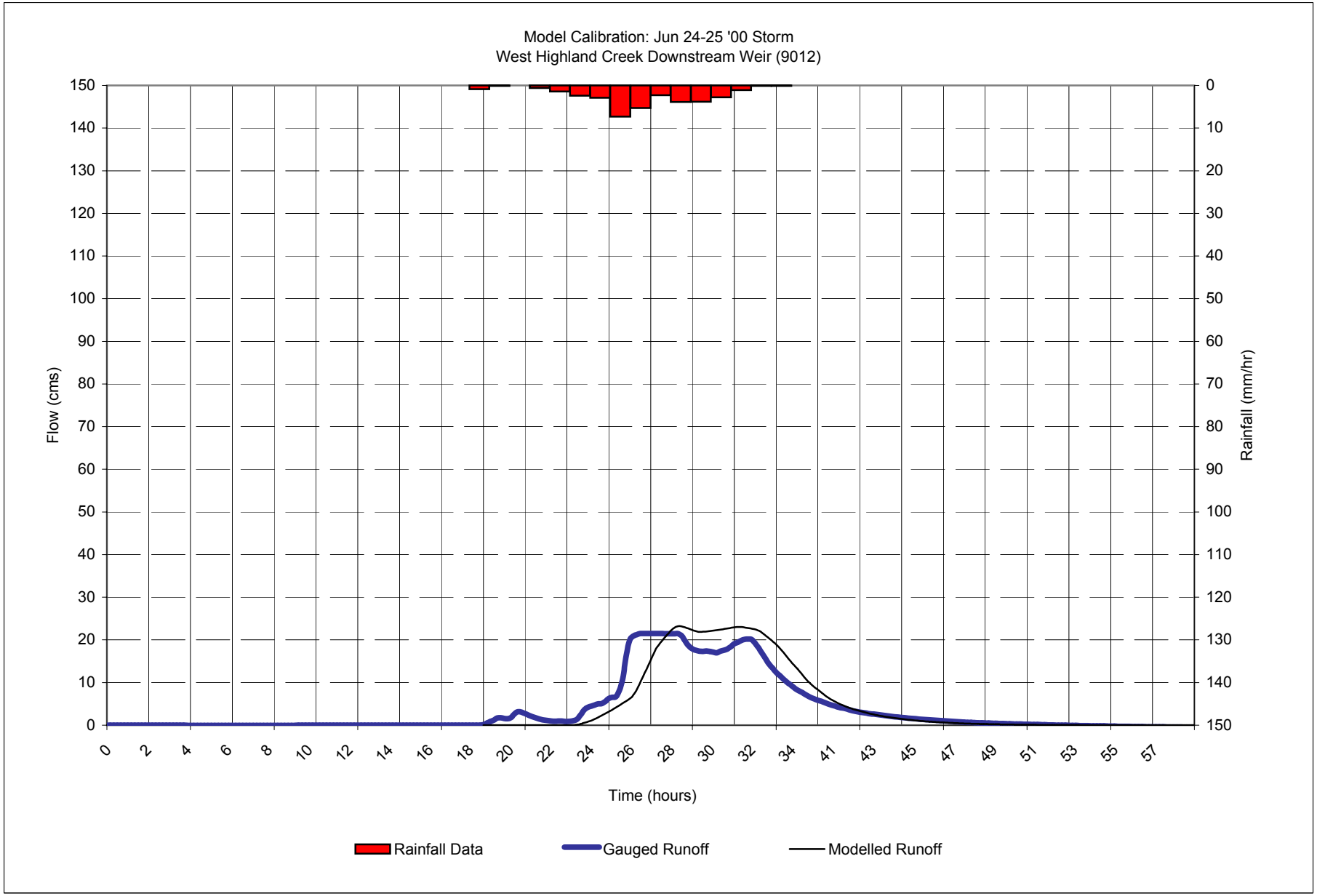

Model Calibration: Oct 5-6 '95 Storm
Highland Creek (02HC013)
Flow (cms)
Rainfall (mm/hr)
Time (hours)
Rainfall Data
Gauged Runoff
Modelled Runoff

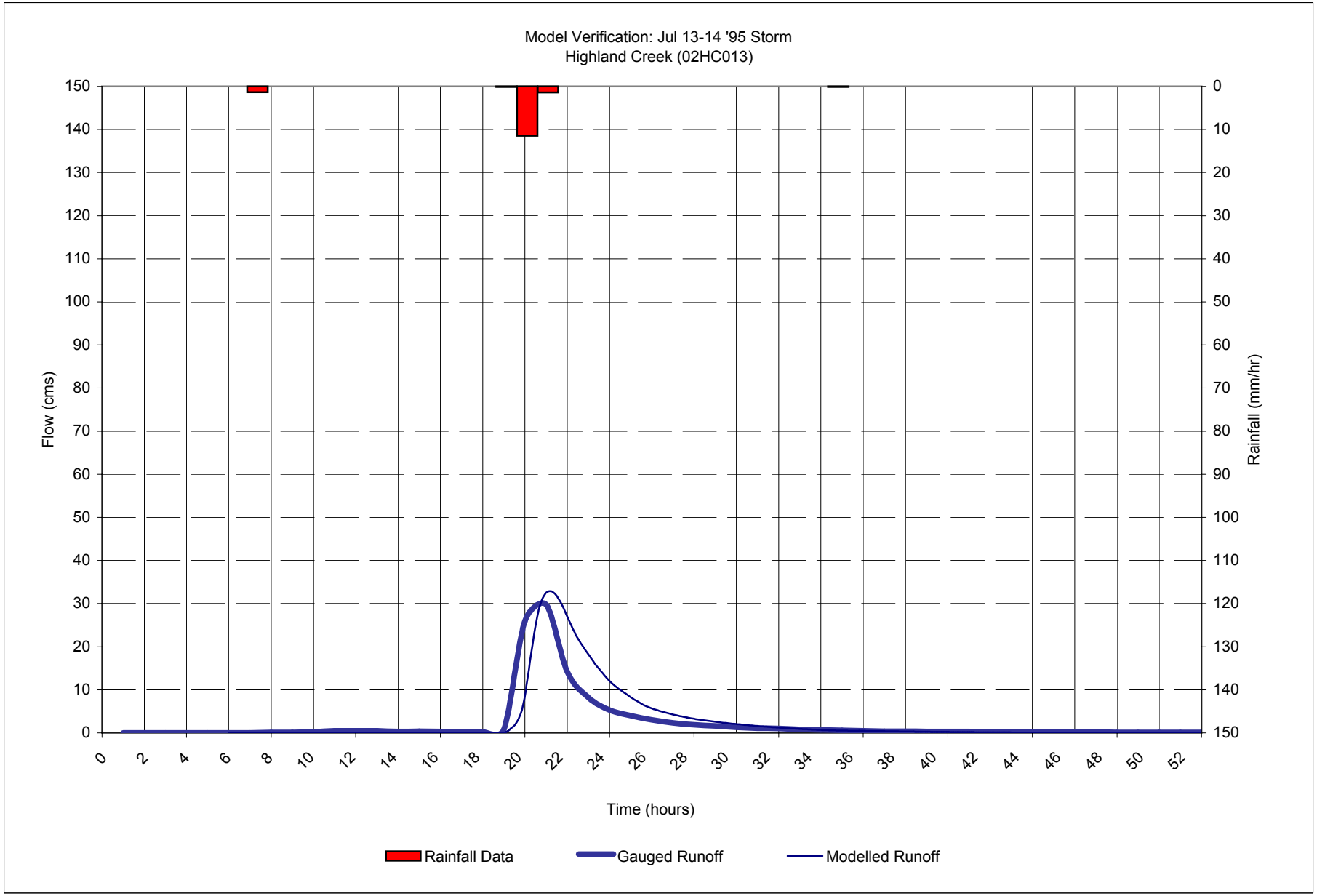

Model Calibration: Nov 10-11 '95 Storm
Highland Creek (02HC013)
Flow (cms)
Rainfall (mm/hr)
Time (hours)
Rainfall Data
Gauged Runoff
Modelled Runoff

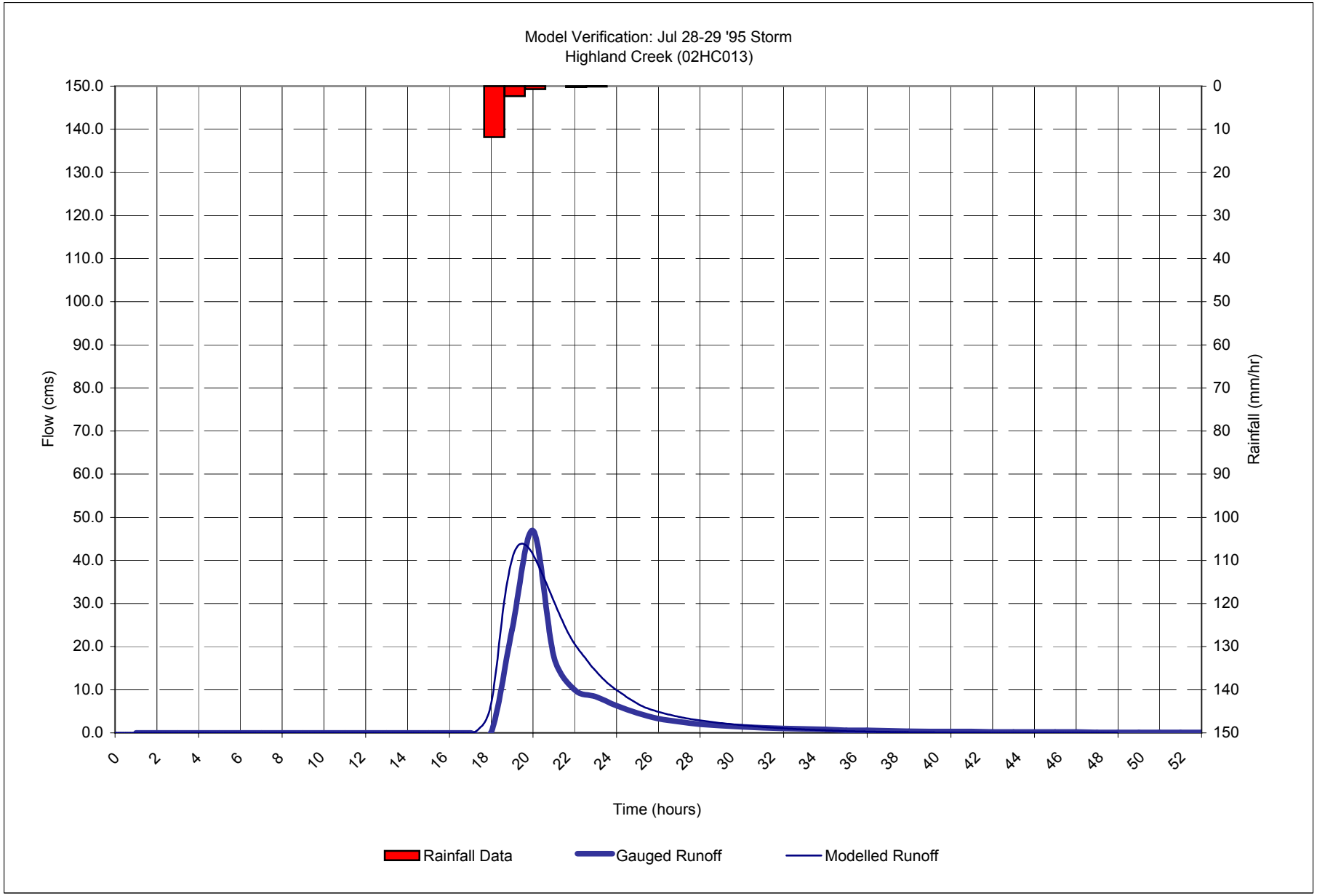

Model Calibration: Sep 7-8 '96 Storm
Highland Creek (02HC013)
Flow (cms)
Rainfall (mm/hr)
Time (hours)
Rainfall Data
Gauged Runoff
Modelled Runoff


Model Calibration: Sep 29-30 '99 Storm
Highland Creek Upstream without Weir
(02HC013)
Flow (cms)
Rainfall (mm/hr)
Time (hours)
Rainfall Data
Gauged Runoff
Modelled Runoff


Model Calibration: Jun 24-25 '00 Storm
West Highland Creek Upstream Weir (9012)
Flow (cms)
Rainfall (mm/hr)
Time (hours)
Rainfall Data
Gauged Runoff
Modelled Runoff


Model Calibration: Jun 24-25 '00 Storm
West Highland Creek Downstream Weir (9012)
Flow (cms)
Rainfall (mm/hr)
Time (hours)
Rainfall Data
Gauged Runoff
Modelled Runoff


Model Verification: Jul 13-14 '95 Storm
Highland Creek (02HC013)
Flow (cms)
Rainfall (mm/hr)
Time (hours)
Rainfall Data
Gauged Runoff
Modelled Runoff


Model Verification: Jul 28-29 '95 Storm
Highland Creek (02HC013)
Flow (cms)
Rainfall (mm/hr)
Time (hours)
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52
Rainfall Data
Gauged Runoff
Modelled Runoff

APPENDIX C:
Design Storm Hyetographs

2
2-YEAR DESIGN STORM: TORONTO BLOOR ST.
15.0
24
00.7
00.7
00.7
00.7
04.4
04.4
12.5
12.5
33.8
33.8
09.5
09.5
05.1
05.1
02.9
02.9
01.5
01.5
00.7
00.7
00.7
00.7
00.7
00.7
-1

2
5-YEAR DESIGN STORM: TORONTO BLOOR ST.
15.0
24
01.0
01.0
01.0
01.0
05.7
05.7
16.2
16.2
43.8
43.8
12.4
12.4
06.7
06.7
03.8
03.8
01.9
01.9
01.0
01.0
01.0
01.0
01.0
01.0
-1

2
10-YEAR DESIGN STORM: TORONTO BLOOR ST.
15.0
24
01.1
01.1
01.1
01.1
06.6
06.6
18.6
18.6
50.4
50.4
14.2
14.2
07.7
07.7
04.4
04.4
02.2
02.2
01.1
01.1
01.1
01.1
01.1
01.1
-1

2
25-YEAR DESIGN STORM: TORONTO BLOOR ST.
15.0
24
01.3
01.3
01.3
01.3
07.7
07.7
21.7
21.7
58.8
58.8
16.6
16.6
08.9
08.9
05.1
05.1
02.6
02.6
01.3
01.3
01.3
01.3
01.3
01.3
-1

2
50-YEAR DESIGN STORM: TORONTO BLOOR ST.
15.0
24
01.4
01.4
01.4
01.4
08.5
08.5
24.0
24.0
65.0
65.0
18.4
18.4
09.9
09.9
05.6
05.6
02.8
02.8
01.4
01.4
01.4
01.4
01.4
01.4
-1

```
2
100-YEAR DESIGN STORM: TORONTO BLOOR ST.
15.0
24
01.5
01.5
01.5
01.5
09.3
09.3
26.3
26.3
71.1
71.1
20.1
20.1
10.8
10.8
06.2
06.2
03.1
03.1
01.5
01.5
01.5
01.5
01.5
01.5
-1
```

2
HURRICANE HAZEL DESIGN STORM:
15.0
48
06.0
06.0
06.0
06.0
04.0
04.0
04.0
04.0
06.0
06.0
06.0
06.0
13.0
13.0
13.0
13.0
17.0
17.0
17.0
17.0
13.0
13.0
13.0
13.0
23.0
23.0
23.0
23.0
13.0
13.0
13.0
13.0
13.0
13.0
13.0
13.0
53.0
53.0
53.0
53.0
38.0
38.0
38.0
38.0
13.0
13.0
13.0
13.0
-1

APPENDIX D:
Design Storm Flow Estimates

Table D.1
Summary of Estimated Design Flows

Flow Node	Location	Drainage Area (km^2)	Reduction Factor*	Landuse Scenario	Peak Flow Rate (cms) 2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	Regional
104.1	Dorset Park Interceptor at Kennedy Rd	3.24	100.0%	Existing	12.3	17.2	20.9	25.7	29.3	33.7	42.7
				Future uncontrolled	14.1	19.5	23.6	28.7	32.7	37.3	43.4
				Future - control strategy 1	13.6	19.2	23.2	28.5	32.5	37.1	43.4
				Future - control strategy 2	11.4	16.4	20.0	24.7	28.3	32.5	43.4
				Future - control strategy 3	11.4	16.4	20.0	24.7	28.3	32.5	43.4
100.1	Dorset Park Interceptor west of McCowan Road	10.77	100.0%	Existing	34.9	50.3	61.7	76.2	87.1	99.6	138.1
				Future uncontrolled	39.8	56.8	69.1	84.5	96.1	109.3	139.8
				Future - control strategy 1	38.1	55.4	67.9	83.5	95.2	108.4	139.8
				Future - control strategy 2	33.1	47.7	59.3	73.8	84.6	97.0	139.8
				Future - control strategy 3	33.1	47.7	59.3	73.8	84.6	97.0	139.8
100.2	Dorset Park Interceptor downstream east of McCowan Road	13.82	99.2%	Existing	34.4	50.4	62.1	76.0	87.5	100.7	165.1
				Future uncontrolled	38.3	55.8	68.4	83.3	95.7	109.5	166.8
				Future - control strategy 1	36.2	53.6	66.4	81.5	94.0	107.9	166.8
				Future - control strategy 2	33.5	49.1	60.6	75.2	86.8	99.3	166.8
				Future - control strategy 3	33.5	49.1	60.6	75.2	86.8	99.3	166.8
206.1	Bendale Branch south of Finch Avenue	7.28	100.0%	Existing	20.7	30.7	37.9	46.7	54.7	62.3	94.7
				Future uncontrolled	22.0	32.4	39.9	48.9	57.1	64.9	95.0
				Future - control strategy 1	21.7	32.2	39.7	48.7	57.0	64.7	95.0
				Future - control strategy 2	21.1	31.7	39.1	48.3	56.7	64.6	95.0
				Future - control strategy 3	21.1	31.7	39.1	48.3	56.7	64.6	95.0
205.1	Bendale Branch at Sheppard Avenue	14.64	99.2%	Existing	35.7	53.3	65.8	82.8	96.9	110.9	178.9
				Future uncontrolled	36.7	54.8	67.4	84.7	99.1	113.3	179.2
				Future - control strategy 1	36.3	54.4	67.0	84.3	98.7	112.9	179.2
				Future - control strategy 2	36.3	54.4	67.1	84.6	99.1	113.5	179.2
				Future - control strategy 3	36.3	54.4	67.1	84.6	99.1	113.5	179.2
204.1	Bendale Branch at Highway 401	16.19	99.2%	Existing	35.6	53.2	66.0	82.7	96.9	110.9	191.9
				Future uncontrolled	36.6	54.7	67.5	84.5	99.0	112.9	192.0
				Future - control strategy 1	36.1	54.2	67.1	84.1	98.6	112.5	192.0
				Future - control strategy 2	37.0	55.5	68.6	86.1	101.0	115.3	192.0
				Future - control strategy 3	36.1	54.3	67.3	84.3	99.0	113.0	192.0
201.1	Bendale Branch at Ellesmere Road	21.16	98.2%	Existing	44.0	65.8	81.7	102.0	119.7	136.4	242.3
				Future uncontrolled	45.9	68.5	84.5	105.1	123.1	139.7	242.3
				Future - control strategy 1	45.0	67.7	83.8	104.4	122.4	139.1	242.3
				Future - control strategy 2	48.5	71.9	89.0	110.8	129.9	147.5	242.3
				Future - control strategy 3	45.3	67.8	83.8	104.4	122.5	139.3	242.3
200.1	Bendale Branch downstream east of McCowan Road	25.34	97.1%	Existing	34.0	50.5	62.3	78.7	92.1	106.3	256.8
				Future uncontrolled	35.7	52.9	65.0	81.9	95.8	110.3	257.4
				Future - control strategy 1	34.7	51.8	64.0	80.9	94.6	109.2	257.4
				Future - control strategy 2	35.7	53.1	65.4	82.6	96.7	111.7	257.4
				Future - control strategy 3	35.0	52.2	64.4	81.3	95.1	109.8	257.4
608.1	West Branch Upstream west of Markham Road	39.16	96.3%	Existing	61.5	89.3	110.4	139.0	162.3	185.6	399.3
				Future uncontrolled	66.9	96.8	118.9	148.6	172.6	197.1	400.2
				Future - control strategy 1	64.1	94.0	116.2	146.0	170.1	194.2	400.2
				Future - control strategy 2	62.9	92.5	114.9	144.6	168.9	193.3	400.2
				Future - control strategy 3	63.7	93.5	116.0	146.0	170.5	194.7	400.2
608.2	West Branch at Lawrence Avenue	49.48	95.4%	Existing	62.8	90.5	108.0	130.8	151.4	171.5	455.8
				Future uncontrolled	67.2	95.7	113.6	137.5	159.3	179.8	457.7
				Future - control strategy 1	64.6	93.4	111.3	135.1	156.8	177.3	457.7
				Future - control strategy 2	63.7	92.1	110.2	133.9	155.6	176.0	457.7
				Future - control strategy 3	64.5	93.1	111.1	135.0	156.8	177.4	457.7
606.1	West Branch at Neilson Road	50.23	96.3%	Existing	62.8	90.6	108.3	131.3	151.8	171.9	462.5
				Future uncontrolled	67.1	95.8	113.9	138.0	159.7	180.2	464.5
				Future - control strategy 1	64.4	93.4	111.6	135.6	157.2	177.7	464.5
				Future - control strategy 2	63.7	92.1	110.2	133.9	155.6	176.0	464.5
				Future - control strategy 3	64.2	93.1	111.3	135.3	157.0	177.5	464.5

* Areal Reduction Factor Applied to Regional Storm

Table D.1 (continued …)
Summary of Estimated Design Flows

Flow Node	Location	Drainage Area (km^2)	Reduction Factor*	Landuse Scenario	Peak Flow Rate (cms) 2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	Regional
302.1	Markham Branch west of McCowan Road	5.89	100.0%	Existing	17.8	26.7	33.0	40.7	46.3	52.5	75.8
				Future uncontrolled	21.9	32.2	39.4	48.4	54.5	61.5	77.3
				Future - control strategy 1	20.9	31.4	38.7	47.7	53.8	60.8	77.3
				Future - control strategy 2	16.0	24.1	29.4	36.3	42.1	47.8	77.3
				Future - control strategy 3	16.0	24.1	29.4	36.3	42.1	47.8	77.3
304.1	Markham Branch east of McCowan Road	7.37	99.2%	Existing	22.2	33.0	42.2	52.0	60.1	68.4	95.4
				Future uncontrolled	23.9	35.2	44.4	54.4	62.7	71.0	95.6
				Future - control strategy 1	23.8	35.2	44.4	54.4	62.7	71.0	95.6
				Future - control strategy 2	23.1	34.9	43.4	53.2	61.5	69.9	95.6
				Future - control strategy 3	23.1	34.9	43.4	53.2	61.5	69.9	95.6
301.1	Markham Branch at Sheppard Avenue	13.26	99.2%	Existing	40.0	59.7	75.1	92.6	106.3	120.8	170.5
				Future uncontrolled	45.8	67.5	83.8	102.8	116.8	132.0	172.2
				Future - control strategy 1	44.7	66.6	83.0	102.1	116.2	131.4	172.2
				Future - control strategy 2	39.1	59.0	72.7	89.5	103.6	117.7	172.2
				Future - control strategy 3	39.1	59.0	72.7	89.5	103.6	117.7	172.2
301.2	Markham Branch at Highway 401	16.95	98.2%	Existing	52.9	76.5	95.5	119.7	139.5	158.2	215.2
				Future uncontrolled	61.5	88.1	108.6	134.9	155.3	175.1	217.9
				Future - control strategy 1	60.0	86.7	107.4	133.9	154.4	174.3	217.9
				Future - control strategy 2	52.1	77.7	95.8	118.8	137.7	156.1	217.9
				Future - control strategy 3	52.1	77.7	95.8	118.8	137.7	156.1	217.9
300.1	Markham Branch downstream east of Markham Road	21.25	97.1%	Existing	53.6	79.1	97.9	120.6	140.3	159.1	248.0
				Future uncontrolled	64.0	92.6	113.4	137.5	158.5	178.5	250.3
				Future - control strategy 1	60.7	89.8	110.6	135.0	155.7	175.7	250.3
				Future - control strategy 2	56.9	84.5	104.0	127.6	147.6	167.1	250.3
				Future - control strategy 3	56.9	84.5	104.0	127.6	147.6	167.1	250.3
402.1	Malvern Branch north of Finch Avenue	5.29	100.0%	Existing	21.1	29.8	37.0	45.9	52.3	60.7	69.4
				Future uncontrolled	26.6	37.0	44.9	55.0	62.2	71.0	70.8
				Future - control strategy 1	26.1	36.7	44.5	54.9	62.1	70.9	70.8
				Future - control strategy 2	19.9	29.3	34.8	44.2	50.4	57.9	70.8
				Future - control strategy 3	19.9	29.3	34.8	44.2	50.4	57.9	70.8
401.1	Malvern Branch north of Sheppard Avenue	11.21	99.2%	Existing	39.5	56.4	69.7	87.7	101.5	115.9	145.0
				Future uncontrolled	45.2	62.1	75.2	92.2	104.9	119.2	148.9
				Future - control strategy 1	50.7	71.2	87.1	109.0	124.1	140.7	148.9
				Future - control strategy 2	38.9	57.5	69.7	87.8	100.7	114.1	148.9
				Future - control strategy 3	38.9	57.5	69.7	87.8	100.7	114.1	148.9
400.1	Malvern Branch south of Highway 401	14.11	99.2%	Existing	45.4	66.2	81.4	102.4	118.6	135.8	180.5
				Future uncontrolled	49.4	69.4	83.1	102.3	116.9	133.0	185.5
				Future - control strategy 1	55.2	80.8	98.2	123.6	142.2	162.6	185.5
				Future - control strategy 2	45.0	66.5	80.9	102.4	118.0	133.6	185.5
				Future - control strategy 3	45.0	66.5	80.9	102.4	118.0	133.6	185.5
605.1	Malvern Branch downstream west of Neilson Road	38.02	97.1%	Existing	98.5	145.4	180.0	223.3	260.3	296.9	447.9
				Future uncontrolled	112.0	161.3	197.0	241.1	278.3	314.3	455.6
				Future - control strategy 1	113.4	168.3	206.5	257.4	296.5	337.2	455.6
				Future - control strategy 2	101.8	151.4	185.7	231.2	268.1	303.9	455.6
				Future - control strategy 3	101.8	151.4	185.7	231.2	268.1	303.9	455.6
604.1	Highland Creek Upstream east of Neilson Road	88.26	96.3%	Existing	153.5	223.4	272.7	337.1	389.7	441.8	860.8
				Future uncontrolled	170.1	242.5	293.9	359.3	413.2	464.8	863.3
				Future - control strategy 1	168.1	245.3	298.9	369.8	426.6	481.9	863.3
				Future - control strategy 2	158.3	231.3	281.9	348.7	401.8	453.9	863.3
				Future - control strategy 3	159.7	233.3	284.2	351.4	404.8	457.4	863.3

* Areal Reduction Factor Applied to Regional Storm

Table D.1 (continued …)
Summary of Estimated Design Flows

Flow Node	Location	Drainage Area (km^2)	Reduction Factor*	Landuse Scenario	Peak Flow Rate (cms) 2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	Regional
603.1	Highland Creek at Highway 2A	96.60	94.8%	Existing	147.0	211.6	257.1	321.2	368.7	417.3	902.6
				Future uncontrolled	160.5	228.3	278.0	339.1	387.2	436.6	907.0
				Future - control strategy 1	157.6	228.8	281.2	345.6	396.4	447.9	907.0
				Future - control strategy 2	152.4	221.7	270.8	336.1	385.8	435.9	907.0
				Future - control strategy 3	153.6	223.4	272.7	338.4	388.4	439.0	907.0
600.1	Highland Creek downstream south of Lawrence Avenue	97.58	94.2%	Existing	127.6	173.3	213.2	271.9	318.3	365.4	880.3
				Future uncontrolled	135.3	185.6	227.8	288.6	334.6	382.4	885.3
				Future - control strategy 1	133.2	184.3	228.1	292.1	340.1	389.1	885.3
				Future - control strategy 2	133.3	182.7	226.6	290.2	337.2	386.6	885.3
				Future - control strategy 3	134.2	183.9	228.1	292.1	339.5	389.1	885.3
601.1	West Hill Creek downstream	2.98	100.0%	Existing	9.6	13.6	16.5	21.2	24.3	27.5	39.3
				Future uncontrolled	10.5	14.9	17.9	22.7	26.0	29.2	39.5
				Future - control strategy 1	10.5	14.8	17.8	22.7	25.9	29.2	39.5
				Future - control strategy 2	9.6	13.9	16.9	21.1	24.1	27.3	39.5
				Future - control strategy 3	9.6	13.9	16.9	21.1	24.1	27.3	39.5
501.1	Centennial Creek at Highway 2A	1.73	100.0%	Existing	5.7	8.2	9.9	12.4	14.2	16.0	22.9
				Future uncontrolled	5.8	8.2	10.0	12.4	14.2	16.2	22.9
				Future - control strategy 1	5.8	8.3	9.9	12.5	14.3	16.1	22.9
				Future - control strategy 2	5.7	8.2	9.9	12.4	14.2	16.0	22.9
				Future - control strategy 3	5.7	8.2	9.9	12.4	14.2	16.0	22.9
501.2	Centennial Creek downstream south of Lawrence Avenue	4.79	100.0%	Existing	15.7	22.3	26.9	34.0	39.4	44.7	64.0
				Future uncontrolled	15.8	22.4	27.1	34.2	39.6	44.9	64.0
				Future - control strategy 1	15.7	22.5	27.1	34.3	39.6	44.8	64.0
				Future - control strategy 2	15.8	22.4	26.9	34.2	39.5	44.6	64.0
				Future - control strategy 3	15.8	22.4	26.9	34.2	39.5	44.6	64.0
600.2	Highland Creek at Lake Ontario	105.35	93.5%	Existing	130.8	180.2	222.7	285.4	333.7	383.3	936.8
				Future uncontrolled	138.3	192.8	237.6	302.3	349.7	400.3	943.4
				Future - control strategy 1	139.7	191.5	237.9	305.7	355.7	407.7	943.4
				Future - control strategy 2	138.7	188.8	235.3	302.1	351.0	402.6	943.4
				Future - control strategy 3	139.7	190.0	236.8	304.0	353.4	405.1	943.4

* Areal Reduction Factor Applied to Regional Storm

Table D.2
Comparison of Existing vs. Future Design Flows

Flow Node	Location	Drainage Area (km^2)	Reduction Factor*	Landuse Scenario	Existing Peak Flow Rates (cms) and Estimated Future Increases (%)						
					2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	Regional
104.1	Dorset Park Interceptor at Kennedy Rd	3.24	100.0%	Existing	12.3	17.2	20.9	25.7	29.3	33.7	42.7
				Future uncontrolled	14.2%	13.4%	13.0%	11.9%	11.6%	10.7%	1.7%
				Future - control strategy 1	9.9%	11.2%	11.2%	10.8%	11.0%	10.2%	1.7%
				Future - control strategy 2	-7.4%	-5.1%	-4.1%	-3.7%	-3.1%	-3.6%	1.7%
				Future - control strategy 3	-7.4%	-5.1%	-4.1%	-3.7%	-3.1%	-3.6%	1.7%
100.1	Dorset Park Interceptor west of McCowan Road	10.77	100.0%	Existing	34.9	50.3	61.7	76.2	87.1	99.6	138.1
				Future uncontrolled	14.0%	12.9%	12.0%	10.8%	10.4%	9.7%	1.2%
				Future - control strategy 1	9.0%	10.1%	10.0%	9.5%	9.3%	8.8%	1.2%
				Future - control strategy 2	-5.2%	-5.1%	-3.8%	-3.2%	-2.8%	-2.7%	1.2%
				Future - control strategy 3	-5.2%	-5.1%	-3.8%	-3.2%	-2.8%	-2.7%	1.2%
100.2	Dorset Park Interceptor downstream east of McCowan Road	13.82	99.2%	Existing	34.4	50.4	62.1	76.0	87.5	100.7	165.1
				Future uncontrolled	11.2%	10.7%	10.3%	9.6%	9.4%	8.7%	1.0%
				Future - control strategy 1	5.2%	6.5%	7.0%	7.2%	7.4%	7.1%	1.0%
				Future - control strategy 2	-2.6%	-2.5%	-2.3%	-1.1%	-0.8%	-1.3%	1.0%
				Future - control strategy 3	-2.6%	-2.5%	-2.3%	-1.1%	-0.8%	-1.3%	1.0%
206.1	Bendale Branch south of Finch Avenue	7.28	100.0%	Existing	20.7	30.7	37.9	46.7	54.7	62.3	94.7
				Future uncontrolled	6.0%	5.6%	5.2%	4.6%	4.4%	4.2%	0.3%
				Future - control strategy 1	4.6%	4.9%	4.7%	4.3%	4.1%	3.9%	0.3%
				Future - control strategy 2	1.8%	3.1%	3.2%	3.5%	3.7%	3.7%	0.3%
				Future - control strategy 3	1.8%	3.1%	3.2%	3.5%	3.7%	3.7%	0.3%
205.1	Bendale Branch at Sheppard Avenue	14.64	99.2%	Existing	35.7	53.3	65.8	82.8	96.9	110.9	178.9
				Future uncontrolled	2.8%	2.7%	2.5%	2.3%	2.3%	2.1%	0.2%
				Future - control strategy 1	1.6%	1.9%	1.9%	1.8%	1.9%	1.8%	0.2%
				Future - control strategy 2	1.5%	2.1%	2.0%	2.2%	2.3%	2.3%	0.2%
				Future - control strategy 3	1.5%	2.1%	2.0%	2.2%	2.3%	2.3%	0.2%
204.1	Bendale Branch at Highway 401	16.19	99.2%	Existing	35.6	53.2	66.0	82.7	96.9	110.9	191.9
				Future uncontrolled	3.0%	2.8%	2.3%	2.3%	2.2%	1.8%	0.1%
				Future - control strategy 1	1.6%	1.9%	1.7%	1.7%	1.7%	1.5%	0.1%
				Future - control strategy 2	4.2%	4.2%	4.0%	4.1%	4.2%	4.0%	0.1%
				Future - control strategy 3	1.6%	2.0%	1.9%	2.0%	2.1%	1.9%	0.1%
201.1	Bendale Branch at Ellesmere Road	21.16	98.2%	Existing	44.0	65.8	81.7	102.0	119.7	136.4	242.3
				Future uncontrolled	4.4%	4.2%	3.5%	3.0%	2.8%	2.4%	0.0%
				Future - control strategy 1	2.3%	2.9%	2.6%	2.3%	2.2%	2.0%	0.0%
				Future - control strategy 2	10.3%	9.4%	9.0%	8.6%	8.5%	8.2%	0.0%
				Future - control strategy 3	3.1%	3.1%	2.6%	2.4%	2.4%	2.1%	0.0%
200.1	Bendale Branch downstream east of McCowan Road	25.34	97.1%	Existing	34.0	50.5	62.3	78.7	92.1	106.3	256.8
				Future uncontrolled	4.8%	4.8%	4.3%	4.1%	3.9%	3.8%	0.2%
				Future - control strategy 1	1.9%	2.7%	2.7%	2.8%	2.7%	2.7%	0.2%
				Future - control strategy 2	4.8%	5.1%	4.9%	4.9%	5.0%	5.0%	0.2%
				Future - control strategy 3	2.9%	3.4%	3.3%	3.3%	3.3%	3.3%	0.2%
608.1	West Branch Upstream west of Markham Road	39.16	96.3%	Existing	61.5	89.3	110.4	139.0	162.3	185.6	399.3
				Future uncontrolled	8.9%	8.3%	7.8%	6.9%	6.4%	6.2%	0.2%
				Future - control strategy 1	4.3%	5.2%	5.3%	5.1%	4.9%	4.7%	0.2%
				Future - control strategy 2	2.3%	3.6%	4.1%	4.0%	4.1%	4.1%	0.2%
				Future - control strategy 3	3.6%	4.7%	5.1%	5.0%	5.1%	4.9%	0.2%
608.2	West Branch at Lawrence Avenue	49.48	95.4%	Existing	62.8	90.5	108.0	130.8	151.4	171.5	455.8
				Future uncontrolled	7.0%	5.8%	5.2%	5.1%	5.2%	4.9%	0.4%
				Future - control strategy 1	2.8%	3.2%	3.1%	3.3%	3.6%	3.4%	0.4%
				Future - control strategy 2	1.3%	1.8%	2.0%	2.4%	2.8%	2.6%	0.4%
				Future - control strategy 3	2.6%	2.9%	2.9%	3.2%	3.6%	3.4%	0.4%
606.1	West Branch at Neilson Road	50.23	96.3%	Existing	62.8	90.6	108.3	131.3	151.8	171.9	462.5
				Future uncontrolled	6.9%	5.8%	5.2%	5.1%	5.2%	4.9%	0.4%
				Future - control strategy 1	2.6%	3.1%	3.1%	3.2%	3.5%	3.4%	0.4%
				Future - control strategy 2	1.4%	1.8%	1.8%	2.0%	2.5%	2.4%	0.4%
				Future - control strategy 3	2.4%	2.8%	2.8%	3.0%	3.4%	3.3%	0.4%

* Areal Reduction Factor Applied to Regional Storm

Table D.2 (continued …)
Comparison of Existing vs. Future Design Flows

Flow Node	Location	Drainage Area (km2)	Reduction Factor*	Landuse Scenario	Existing Peak Flow Rates (cms) and Estimated Future Increases (%) 2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	Regional
302.1	Markham Branch west of McCowan Road	5.89	100.0%	Existing	17.8	26.7	33.0	40.7	46.3	52.5	75.8
				Future uncontrolled	23.0%	21.0%	19.5%	19.0%	17.9%	17.2%	2.1%
				Future - control strategy 1	17.2%	17.9%	17.3%	17.4%	16.3%	15.9%	2.1%
				Future - control strategy 2	-10.5%	-9.7%	-10.9%	-10.8%	-9.0%	-8.9%	2.1%
				Future - control strategy 3	-10.5%	-9.7%	-10.9%	-10.8%	-9.0%	-8.9%	2.1%
304.1	Markham Branch east of McCowan Road	7.37	99.2%	Existing	22.2	33.0	42.2	52.0	60.1	68.4	95.4
				Future uncontrolled	7.5%	6.5%	5.3%	4.6%	4.3%	3.9%	0.2%
				Future - control strategy 1	7.2%	6.4%	5.2%	4.6%	4.2%	3.9%	0.2%
				Future - control strategy 2	4.1%	5.7%	2.9%	2.3%	2.2%	2.2%	0.2%
				Future - control strategy 3	4.1%	5.7%	2.9%	2.3%	2.2%	2.2%	0.2%
301.1	Markham Branch at Sheppard Avenue	13.26	99.2%	Existing	40.0	59.7	75.1	92.6	106.3	120.8	170.5
				Future uncontrolled	14.4%	13.0%	11.5%	11.0%	9.9%	9.2%	1.0%
				Future - control strategy 1	11.7%	11.5%	10.5%	10.2%	9.3%	8.8%	1.0%
				Future - control strategy 2	-2.4%	-1.2%	-3.2%	-3.4%	-2.6%	-2.6%	1.0%
				Future - control strategy 3	-2.4%	-1.2%	-3.2%	-3.4%	-2.6%	-2.6%	1.0%
301.2	Markham Branch at Highway 401	16.95	98.2%	Existing	52.9	76.5	95.5	119.7	139.5	158.2	215.2
				Future uncontrolled	16.3%	15.1%	13.7%	12.6%	11.4%	10.7%	1.2%
				Future - control strategy 1	13.4%	13.3%	12.5%	11.8%	10.7%	10.2%	1.2%
				Future - control strategy 2	-1.5%	1.6%	0.3%	-0.8%	-1.3%	-1.3%	1.2%
				Future - control strategy 3	-1.5%	1.6%	0.3%	-0.8%	-1.3%	-1.3%	1.2%
300.1	Markham Branch downstream east of Markham Road	21.25	97.1%	Existing	53.6	79.1	97.9	120.6	140.3	159.1	248.0
				Future uncontrolled	19.3%	17.0%	15.8%	14.0%	12.9%	12.1%	1.0%
				Future - control strategy 1	13.3%	13.5%	12.9%	11.9%	11.0%	10.4%	1.0%
				Future - control strategy 2	6.1%	6.8%	6.2%	5.8%	5.2%	5.0%	1.0%
				Future - control strategy 3	6.1%	6.8%	6.2%	5.8%	5.2%	5.0%	1.0%
402.1	Malvern Branch north of Finch Avenue	5.29	100.0%	Existing	21.1	29.8	37.0	45.9	52.3	60.7	69.4
				Future uncontrolled	26.2%	24.4%	21.1%	19.9%	18.9%	17.0%	2.0%
				Future - control strategy 1	23.8%	23.5%	20.1%	19.6%	18.7%	16.9%	2.0%
				Future - control strategy 2	-5.6%	-1.4%	-5.9%	-3.7%	-3.7%	-4.5%	2.0%
				Future - control strategy 3	-5.6%	-1.4%	-5.9%	-3.7%	-3.7%	-4.5%	2.0%
401.1	Malvern Branch north of Sheppard Avenue	11.21	99.2%	Existing	39.5	56.4	69.7	87.7	101.5	115.9	145.0
				Future uncontrolled	14.2%	10.2%	7.9%	5.2%	3.3%	2.8%	2.6%
				Future - control strategy 1	28.2%	26.3%	25.0%	24.4%	22.2%	21.4%	2.6%
				Future - control strategy 2	-1.5%	2.1%	0.1%	0.1%	-0.8%	-1.6%	2.6%
				Future - control strategy 3	-1.5%	2.1%	0.1%	0.1%	-0.8%	-1.6%	2.6%
400.1	Malvern Branch south of Highway 401	14.11	99.2%	Existing	45.4	66.2	81.4	102.4	118.6	135.8	180.5
				Future uncontrolled	8.8%	4.8%	2.1%	-0.1%	-1.4%	-2.1%	2.7%
				Future - control strategy 1	21.4%	22.0%	20.6%	20.8%	19.9%	19.8%	2.7%
				Future - control strategy 2	-0.9%	0.3%	-0.6%	0.1%	-0.5%	-1.6%	2.7%
				Future - control strategy 3	-0.9%	0.3%	-0.6%	0.1%	-0.5%	-1.6%	2.7%
605.1	Malvern Branch downstream west of Neilson Road	38.02	97.1%	Existing	98.5	145.4	180.0	223.3	260.3	296.9	447.9
				Future uncontrolled	13.7%	11.0%	9.5%	8.0%	6.9%	5.9%	1.7%
				Future - control strategy 1	15.1%	15.8%	14.7%	15.3%	13.9%	13.6%	1.7%
				Future - control strategy 2	3.3%	4.1%	3.1%	3.6%	3.0%	2.4%	1.7%
				Future - control strategy 3	3.3%	4.1%	3.1%	3.6%	3.0%	2.4%	1.7%
604.1	Highland Creek Upstream east of Neilson Road	88.26	96.3%	Existing	153.5	223.4	272.7	337.1	389.7	441.8	860.8
				Future uncontrolled	10.8%	8.5%	7.8%	6.6%	6.0%	5.2%	0.3%
				Future - control strategy 1	9.5%	9.8%	9.6%	9.7%	9.5%	9.1%	0.3%
				Future - control strategy 2	3.1%	3.5%	3.3%	3.4%	3.1%	2.8%	0.3%
				Future - control strategy 3	4.0%	4.4%	4.2%	4.2%	3.9%	3.5%	0.3%

* Areal Reduction Factor Applied to Regional Storm

Table D.2 (continued …)
Comparison of Existing vs. Future Design Flows

Flow Node	Location	Drainage Area (km2)	Reduction Factor*	Landuse Scenario	Existing Peak Flow Rates (cms) and Estimated Future Increases (%)						
					2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	Regional
603.1	Highland Creek at Highway 2A	96.60	94.8%	Existing	147.0	211.6	257.1	321.2	368.7	417.3	902.6
				Future uncontrolled	9.2%	7.9%	8.1%	5.6%	5.0%	4.6%	0.5%
				Future - control strategy 1	7.2%	8.2%	9.4%	7.6%	7.5%	7.3%	0.5%
				Future - control strategy 2	3.7%	4.8%	5.3%	4.6%	4.6%	4.4%	0.5%
				Future - control strategy 3	4.5%	5.6%	6.1%	5.4%	5.3%	5.2%	0.5%
600.1	Highland Creek downstream south of Lawrence Avenue	97.58	94.2%	Existing	127.6	173.3	213.2	271.9	318.3	365.4	880.3
				Future uncontrolled	6.0%	7.1%	6.8%	6.2%	5.1%	4.7%	0.6%
				Future - control strategy 1	4.4%	6.3%	7.0%	7.4%	6.8%	6.5%	0.6%
				Future - control strategy 2	4.4%	5.4%	6.3%	6.7%	5.9%	5.8%	0.6%
				Future - control strategy 3	5.2%	6.1%	7.0%	7.4%	6.6%	6.5%	0.6%
601.1	West Hill Creek downstream	2.98	100.0%	Existing	9.6	13.6	16.5	21.2	24.3	27.5	39.3
				Future uncontrolled	9.8%	9.0%	8.1%	7.2%	6.8%	6.4%	0.5%
				Future - control strategy 1	9.4%	8.7%	7.8%	6.9%	6.6%	6.2%	0.5%
				Future - control strategy 2	0.4%	2.1%	2.3%	-0.6%	-0.7%	-0.7%	0.5%
				Future - control strategy 3	0.4%	2.1%	2.3%	-0.6%	-0.7%	-0.7%	0.5%
501.1	Centennial Creek at Highway 2A	1.73	100.0%	Existing	5.7	8.2	9.9	12.4	14.2	16.0	22.9
				Future uncontrolled	1.2%	-0.2%	1.7%	0.0%	0.1%	0.9%	0.0%
				Future - control strategy 1	0.9%	0.7%	0.6%	0.5%	0.5%	0.4%	0.0%
				Future - control strategy 2	0.3%	-0.1%	-0.1%	-0.1%	-0.1%	-0.2%	0.0%
				Future - control strategy 3	0.3%	-0.1%	-0.1%	-0.1%	-0.1%	-0.2%	0.0%
501.2	Centennial Creek downstream south of Lawrence Avenue	4.79	100.0%	Existing	15.7	22.3	26.9	34.0	39.4	44.7	64.0
				Future uncontrolled	0.6%	0.7%	0.7%	0.5%	0.5%	0.5%	0.0%
				Future - control strategy 1	0.0%	1.0%	0.4%	0.7%	0.4%	0.3%	0.0%
				Future - control strategy 2	0.5%	0.5%	0.0%	0.5%	0.3%	0.0%	0.0%
				Future - control strategy 3	0.5%	0.5%	0.0%	0.5%	0.3%	0.0%	0.0%
600.2	Highland Creek at Lake Ontario	105.35	93.5%	Existing	130.8	180.2	222.7	285.4	333.7	383.3	936.8
				Future uncontrolled	5.7%	7.0%	6.7%	5.9%	4.8%	4.4%	0.7%
				Future - control strategy 1	6.8%	6.3%	6.8%	7.1%	6.6%	6.4%	0.7%
				Future - control strategy 2	6.1%	4.8%	5.6%	5.9%	5.2%	5.1%	0.7%
				Future - control strategy 3	6.8%	5.5%	6.3%	6.5%	5.9%	5.7%	0.7%

* Areal Reduction Factor Applied to Regional Storm