Appendix A

Greater Cardinal Creek Subwatershed Management Plan

- **Cardinal Creek Subwatershed Hydrology Update**

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Memorandum

To	Glenn Farmer	Page	1
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Subject	Greater Cardinal Creek Subwatershed Plan Hydrology Update		
From	Janelle Weppler		
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1. Existing XPSWMM Model

The XPSWMM model previously prepared for the *City of Ottawa Greater Cardinal Creek Subwatershed Study XPSWMM Model Calibration and Verification Report* (AECOM, 2009) used the XPSWMM model taken from the Master Drainage Plan Update Report, prepared by Cumming Cockburn Limited (CCL) in August of 2000. This XPSWMM model was calibrated by AECOM in 2009 by adjusting hydrologic parameters to more accurately represent the study area. The calibrated model was then verified using available precipitation and flow data for gauges within Cardinal Creek.

2. XPSWMM Model Updates

2.1 Hydrology

2.1.1 Rural Subcatchments

Updated topographic data collected using LiDAR was provided by the City of Ottawa in 2011 and was used to generate new contour elevations and refine the delineation of rural subcatchment areas used in both the 2000 (CCL) and 2009 (AECOM) XPSWMM models. Refined rural subcatchment area delineation was also verified with available Ontario Base Mapping (OBM) data. The overall Cardinal Creek catchment area increased by approximately 400ha (16% of total), with the majority of increase (293ha) contained with the updated “Area 1” that drains to flow point “A”, as identified in Figure 1.

The SCS Hydrology method for routing used for rural subcatchments by CCL (2000) and AECOM (2009) was maintained in the updated model for the refined subcatchment delineations. Previously calibrated SCS Curve Numbers (CN) values determined by AECOM (2009) were maintained by applying the same CN value for each ‘lumped’ subcatchment area to the corresponding further discretized areas. The previously calibrated initial abstraction value of 5mm (AECOM, 2009) was also maintained for each of the further discretized subcatchment areas. Time of concentration values were recalculated where required using several methods including Watt & Chow, HYMO-3 parameter (where applicable), HYMO-2 (where applicable) and Bransby-Williams (where applicable). The time of concentration using the Watt & Chow method was found to be the most reasonable and representative for each of the subcatchment areas. Calculated values for time of concentration were

compared to those within the XPSWMM model (CCL, 2000 & AECOM, 2009) and found to be relatively consistent.

2.1.2 Existing Urban Subcatchments

Urban drainage boundaries and distributed storage were confirmed using detailed design drawings and visual verification through field investigations. The RUNOFF routing method utilized within urban drainage areas for the 2000 (CCL) and 2009 (AECOM) XPSWMM models, was maintained in the updated XPSWMM model for this analysis.

The updated and refined subcatchment areas are shown in Figure 1 with previously determined areas as applied by CCL (2000) and AECOM (2009) modeling.

2.1.3 Cardinal Village (Subcatchment Area 11)

Additional subcatchments were discretized within Subcatchment 11 in order to obtain peak flow estimates within tributaries of the future Cardinal Village development (refer to Figure 2).

SCS Curve Numbers (CN) were updated for each subcatchment within Area 11 to reflect existing land use based on recent aerial photos obtained from the City of Ottawa in 2011 (e.g., changes to forest cover within Parcels 11g and 11h). Weighted CN values were determined based on land use within Area 11 including forest, cultivated areas, pasture and rural developments. All updated CN values within Area 11 resulted in an increase from previously assigned CN values documented in the 2000 (CCL) and 2009 (AECOM) XPSWMM model for the associated 'lumped' areas.

The above noted revisions are reflected in updated modelling results included in Tables 2.1, 2.2 and 2.3.

2.2 Hydraulics

Additional channels located in smaller tributaries of Cardinal Creek were added to the hydraulics portion of the XPSWMM model to connect the further discretized subcatchment areas. The additional channels were assigned similar cross-sections to those downstream and within Cardinal Creek. Applied floodplain and channel roughness characteristics were based on values documented in the technical memorandum *Flood and Generic Regulation Limits Mapping for Cardinal Creek from Ottawa River to O'Toole Road, for the purposes of administering Ontario Regulation 174/06,* prepared by the Rideau Valley Conservation Authority on March 2, 2012.

2.2.1 CCOM On-Line Stormwater Facility

The Cardinal Creek online SWM facility (CCOM) was included in the 2000 (CCL) and 2009 (AECOM) XPSWMM model and represented using a storage node to reflect the stage-discharge relationship at varying depths within the permanent pool and active storage volumes. Within the XPSWMM model, the CCOM was connected downstream using a link to represent the low-flow outlet to the Karst feature and a rating curve to represent the overflow channel up to and under Watters Road.

Updated LiDAR data provided by the City of Ottawa used to generate new contour elevations was applied to refine the stage-storage relationship within the XPSWMM model. A bathymetric survey of the CCOM was completed by the City of Ottawa in October, 2011 to confirm the permanent pool volume as well as details of the outlet structure and overflow towards Watters Road and the downstream system. A HEC-RAS model was prepared by AECOM using the City's survey information in order to verify the stage-discharge through the overflow structure beneath Watters Road. The resultant stage-discharge data for the overflow was input into the XMSWMM model for the CCOM.

Peak flow results for flow points along Cardinal Creek as show in Figure 1, were compared for the updated model including the hydrological and hydraulic refinements described above and are illustrated in Tables 2.1, 2.2 and 2.3.

Table 2.1: Comparison of Peak Flow Results for Cardinal Creek Flow Points for 3-Hour Chicago Distribution of 2, 5 and 100-year Design Storm Events for Existing and Updated XPSWMM Models

Flow Point at Cardinal Creek	Chicago Distribution, 3-Hour					
	2-Year Design Storm Event (m^3/s)		5-Year Design Storm Event (m^3/s)		100-Year Design Storm Event (m^3/s)	
	Existing XPSWMM Model	Updated XPSWMM Model	Existing XPSWMM Model	Updated XPSWMM Model	Existing XPSWMM Model	Updated XPSWMM Model
"A"	0.2	0.3	0.4	0.7	0.7	1.1
"B"	0.7	0.9	1.3	1.7	2.1	2.9
"C"	1.3	1.9	2.5	3.7	4.5	6.6
"D"	2.5	3.6	4.8	6.6	8.0	10.5
"F" (D/S of Watters Rd.)	4.6	6.3	8.4	10.3	12.1	14.7
"G"	4.7	6.4	8.6	10.4	12.3	14.8
"H"	5.3	7.4	9.8	12.2	14.3	17.8
"O"	7.6	7.9	10.3	13.0	15.0	20.0

Table 2.2: Comparison of Peak Flow Results for Cardinal Creek Flow Points for July 1, 1979 Observed Storm Event and Snow 100-Year Event Distribution for Existing and Updated XPSWMM Models

Flow Points at Cardinal Creek	July 1, 1979 Observed Storm Event (m^3/s)		Snow 100-Year Event Distribution (m^3/s)	
	Existing XPSWMM Model	Updated XPSWMM Model	Existing XPSWMM Model	Updated XPSWMM Model
"A"	1.3	2.2	2.4	4.0
"B"	3.9	5.3	5.5	7.6
"C"	8.4	12.1	10.8	14.2
"D"	13.3	17.7	13.1	17.2
"F" (D/S of Watters Rd.)	17.0	21.8	14.4	19.1
"G"	17.8	22.0	14.4	19.1
"H"	21.5	27.9	18.7	22.1
"O"	22.9	31.7	20.5	24.6

Additional design storm events including the SCS Type II (24-hour) and Chicago (24-hour, Keifer & Chu) distributions were extracted from Section 5.3.2 of *The City of Ottawa Sewer Design Guidelines* and run to compare results for both the existing and updated XPSWMM models. Peak flow results are detailed in Table 2.3.

Table 2.3: Comparison of Peak Flow Results for Cardinal Creek Flow Points for 24-Hour Chicago and SCS Type II Distributions of 2, 5 and 100-year Design Storm Events for Existing and Updated XPSWMM Models

Flow Point at Cardinal Creek	2-Year Design Storm Event (m^3/s)		5-Year Design Storm Event (m^3/s)		100-Year Design Storm Event (m^3/s)	
	Existing XPSWMM Model	Updated XPSWMM Model	Existing XPSWMM Model	Updated XPSWMM Model	Existing XPSWMM Model	Updated XPSWMM Model
Chicago Distribution, 24-Hour						
"A"	0.4	0.6	0.6	1.0	1.6	2.6
"B"	1.0	1.4	2.1	2.4	4.5	6.1
"C"	1.9	2.3	3.4	4.2	8.7	11.1
"D"	3.0	3.9	5.3	6.9	12.3	16.6
"F" (D/S of Watters Rd.)	6.4	7.5	10.2	11.6	17.2	21.4
"G"	6.5	7.6	10.4	11.7	17.6	21.5
"H"	7.2	8.8	11.7	13.7	21.1	26.5
"O"	8.6	9.4	12.2	15.1	22.7	30.1
SCS Type II Distribution, 24-Hour						
"A"	0.4	0.6	0.6	1.1	1.7	2.8
"B"	1.1	1.5	2.3	2.6	4.7	6.5
"C"	2.0	2.5	3.6	4.5	9.0	11.7
"D"	3.7	4.0	5.6	7.1	12.5	16.5
"F" (D/S of Watters Rd.)	6.8	7.5	10.3	11.4	17.0	21.4
"G"	6.9	7.5	10.6	11.5	17.6	21.4
"H"	7.7	8.7	12.0	13.6	21.1	26.0
"O"	8.1	9.4	12.5	15.0	22.8	29.9

2.3 Existing Conditions - Results

A comparison between the AECOM 2009 and AECOM 2012 XPSWMM models (refer to Tables 2.1 and 2.2) shows some minor increases in peak flows under the same duration design storm events. These minimal peak flow increases identified during same duration design storm events are due to:

- Revisions to subcatchment areas resulting from updated topographic information (LiDAR),
- Modifications to the CCOM's stage-discharge relationship for the overflow structure based on additional survey data; and
- Further discretization of Catchment Area 11 to represent Cardinal Village.

Further increases in peak flows are noted when comparing the previously applied 3-hour design storms with updated design storm duration and depths based on the *City of Ottawa Sewer Design Guidelines*. The updated design storms included the 24-hour Chicago distribution (Kiefer and Chu) and the 24-hour SCS Type II distribution. Resulting peak flows from the 24-hour Chicago distribution were similar to those calculated using the 24-hour SCS Type II distribution, as shown in Table 2.3.

The significant increase in peak flow estimates using the 24-hour storm distributions resulted in flows that exceed the previously determined 100-year snow and rainfall event.

3. Area 11 of City of Ottawa Urban Expansion Document

Catchments within the Cardinal Village Area were further revised to represent proposed conditions by updating land uses to include an estimated 50% impervious cover within the developable area. Approximate developable areas were delineated using the latest NHS and hazard land mapping prepared for the Cardinal Creek and is illustrated on attached Figure 2.

Area 11 subcatchments were revised to apply the RUNOFF computational routine for routing due to the proposed urban nature of the updated subcatchments. Weighted impervious values were calculated using 50% imperviousness for developable area. Subcatchment slopes were assigned using similar slopes of adjacent urban areas with 0.005m/m and subcatchment widths were calculated using 90m/ha, as taken from Table B-2 of the *City of Ottawa Greater Cardinal Creek Subwatershed Study XPSWMM Model Calibration and Verification Report* (AECOM, 2009).

Flow locations within the Cardinal Village (Area 11) are shown in Figure 2 and a comparison of peak flows existing and proposed conditions has been included in Tables 2.4, 2.5 and 2.6. Note that the proposed flows reported in Table 2.4 are “uncontrolled” in order to illustrate the impact of proposed development on peak flow rates.

Table 3.1: Comparison of Peak Flow Results for Area 11 Flow Points for 3-Hour Chicago Distribution of 2, 5 and 100-year Design Storm Events for Existing and Proposed Conditions

Flow Point Within Area 11	Chicago Distribution, 3-Hour					
	2-Year Design Storm Event (m^3/s)		5-Year Design Storm Event (m^3/s)		100-Year Design Storm Event (m^3/s)	
	Existing Conditions	Proposed Conditions	Existing Conditions	Proposed Conditions	Existing Conditions	Proposed Conditions
"F1"	0.2	0.3	0.4	0.5	0.9	1.2
"H2"	1.1	4.1	2.0	6.7	5.3	16.2
"H3"	1.2	4.3	2.1	7.1	5.6	17.6
"I1"	0.1	0.3	0.2	0.4	0.4	0.9
"O2"	0.5	1.6	0.8	2.4	2.2	5.1
"O3"	0.5	1.7	1.3	3.1	3.4	8.0
"O4"	0.4	1.4	0.7	2.0	1.7	4.2

Table 3.2: Comparison of Peak Flow Results for Area 11 Flow Points for July 1, 1979 Observed Storm Event and Snow 100-Year Event Distribution for Existing and Proposed Conditions

Flow Point Within Area 11	July 1, 1979 Observed Storm Event (m^3/s)		Snow 100-Year Event Distribution (m^3/s)	
	Existing Conditions	Proposed Conditions	Existing Conditions	Proposed Conditions
"F1"	1.0	1.1	0.2	0.1
"H2"	6.1	16.2	4.5	3.1
"H3"	6.5	17.9	4.7	3.1
"I1"	0.4	0.7	0.0	0.1
"O2"	2.7	4.9	1.1	0.8
"O3"	3.7	9.8	2.8	2.1
"O4"	1.9	3.1	0.5	0.2

Table 3.3: Comparison of Peak Flow Results for Area 11 Flow Points for 24-Hour Chicago and SCS Type II Distributions of 2, 5 and 100-year Design Storm Events for Existing and Proposed Conditions

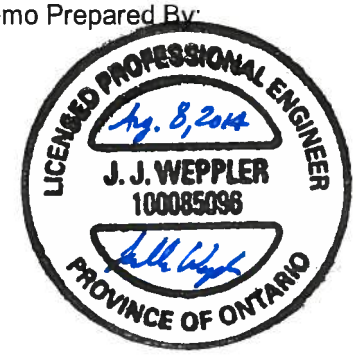
Flow Point Within Area 11	2-Year Design Storm Event (m^3/s)		5-Year Design Storm Event (m^3/s)		100-Year Design Storm Event (m^3/s)	
	Existing Conditions	Proposed Conditions	Existing Conditions	Proposed Conditions	Existing Conditions	Proposed Conditions
Chicago Distribution, 24-Hour						
"F1"	0.2	0.3	0.4	0.5	0.9	1.2
"H2"	1.1	4.1	2.0	6.7	5.3	16.2
"H3"	1.2	4.3	2.1	7.1	5.6	17.6
"I1"	0.1	0.3	0.2	0.4	0.4	0.9
"O2"	0.5	1.6	0.8	2.4	2.2	5.1
"O3"	0.5	1.7	1.3	3.1	3.4	8.0
"O4"	0.4	1.4	0.7	2.0	1.7	4.2
SCS Type II Distribution, 24-Hour						
"F1"	0.2	0.3	0.4	0.5	0.9	1.0
"H2"	1.2	3.8	2.2	6.3	5.4	14.5
"H3"	1.3	4.0	2.3	6.7	5.8	15.6
"I1"	0.1	0.2	0.1	0.3	0.3	0.7
"O2"	0.5	1.5	0.9	2.2	2.2	4.6
"O3"	0.6	1.6	1.4	2.8	3.5	7.1
"O4"	0.4	1.0	0.7	1.5	1.7	3.0

4. CCOM Water Quality Monitoring Reports

Three monitoring reports (2010, 2011 and 2012) were provided to AECOM by the City for the water quality monitoring of the Cardinal Creek Stormwater Facility. The reports indicate that the facility

generally functions as intended and provides minimal level of treatment to the creek. The reports also indicate that the creek does not appear to endure additional degradation as it flows through the urbanized area of the catchment.

Memo Prepared By:



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