APPENDIX C

Stormwater and Drainage Assessment

Memo

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From: Isabelle Hemmings, P.Eng., Dillon Consulting Limited

Date: March 13, 2020

Subject: Stormwater and Drainage Assessment – Livingston Avenue Extension Environmental Assessment

Our File: 18-7650

The Regional Municipality of Niagara (the Region) retained Dillon Consulting Limited (Dillon) in 2018 to complete an Environmental Assessment (EA) Study (hereafter referred to as the Study) for proposed improvements to Casablanca Boulevard (from the North Service Road to Main Street West) and other adjacent roadways (the North Service Road, South Service Road, and Livingston Avenue) to support the projected population and employment growth targeted for 2041 in the vicinity of the aforementioned road network and to support the planned Grimsby GO Transit Station, scheduled for opening day in 2021. As part of the planned improvements Livingston Avenue is proposed to be extended from just west of Emily Street to Oakes Road North.

This memo presents the existing and proposed hydrology for the Study Area of the proposed Livingston Avenue extension, hydraulics for the proposed culverts under the extension and a preliminary evaluation of the ditch size requirements along Livingston Avenue. The proposed location for the road extension is located within the Greenbelt, through agricultural land located in the Town of Grimsby, north of the Niagara Escarpment, south of the Queen Elizabeth Way (QEW), east of Oakes Road North and west of Emily Street, as illustrated in **Figure 1**.

Criteria

General stormwater management design criteria, related to Livingston Avenue, have been based on a review of available background documents including the Niagara Peninsula Conservation Authority (NPCA)'s Stormwater Management (SWM) Guidelines Report (2010), the Ministry of Transportation (MTO)'s Drainage Management Manual (DMM) (1997), the MTO's Highway Drainage Design Standards (HDDS) (2008), and site specific design constraints. The general stormwater management design criteria adopted for this project includes the following:

- Culvert design flows are based on the MTO HDDS, references SD-1 and WC-1:
  - For a non-watercourse crossing: SD-1 – Design flow return period for major system is 1:100-year (urban/rural arterial)
  - For a watercourse crossing: WC-1 – Design flow return period for structure with a span less than 6.0 m is 1:50-year (urban arterial)
- The alteration of hydrologic characteristics, resulting from the increase in imperviousness within the Livingston Avenue road corridor should have no-net-impact on the rate of stormwater runoff discharged to any given receiving water system. This includes changes in flow regime for design flows up to and including the 'Major' storm event, as described in the NPCA SMW Guidelines.
- Based on guidelines in the MTO DMM, alterations of the hydrologic characteristics within the impacted road corridor should not result in a reduction in the level of service of existing MTO drainage infrastructure, specifically the freeboard and clearance of the QEW culverts that facilitate drainage.

- The proposed improvements should not increase the risk of flooding within any one of the receiving water systems, particularly the Vine Road intermittent drainage channel which has been previously identified as having limited capacity to convey 'Major' storm events.
- Culverts should be sized to convey the design flows under non-pressurized conditions.

As part of the preliminary design process several overall drainage and stormwater management strategies have been developed to address the change in hydrologic characteristics that will result from the Livingston Avenue extension. The key drivers behind the development of the stormwater management strategy include:

- The need to effectively collect and convey stormwater runoff from the roadway corridor and direct runoff to an outlet with sufficient capacity for post-development design flows;
- The need to control post-development runoff rates to a level that does not worsen flooding concerns within the Vine Road rear-yard intermittent drainage channel, specifically in the areas that the drainage channel is located on private property;
- The need to control post-development runoff rates to a level that does not worsen flow rates of the identified, unnamed, watercourse that outlets to Lake Ontario;
- The need to control post-development runoff rates to a level that does not result in a reduction in the level of service of existing MTO drainage infrastructure downstream of Livingston Avenue.

Methodology

Assessment of hydrologic conditions of existing and proposed catchment areas was undertaken using the Rational Method equation. The Rational Method flow equation is:

$$Q = 0.0028 \times CIA$$

Where:

Q = flow rate (m^3/s)

C = weighted runoff coefficient

A = drainage area (ha)

I = intensity of rainfall (mm/hr)

Runoff coefficients from the NPCA SWM Guidelines were used to calculate the weighted runoff coefficients for the catchment areas. The runoff coefficients for the land use of the catchment areas are presented in **Table 1**.

Table 1: Runoff Coefficients

Surface Type	Runoff Coefficient
Paved Areas	0.95
Commercial	0.90
Low Density Residential	0.50
Park / Open Space	0.20

The Airport and Bransby-Williams formulas were used to calculate the time of concentration for the catchment areas. According to the MTO DMM, the Airport formula is used when the runoff coefficient for the catchment area is less than 0.40; and the Bransby-Williams formula is to be used when the runoff coefficient for the catchment area is greater than 0.40. When the time of concentration was calculated as less than 10 minutes, an assumed time of concentration for those catchments is 10 minutes.

$$\text{Airport: } t_{\square} = \frac{3.26(1.1 - C)L^{0.5}}{S^{0.33}} \qquad \text{Bransby-Williams: } t_c = \frac{0.57L^{0.5}}{S^{0.2}A^{0.1}}$$

t_c = time of concentration (minute)

L = Catchment length (m)

C = Runoff coefficient

S = Catchment slope (%)

A = Catchment area (m^2)

Rainfall intensity-duration-frequency (IDF) curves for Town of Grimsby, from NPCA SWM Guidelines, were applied. IDF parameters are shown in **Table 2**. The following equation was used to calculate rainfall intensity:

$$Rainfall\ Intensity\ (i) = \frac{A}{(t_c + B)^c}$$

Table 2: A and C Parameters for Rainfall Intensity

Return Period (Year)	A	B	C
2	603.25	6.00	0.79
5	785.59	6.00	0.79
10	953.64	7.00	0.79
25	1119.02	7.00	0.79
50	1301.80	8.00	0.80
100	1426.13	8.00	0.80

Existing Conditions

To facilitate comparisons between pre- and post-development conditions, catchments in the existing condition were created to reflect the proposed road configuration. **Figure 2** presents the existing catchment delineation for the Study Area. The catchment areas consist primarily of agricultural, forest, and residential land uses. Livingston Avenue is proposed to run through existing agricultural land between Emily Street and Oakes Road North. The agricultural land extends between Oakes Road North and Emily Street, and from the escarpment to the CN tracks. The CN tracks run west and east along the northern boundary of the agricultural land. The Niagara Escarpment, located to the south of the Study Area is mainly comprised of forested area. Residential land use is concentrated primarily at the eastern limit of the Study Area toward Casablanca Boulevard, and along Hunter Road towards the centre of the Study Area. The stormwater runoff for the catchments flows south to north and, ultimately, outlet to Lake

Ontario. There are two existing drainage features identified. There is an unnamed watercourse located in the agricultural land between Emily Street and Hunter Road, which appears to form at the base of the escarpment, flows under the QEW and outlets to Lake Ontario. The other identified drainage feature in the agricultural land is the Vine Road rear-yard intermittent drainage channel that flows through private properties east of Casablanca Boulevard and outlets to Lake Ontario.

Existing Hydrology

Assessment of hydrologic conditions was completed in accordance with accepted methods outlined in the MTO DMM (1997) and the NPCA SWM Guidelines Report (2010). A weighted runoff coefficient was calculated for each of the catchments based on the land use within them, see **Appendix A** for details. **Table 3** outlines the hydrologic characteristics of the existing catchments.

Table 3: Existing Hydrologic Characteristics

Catchment ID	Catchment Area (ha)	Weighted Runoff Coefficient	Catchment Length (m)	Catchment Slope (%)	Time of Concentration (min)
1	18.5	0.23	676	1.33	27
2	0.6	0.20	20	1.25	10
3	8.5	0.31	354	0.85	17
4	202.8	0.21	2570	4.71	63
5	1.3	0.20	150	2.67	10*
6	17.2	0.20	322	0.31	17
7	8.1	0.34	403	0.99	19
8	0.8	0.20	20	1.25	10*
9	9.7	0.20	323	0.93	15
10	5.1	0.33	180	2.22	10*
11	1.6	0.20	20	1.25	10*
12	18.9	0.29	335	0.90	15

* Time of concentration is calculated to be less than 10 minutes, an assumed time of concentration for these catchments was set at 10 minutes.

As discussed in the methodology section, stormwater runoff peak flows were calculated based on the Rational Method and NPCA recommended land use coefficients and IDF parameter values. The existing peak flows are summarized in **Table 4**. The Rational Method peak flow calculations are presented in **Appendix A**.

Table 4: Existing Peak Flow Summary

Catchment ID	Peak Flow Rate (m^3/s)					
	2 Year	5 Year	10 Year	25 Year	50 Year	100 year
1	0.46	0.60	0.71	0.83	0.91	1.00
2	0.02	0.03	0.03	0.04	0.04	0.05
3	0.38	0.49	0.58	0.68	0.74	0.81
4	2.56	3.33	4.00	4.69	5.17	5.66
5	0.05	0.06	0.07	0.09	0.09	0.10
6	0.48	0.63	0.73	0.86	0.94	1.03
7	0.37	0.48	0.57	0.66	0.72	0.79
8	0.03	0.04	0.05	0.06	0.06	0.07
9	0.30	0.38	0.45	0.53	0.57	0.63
10	0.32	0.41	0.48	0.56	0.61	0.67
11	0.06	0.08	0.09	0.11	0.12	0.13
12	0.84	1.09	1.28	1.50	1.63	1.79

Proposed Conditions

Livingston Avenue is proposed to extend from where it currently terminates, at the west of Emily Street, to Oakes Road North. **Figure 3** presents the proposed catchment delineation for the Study Area. The future land use for the area surrounding Livingston Avenue will remain agricultural because the proposed road extension is located within the Greenbelt, where future development is limited. The land use for the Study Area will only change within the right-of-way of Livingston Avenue. The proposed Livingston Avenue extension will be constructed with curbs and gutters, pedestrian path and cycling lanes.

The curb and gutter system is proposed for Livingston Avenue to capture stormwater runoff from the road right-of-way and transfer it to storm sewers. The storm sewers will convey the stormwater to a drainage point along the road that maintains the existing drainage pattern to the best extent possible. The stormwater, in the storm sewers, will have a controlled release rate that matches pre-development peak flows. Storm sewer outfall locations include the unnamed watercourse, a proposed crossing culvert at the eastern limit of the proposed extension, two crossing culverts under Hunter Road, and the existing storm sewer system at the intersection of Oakes Road North and Main Street West. In order to maintain existing drainage patterns, stormwater runoff from the northern external catchments must continue to flow under the extension. Culverts are required to convey these flows. A culvert must be sized to allow for the extension to cross the unnamed water course. Additionally, the two culverts proposed for the west and east sides of Hunter Road, are to convey flows through the existing ditches along Hunter Road.

Proposed Hydrology

Assessment of hydrologic conditions was completed in accordance with accepted methods outlined in the MTO DMM (1997) and the NPCA SWM Guidelines Report (2010). A weighted runoff coefficient was calculated for the catchments based on the land use within them, see **Appendix B** for details. **Table 5** outlines the hydrologic characteristics of the proposed catchments.

Table 5: Proposed Hydrologic Characteristics

Catchment ID	Catchment Area (ha)	Weighted Runoff Coefficient	Catchment Length (m)	Catchment Slope (%)	Time of Concentration (min)
1A	18.5	0.23	676	1.33	27
2A	0.6	0.95	190	0.53	10*
3A	8.5	0.31	354	0.85	17
4A	202.8	0.21	2570	4.71	63
5A	1.3	0.95	355	0.85	10*
6A	17.2	0.20	322	0.31	17
7A	8.1	0.34	403	0.99	19
8A	0.8	0.95	250	1.20	10*
9A	9.7	0.20	323	0.93	15
10A	5.1	0.33	180	2.22	10*
11A	1.6	0.95	563	0.53	14
12A	18.9	0.24	335	0.90	15

* Time of concentration is calculated to be less than 10 minutes, an assumed time of concentration for these catchments was set at 10 minutes.

As discussed in the methodology section, stormwater runoff peak flows were calculated based on the Rational Method and NPCA recommended land use coefficients and IDF parameter values. The proposed peak flows are summarized in **Table 6**. The Rational Method peak flow calculations are presented in **Appendix B**.

Table 6: Proposed Peak Flow Summary

Catchment ID	Peak Flow Rate (m^3/s)					
	2 Year	5 Year	10 Year	25 Year	50 Year	100 year
1A	0.46	0.60	0.71	0.83	0.91	1.00
2A	0.11	0.14	0.16	0.19	0.20	0.22
3A	0.38	0.49	0.58	0.68	0.74	0.81
4A	2.56	3.33	4.00	4.69	5.17	5.66
5A	0.23	0.30	0.35	0.41	0.45	0.49
6A	0.48	0.63	0.73	0.86	0.94	1.03
7A	0.37	0.48	0.657	0.66	0.72	0.79
8A	0.15	0.19	0.22	0.26	0.28	0.31
9A	0.30	0.38	0.45	0.53	0.57	0.63
10A	0.32	0.41	0.48	0.56	0.61	0.67
11A	0.24	0.31	0.36	0.43	0.46	0.51
12A	0.84	1.09	1.28	1.50	1.63	1.79

Proposed Hydraulics

As a result of the proposed road extension, culverts are required to ensure adequate flow passage to maintain existing drainage patterns. In total, there are four culverts proposed along the length of Livingston Avenue. Culvert 1 is used to ensure flow to the Vine Road rear-yard intermittent drainage channel is unobstructed. Culvert 2 is used to ensure flow of the unnamed watercourse is not obstructed. Culvert 3 is used to convey the ditch drainage along Hunter Road. Culvert 4 is under Hunter Road to convey the catchment area to the west of Hunter Road and south of Livingston Avenue. Please see **Figure 3** for the location of each culvert.

The hydraulic performance of the culverts was assessed using CulvertMaster®. The hydraulic modelling software was used to evaluate how the proposed culverts performed. The following assumptions and considerations were used in the hydraulic assessment:

- The theoretical headwater (HW) elevation is determined by CulvertMaster® based on the flow rates established for the proposed hydrologic conditions.
- Lengths and inverts from drawings, were used for the CulvertMaster® analysis.

As described in the Criteria section, the design flows for culverts that are not a watercourse is the 1:100-year flow event and the design storm for culverts that are a watercourse is the 1:50-year flow event. The design criteria for the culverts is to size them to allow for the safe passage of the design storm peak flow rate of the culverts to flow under non-pressurized conditions. The culverts' upstream inverts were determined based on the survey data provided by the Region of Niagara for the Town of Grimsby. The downstream inverts were calculated assuming the culverts' slopes will be 0.3%. The culverts' lengths are assumed to be 25 m, the width of Livingston Avenue's right-of-way. **Table 7**, summarizes the culvert

attributes. The proposed hydraulic performance with respect to the design criteria is summarized **Table 8**. Detailed CulvertMaster® output is included in **Appendix C**. Further analysis of the culverts is required in detailed design to ensure that all hydraulic criteria from the HDDS are met based on the finalized road elevations.

Table 7: Proposed Culvert Conditions

Culvert ID	Type	Diameter/ Rise (mm)	Width (mm)	US Invert (m)	DS Invert (m)	Length (m)	Slope (%)
1	Box – Crossing	910	1220	91.00	90.92	25	0.3
2	Box – Watercourse	1520	3050	89.00	88.92	25	0.3
3	Circular – Crossing	1050	-	92.00	91.92	25	0.3
4	Circular – Crossing	1050	-	92.00	91.92	25	0.3

Table 8: Hydraulic Performance under Proposed Conditions

Culvert ID	Design Storm	Headwater Elevation (m)	US Obvert of culvert (m)	Clearance between US Obvert and HW Elev. (m)
1	100-year	91.88	91.91	0.03
2	50-year	90.29	90.52	0.23
3	100-year	93.04	92.91	0.01
4	100-year	93.04	92.91	0.01

Roadside Conveyance

Roadside conveyance along Livingston Avenue is provided by ditches on both north and south sides. Ditches along the Livingston Avenue extension will be graded to maintain existing drainage patterns. **Figure 4** highlights the location of the proposed roadside conveyance along Livingston Avenue.
Ditch D1S will be graded to divert Catchment 1A through Culvert 1 in the east. After this culvert, flows will continue through an existing ditch and continue through the Vine Road rear-yard intermittent drainage channel to the existing culvert under the CN tracks. Ditch D2S will be graded to divert Catchment 4AA to the unnamed watercourse that flows through Culvert 2. After this culvert, flows will continue along the watercourse and continue under the CN tracks. Ditch D3S will be graded to divert Catchment 7A through Culvert 4 on the west side of Hunter Road. After this culvert, flows will continue through the roadside ditch along Hunter Road. Ditch D4S will be graded to divert Catchment 10A to the existing storm sewer system located at Main Street West and Oakes Road North. The storm sewer ultimately outlets to Lake Ontario. There will be ditches along the north side of Livingston Avenue. These ditches will be graded to convey stormwater flow from a small segment of the proposed Livingston Avenue right-of-way that cannot be captured by the storm sewer system on the road. The north side ditches will slope in the same direction as the south side ditches. **Table 9** provides the design details for the ditches along Livingston Avenue. Ditch design calculations are presented in **Appendix D**.

Table 9: Proposed Ditches Design Details

Ditch ID	Catchment ID	Catchment Area (ha)	Weighted Runoff Coeff.	Design Storm (year)	Peak Flow Rate (m^3/s)	Length (m)	Bottom Width (m)	Top Width (m)	Minimum Depth (m)	Side Slope (X:1)
D1S	1A	18.9	0.21	100	0.93	195	1.00	4.08	0.77	2
D2S	4AA	22.9	0.31	100	1.73	400	1.00	3.72	0.68	2
D3S	7A	8.6	0.38	100	0.78	250	1.00	3.28	0.57	2
D4S	10A	6.2	0.31	100	0.55	545	1.00	1.72	0.18	2
D1N	2A	0.6	0.95	100	0.22	195	1.00	1.40	0.10	2
D2N	5A	1.3	0.95	100	0.49	400	1.00	1.36	0.09	2
D3N	8A	0.8	0.95	100	0.31	250	1.00	1.32	0.08	2
D4N	11A	1.6	0.95	100	0.51	545	1.00	1.48	0.12	2

Summary

The Environmental Assessment Study recommends the extension of Livingston Avenue from west of Emily Street through to Oakes Road North. The road will be constructed on agricultural land within the Greenbelt, north of the Niagara Escarpment and south of the CN tracks. The proposed road will be designed to ensure there is no-net-impact on the rate of stormwater runoff discharge to any given receiving water system. The proposed road and ditches will be graded to ensure the pre- to post-development catchment flows to the outlets remain the same. The stormwater runoff from the proposed road will be conveyed via curb and gutter to a storm sewer. The stormwater will be controlled in the storm sewer and released downstream at the same rate as the pre-development flow rates. The storm sewer design is left to later stages of design as it depends on the finalized road profile and elevations.

Four culverts are proposed along the extension. Culvert 1 will permit external flows from the south side of the Livingston Avenue extension to continue to flow to the Vine Road rear-yard intermittent drainage channel in the eastern section of the Study Area. Culvert 2 will permit the unnamed watercourse to flow unimpeded from the south side of the Livingston Avenue extension. Culvert 3 will convey the ditch flows along the east side of Hunter Road from the south side to the north side of the Livingston Avenue extension. Culvert 4 will permit external flows from the south side of the Livingston Avenue extension to continue to flow to the ditch along the west side of Hunter Road.

The culverts have been sized to ensure hydraulic passage of the appropriate design storm. However, further analysis is required in the detailed design stage to ensure that all hydraulic criteria are met for the culverts as found in the MTO HDDS.

Ditches are proposed along both the north and the south side of the extension. The south side ditches will divert flows from external catchments in the south to the appropriate culvert to maintain existing drainage patterns. The north side ditches will capture a small segment of the extension right-of-way that cannot be captured from the road storm sewer system. The full design of the ditches will be completed at the detail design stage.

Figures

Appendices