Kirby Road Widening Class Environmental Assessment

Jane Street to Dufferin Street

Drainage and Stormwater Management Report

City of Vaughan
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1 Introduction

The City of Vaughan is undertaking a Municipal Class Environmental Assessment (EA) Study to assess potential transportation improvements to Kirby Road from Jane Street to Dufferin Street. HDR has been retained by City of Vaughan to conduct the Kirby Road Widening EA study.

This Drainage and Stormwater Management Report has been prepared in support of the Class EA study and complies with the Ministry of the Environment, Conservation and Parks (MECP), Toronto and Region Conservation Authority (TRCA), York Region Road Design Guidelines, and the City of Vaughan's Policies and Standards. The Kirby Road Widening EA study limits are shown in **Figure 1.**

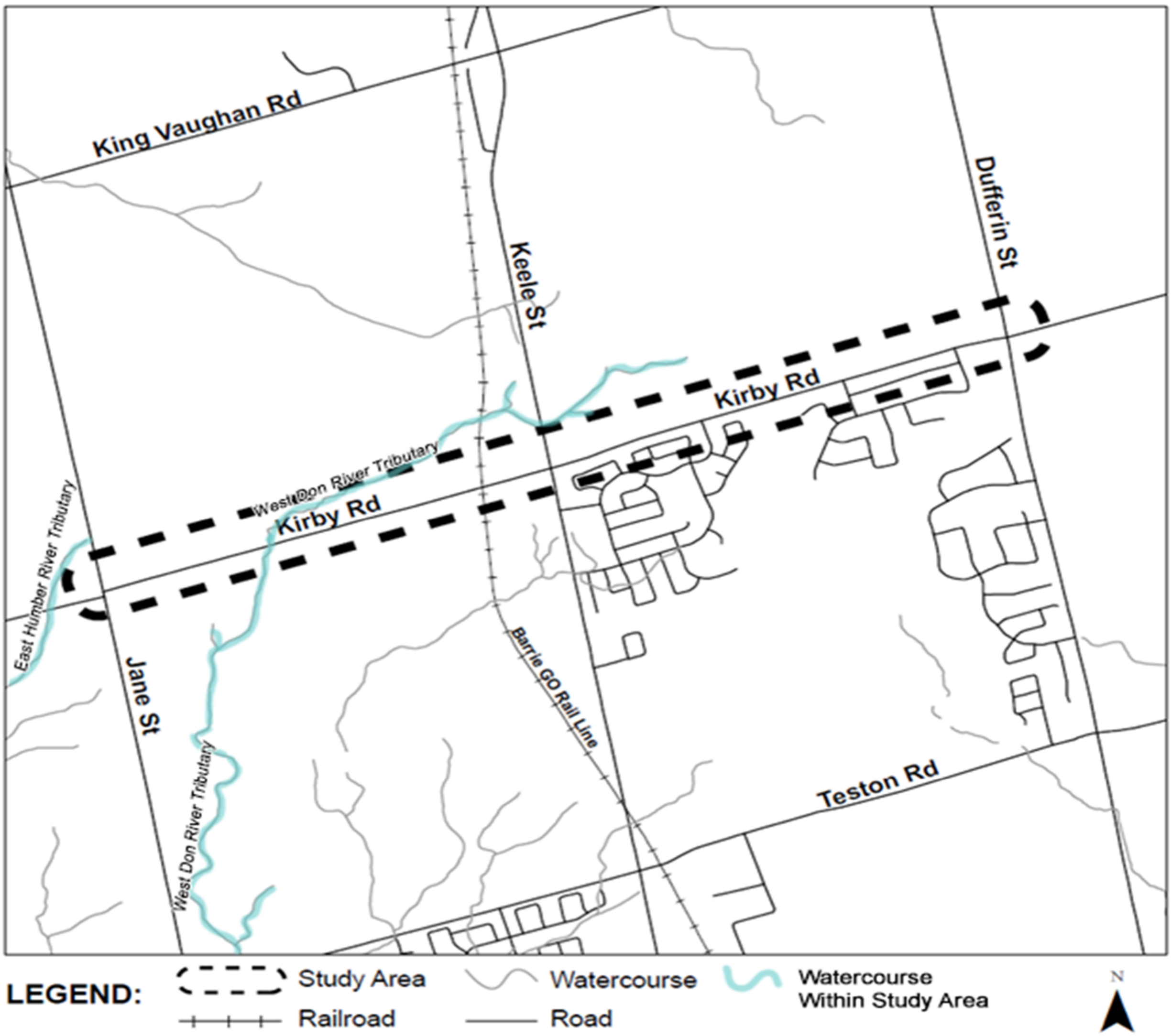


Figure 1: Study Area and Study Corridor

The Kirby Road Widening EA study limits span approximately 4.2 km in the City of Vaughan. Kirby Road is a two-lane east-west arterial road and intersects with a number of existing and future local roads and entrances within the project limits. The Barrie GO Rail line crosses Kirby Road approximately 315 m west of Keele Street. The existing right-of-way width and land use varies throughout the corridor.

There is one watercourse crossing located within the study area. It is a tributary of the West Don River and is within the jurisdiction of Toronto and Region Conservation Authority (TRCA).

The objective of the Drainage and Stormwater Management Report is to develop a strategic approach to the level of development of the proposed project that will:

- Identify and evaluate existing drainage patterns and transverse culvert locations;
- Identify potential stormwater runoff quality and quantity impacts to the receiving watercourses/ storm sewer systems resulting from changes to the roadway cross-section (i.e. increased pavement area); and
- Propose an appropriate drainage system and transverse culvert upgrades, and a stormwater management system in conjunction with the proposed road widening to mitigate any potential impact.

1.1 Background information

In preparation of the Kirby Road widening EA Drainage and Stormwater Management Report, the following essential documents were obtained and reviewed:

1. York Region Road Design Guidelines, June 2020;
2. Ministry of the Environment, Conservation and Parks (MECP) Stormwater Management Practices Planning and Design Manual, March 2003;
3. Ministry of Transportation (MTO) Highway Drainage Design Standards, January 2008;
4. Toronto Region Conservation Authority Stormwater Management Criteria, August 2012;
5. City of Vaughan Engineering Design Criteria & Standard Drawings, 2016;
6. North Vaughan and new Communities, Transportation Master Plan, Final Report, prepared by HDR, January 2019;
7. Stormwater Management Master Plan, The City of Vaughan, prepared by Cole Engineering Group Ltd., June 2014;
8. Block 27 Subwatershed Study, Teston Green (Block 27) Landowners Group, prepared by Cole Engineering Group Ltd., June 2017;
9. Kirby Road Extension, Environmental Study Report, Appendix C11, Stormwater Management, prepared by Schaeffer & Associates Ltd., May 2019;
10. Don River Watershed Plan, Aquatic System – Report on Current Conditions, TRCA, 2009
11. Don River Watershed Plan, Surface Water Hydrology/Hydraulics and Stormwater Management – Report on Current Conditions, TRCA, 2009
12. MECP Response to Notice of Commencement Letter dated February 20, 2020.

2 Existing Drainage Conditions

2.1 Watershed and Subwatershed

The Toronto and Region Conservation Authority (TRCA) has jurisdiction with respect to drainage and stormwater management of the Don River Watershed within the Kirby Road widening EA project limits. The Don River Watershed encompasses approximately 360 km^2 of land area. The Study area falls within the Upper West Don and Upper East Don River subwatersheds per the Don River Watershed Plan, Surface Water Hydrology/Hydraulics and Stormwater Management – Report on Current Conditions (TRCA, 2009). The study area also falls under the jurisdiction of the Ministry of Northern Development, Mines, Natural Resources and Forestry (NDMNRF) Aurora District. There is one (1) watercourse crossing within the study limit. The West Don River originated to the North of the Kirby Road and crosses Kirby Road approximately 750 m east of Jane Street. Refer to the Drainage Plan in **Appendix A** for water crossing location. The West Don River is ephemeral where it crosses the Kirby road. The channel is intermittent in nature at the south of Kirby Road and gradually becomes permanent just upstream of the Teston Road.

2.2 Land Use

The existing land use along Kirby Road is mostly agricultural with significant environmental features including greenbelt, woodland, wetland and provincially significant wetland (PSW). **Figure 2** shows the natural heritage provided in the vicinity of the study area. There are also residential settlements along the south side of Kirby Road from Keele Street to Dufferin Street.

Moreover, six potential Headwater Drainage Features (HDFs) were identified within the study area. HDF1 is a roadside ditch within the northeast corner of the study area. HDF2 and HDF2-001 are an unconstrained feature leading to a roadside ditch located along the northern edge of the study area. HDF3 and HDF4 are undefined features that connect to the roadside ditches in the western extent of the study area. HDF5 is the wetland along the northern extent of the study area.

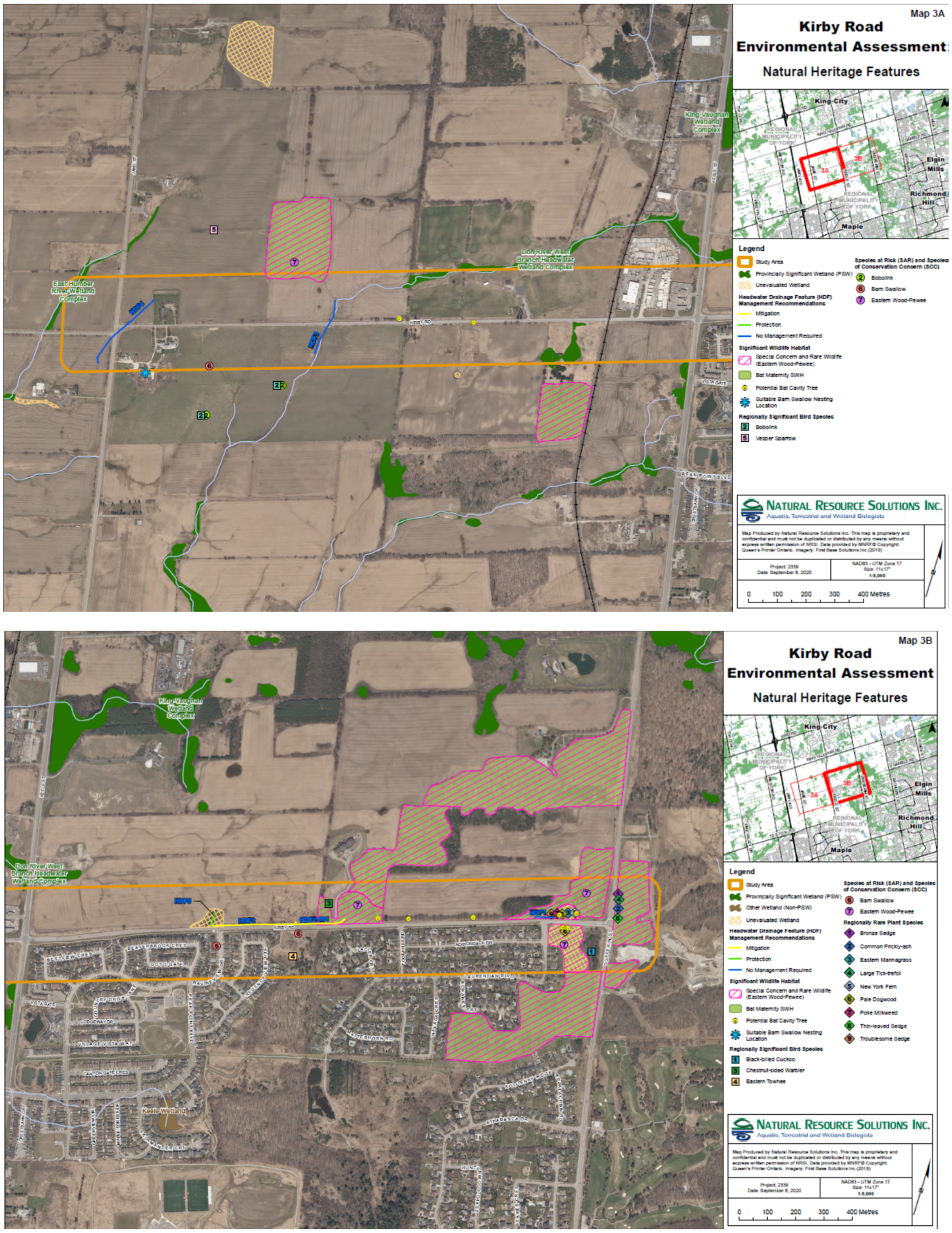


Figure 2: Existing Conditions Natural Heritage (September 8, 2020)

2.3 Hydrogeological Conditions

Preliminary Geotechnical and Hydrogeological Investigations were completed for the Kirby Road EA by Thurber Engineering Ltd. in January 2021 and June 2021, respectively. For these investigations, thirteen (13) boreholes were drilled to depths ranging from 3.7 m to 31.1 m. To support the hydrogeological investigation, twelve (12) monitoring wells, including 4 pairs of nested wells, were installed in selected boreholes within the project corridor to measure groundwater levels and soil material properties.

Based on the results of the Geotechnical Investigation, the soil material at the locations where low impact development (LID) measures are proposed was classified as Sandy and Gravelly. The estimated hydraulic conductivity of this type of material is 120 mm/hr, or 3.3 x 10-3 cm/s (Rawls, W.J. et al., 1983). This approximately corresponds to an infiltration rate of 98 mm/hr, per Table C1 in Appendix C of the CVC/TRCA LID SWM Planning and Design Guide (2010). A safety correction factor of 3.0 was applied to estimate the soil infiltration rate at the base of the proposed BMPs. Accordingly, the percolation rate of the native soil is estimated to be 32.7 mm/hr.

As part of the Hydrogeological Investigation, groundwater levels were measured manually at monitoring wells in July and September 2020. In addition, the study includes a monitoring well program to measure groundwater level over a duration of two years and observed groundwater levels over the first year is available, from July 2020 to June 2021. Based on the results currently available, in the locations where LID measures are generally proposed groundwater was not observed. Throughout the entire project corridor, where groundwater was observed at monitoring wells, the groundwater levels ranged from 1.7 m to 26.9 m below the ground surface.

During the detailed design stage, in-situ measurements should be completed at all proposed LID locations to confirm the soil infiltration rates and groundwater levels.

2.4 Existing Drainage Pattern

The Kirby Road corridor has a primarily rural cross-section within the study limit, the roadway is drained by roadside ditch and culvert systems with ultimate discharge to the tributaries of West Don Rivers and East Humber River. Refer to the Drainage Plans in **Appendix A** for additional details. **Table 2-1** summarizes the approximate locations and areas for each of the drainage areas.

Table 2-1: Summary of Existing Drainage Areas

Drainage Area ID	Description	Drainage Area (ha)	From Station	To Station	Discharge Location
A	From 235 m west of Jane Street to Jane Street	0.89	0+078	0+313	Discharge to East Humber River
B	From Jane Street to 235 m east of Jane Street	0.97	0+313	0+548	Discharge to Existing Ditch along Jane Street
C	From 235 m east of Jane Street to Keele Street	6.64	0+548	2+350	Discharge to West Don River
D	From Keele Street to 650 m east of Keele Street	3.35	2+350	3+003	Discharge to Existing Ditches along Keele Street
E	From 650 m east of Keele Street to Dufferin Street	6.05	3+003	4+433	Discharge to Existing Storm sewer system on Foot Hills Road via Ditch Inlet

2.5 Aquatic Resources

The watercourse that exists within the study limits is part of the West Don Subwatershed and is under the jurisdiction of Toronto and Region Conservation Authority (TRCA) and Ministry of Northern Development, Mines, Natural Resources and Forestry (NDMNRF) Aurora District. The watercourse crossing identified within the study limits is the West Don River, which is classified as intermittent cool to warm water system in the Don River Watershed Plan, Aquatic System – Report on Current Conditions (TRCA 2009). This tributary of Don River is entirely contained within the Natural Heritage System of the Protected Countryside area of the provincial Greenbelt Plan (MMAH 2010).

Based on a review of fisheries collection records from the DFO Distribution of Fish and Species at Risk maps, no regulated habitats for aquatic species at risk were identified within the study limits. Instream barriers to fish movement have been identified at the crossing within Kirby Road and as part of future development process consideration should be given to the removal of these barriers to facilitate opportunities for fish to move further upstream.

2.6 Transverse Drainage Crossings

There is one (1) transverse crossings identified within the Kirby Road Widening EA study corridor, **Table 2-2** summarizes the size, type and location of the existing culvert structure. Refer to the Drainage Plans in **Appendix A** for additional details.

Table 2-2: Summary of Transverse Crossings

Crossing (Watercourse)	Crossing Location	Culvert Dimensions (Diameter / Span x Rise) (m)	Culvert Description	Culvert Length (m)
West Don River	750 m east of Jane Street	2 – 0.6	Twin CSP[1]	10

Note 1: CSP: Corrugated Steel Pipe

2.6.1 Existing Condition Summary

The Kirby Road EA Draft Structural Assessment Report by HDR (October 2020) provides detailed information regarding the existing condition of the crossing structure within the project limits. A site visit was conducted by HDR structural staff on October 30, 2020.

Table 2-3 provides a summary of the structural conditions of the existing culvert crossing.

Table 2-3: Summary of Transverse Crossings Condition Assessment

Crossing (Watercourse)	Material/ Crossing Type	Overall Condition[1]
West Don River	Twin CSP	Good condition

Note 1: Per Structural Assessment Report by HDR (October 9, 2020)

2.6.2 Assessment Criteria - Culverts Crossings on a Watercourse

Hydraulic assessments of the watercourse crossings within the Kirby Road Widening EA study area were undertaken in accordance with the Ontario Ministry of Transportation's Highway Drainage Design Standards (2008) and the York Region Road Design Guidelines (2020).

Design Flows

Based on the MTO Drainage Standard WC-1, the design flow for structures crossing Urban Arterial roadways with spans less than 6.0 m is the 50 year flow. For structures with spans greater than 6.0 m, the design flow is the 100 year flow.

Freeboard

The minimum required freeboard for culverts crossing Arterial roadways has been specified as 1.0 m between the design high water level and the edge of the travelled lane per MTO Drainage Standard WC-7: Culvert Crossings on a Watercourse.

Clearance

The minimum required clearance between the design water level and the lowest soffit of the structure has been specified as 1.0 m per MTO Drainage Standard WC-2: Freeboard and Clearance at Bridge Crossings for Freeway & Urban Arterial roadways.

2.6.3 Hydraulic Assessment of Transverse Crossings

The TRCA hydraulic (HEC-RAS) models were available and provided for the West Don River crossing, and the design peak flows were obtained from the existing hydraulic models.

It is recommended that during the Detailed Design, the design flows be reviewed and verified to confirm any changes to the land-use and associated hydrologic information that may affect the peak flows presented in this Class EA study. A summary of the storm design peak flows of the transverse crossings is presented in **Table 2-4**.

Table 2-4: Design Peak Flows - Transverse Crossings

Watercourse Crossing	Crossing location in HEC-RAS	Type	Peak Flow (m^3/s)		
			50 Year Storm	100 Year Storm	Regional Storm
West Don River	3307.12	Twin CSP Culverts	0.79	0.87	25.77

A hydraulic assessment of the existing crossings was conducted to determine the hydraulic performance under existing conditions. The HEC-RAS hydraulic models provided by the TRCA were reviewed and updated to reflect the existing crossing conditions based on the available record drawings and survey data completed for this EA study.

Based on the MTO Highway Drainage Design Standards, culvert capacities were assessed based on the 50 year design storm event for structure with spans less than 6.0 m to determine the freeboard between the water surface elevation and the road elevation and the vertical clearance between water surface elevation and the lowest point of soffit.

Table 2-5 summarizes the hydraulic analysis results for the watercourse crossing along the study corridor. All hydraulic assessment output files are provided in **Appendix B**.

Table 2-5: Hydraulic Assessment Results for Transverse Crossings (Existing Condition)

Crossing	Type	U/S Invert (m)	D/S Invert (m)	Length (m)	Road Elev. (m)	Water Surface Elev. (m)			Freeboard (m)	Remarks
						50 Yr	100 Yr	Reg.		
West Don River	Twin Culvert	271.32	270.51	10	272.41	272.08	272.14	272.85	0.33 (50 yr)	Does not meets MTO freeboard criteria, Regional storm overtops roadway

The results presented in **Table 2-5** indicate that West Don River Crossing does not meet the freeboard criteria of minimum 1.0 m from the design high water level under the 50 year storm event. The Regional Storm event results in overtopping Kirby Road at the crossings.

3 Proposed Drainage Conditions

3.1 Roadway Drainage System

The preferred alternative design concept for Kirby Road from Jane Street to Dufferin Street recommends widening the road from two to four lanes, urbanization, the addition of cycle tracks and sidewalks on both sides of the road. The design concept also includes an underpass at the Barrie GO Rail corridor crossing and realignment of Kirby Road at the intersection of Jane Street. Overall, the existing drainage patterns and discharge locations will not be altered per the proposed roadway improvements, with the exception of the drainage pattern at the underpass, as a result of the proposed roadway profile.

3.1.1 Minor Drainage System

The overall drainage pattern will be consistent with the existing conditions. The storm sewer system for the proposed roadway configuration is to be designed for a 5 year storm event per the City of Vaughan Design Criteria. To accommodate the widening and urbanizing the roadway cross-section between Jane Street to Dufferin Street, the existing conveyance ditches will be replaced with a series of catchbasins and storm sewers, which will convey runoff to the existing discharge locations. The area west of Jane Street will remain rural and should be tied back to the existing system. For the storm sewer discharge locations, refer to the Drainage Plans in **Appendix A**. A summary listing the right-of-way drainage area characteristics is provided in **Table 2-1.**

3.1.2 Major Drainage System

The major drainage system utilizes the Kirby Road right-of-way to convey overland flows from major storm events (greater than 5 year storm event up to and including the 100 year storm event). Major system relief will occur at major watercourse crossing and intersections. At these locations, major system inlets will capture the 100 year flow and direct it to the appropriate outfalls. For major system flow route details refer to the Drainage Plans in **Appendix A**.

3.2 Transverse Crossings

There is one watercourse crossing within the study corridor. The proposed size, structure and location of the crossing were determined based on the existing structure condition assessment, fluvial geomorphologic assessment, proposed roadway geometry, grading impacts, and hydraulic performance, with the objective of improving the drainage condition at the crossing and addressing any existing deficiencies. Extension of the twin CSP culverts at the Crossing is required to accommodate the proposed roadway improvements, and the angle of the culvert is proposed to be straightened from a skewed position. A summary of the recommended approach for upgrades at the watercourse crossing is provided in **Table 3-1**.

Table 3-1: Watercourse Crossing Recommendations

Crossing ID / Watercourse	Location	Recommendations for Bridge / Culvert Upgrades
West Don River	Sta. 1+060	**Culvert extension** is required to accommodate roadway improvements. The required extension is 19 m for a total culvert length of 29 m.

3.2.1 Hydraulic Assessment of Proposed Transverse Crossings

Under proposed conditions, the drainage boundary and design peak flow values for the transverse crossings are considered to remain unchanged compared to the existing conditions. The increase in the pavement area as a result of the corridor improvements is negligible in comparison to the large external drainage areas contributing to the watercourse crossing location. Therefore, the design peak flows based on the current land use conditions (obtained from TRCA's HEC-RAS model) were used to assess the hydraulic performance of the proposed crossings.

The hydraulic assessment for the proposed crossings is based on the preliminary proposed horizontal road design and vertical centreline profile design. Note that the proposed inverts of the crossing culverts are to be confirmed during Detailed Design to accommodate the road design and the roadside ditch grading.

West Don River Crossing

Under proposed conditions, the existing twin CSP culvert is recommended to be extended to accommodate the proposed roadway widening, and the angle of the culvert is proposed to be straightened from a skewed position. Under existing conditions, the current culvert crossing is overtopped by the Regional Storm event by approximately 0.44 m. Under proposed conditions, the culvert crossing is overtopped by approximately 0.45 m. Extending the length of the culvert to accommodate the proposed road widening will result in a negligible increase of 0.01 m in the upstream Regional storm water level as shown in **Table 3-2**.

Table 3-2: Hydraulic Analysis Results for the Transverse Crossings (Proposed Condition)

Crossing	Type	U/S Invert (m)	D/S Invert (m)	Length (m)	Road Elev. (m)	Water Surface Elev. (m)			Remarks
						50 Yr	100 Yr	Reg.	
West Don River	Culvert	271.32	270.51	29	272.41	272.08	272.14	272.86	Does not meets MTO freeboard criteria, Regional storm overtops roadway

The roadway overtopping is attributed to the large flows from West Don River under Regional Storm conditions. A preliminary hydraulic assessment was completed to consider an increase in the hydraulic capacity at this crossing by replacing the culverts with a single concrete box and maintaining the road profile (Option A), the overtopping depth would be reduced to 0.35 m and there would be no increase in the upstream Regional flood level. The freeboard criteria of minimum 1.0 m from the design high water level under the 50 year storm event would not be met.

Another option (B) is to raise the road profile in addition to increasing the hydraulic capacity, the overtopping depth in this scenario would be 0.27 m and there would be no increase in the upstream Regional flood level, but the MTO freeboard criteria would be met.

To eliminate the Regional flood depth over the road, a third Option (C) would be to raise the roadway profile at this location to eliminate overtopping, and provide sufficient freeboard. While this is sufficient from a hydraulic perspective, there would be insufficient cover over the box culvert from a road structure perspective.

Option D considers the effect of increasing the elevation of the road and boulevards while orienting the box culvert to improve downstream morphology. This reduces the required size of the second culvert while eliminating overtopping during the Regional Flood, providing adequate freeboard, and improving constructability.

Additional coordination with both the City of Vaughan and TRCA shall be carried out to finalize the detail design of the culvert and to minimize impacts to the watercourse. The selected alternative will be confirmed during detailed design by completing additional supporting modelling and analysis, using the information available at that time. Updates to the hydraulic modelling and floodplain assessment shall be completed during detailed design to reflect the final design and grading footprint of the crossing.

Table 3-3: Hydraulic Analysis Results for Alternative Scenarios at Don River Crossing

Scenario	Description	Culvert Dimensions (Span x Rise) (m)	Overtopping Elev. (m)	U/S Regional Water Surface Elevation (m)	U/S Water Level Increase (m)	Overtopping Depth (m)	Freeboard (m)
A	Maintain current design profile, increase hydraulic capacity	Single Concrete Box (3900mm x 1200mm)	272.41	272.76	0	0.35	0.95
B	Slightly raising roadway profile and increase in hydraulic capacity	Single Concrete Box (3900mm x 1200mm)	272.57	272.84	0	0.27	1.11
C	Raising roadway profile to eliminate overtopping and increase in hydraulic capacity	Twin Concrete Box (3900mm x 1200mm)	272.57	272.53	0	0	1.18
D	Raising Boulevard, aligning to downstream channel	2 Concrete Box Culverts (3900mm x 1200mm and 3600mm x 900mm)	272.87	272.85	0	0	1.01

3.3 Metrolinx Railway

A grade separation is proposed at the Barrie GO Rail corridor west of Keele street, which will potentially result in Kirby Road being constructed as an underpass beneath the GO Rail crossing. This will result in the disruption of surface flow at this location, as the roadway profile will be lowered by approximately 7.3 meters. Under proposed conditions, the runoff generated from a portion of Drainage Area C will flow towards the low point in the profile below the GO Rail crossing. Based on the available information of the existing catchment outlet location, it may be feasible to drain the surface runoff generated within the underpass area by connecting it to Don River culvert, located approximately 1 km west of the underpass, using a long stretch of storm sewer. This approach may be more cost effective compared to constructing a pumping station to provide drainage during both minor and major storm events. Further investigation and design details, including required water quality and quantity control measures, will need to be completed in the detailed design of the underpass. The proposed design will also address the existing floodplain spill north of the proposed Metrolinx Railway underpass.

4 Stormwater Management Strategy

4.1 Stormwater Management Criteria

The stormwater management plan for the Kirby Road Class EA Study shall be developed to comply with the MECP Stormwater Management Practices Planning and Design Manual, Toronto and Region Conservation Authority (TRCA), York Region Road Design Guidelines, and the City of Vaughan's Policies and Standards.

4.1.1 Water Quality Control

Watercourses within the TRCA's jurisdiction are classified as requiring an "Enhanced" level of protection, which equates to 80% Total Suspended Solids (TSS) removal.

Stormwater management (water quality) measures within the study corridor will be designed to provide an "Enhanced" level of water quality treatment, as a minimum, for the increased pavement area as a result of roadway widening/improvements, per the MECP Response to Notice of Commencement Letter dated February, 2020.

Source Water Protection

Based on a review of the vulnerable areas identified under the Clean Water Act, 2006, the study area is within two vulnerable areas: Significant Groundwater Recharge Area (SGRA) and Highly Vulnerable Aquifer (HVA). To ensure stormwater does not contaminate the groundwater source of municipal drinking water, several ways are identified by MOECC SWM Manual, 2017 to remove storm water constituents before they can reach groundwater resources. The LID design factors for enhancing removal rate specified in Table 4.2.7.1 of MOECC SWM Manual are considered for LID design in the following section and should be followed during the detailed design.

4.1.2 Water Quantity Control

Storm Sewer Systems

Within the project limits, the stormwater runoff from Kirby Road discharges either into the existing storm sewer systems or outlets at the watercourse crossings. For locations where the runoff discharges into an existing system, the minor system design storm (5 year storm) peak flows must be controlled to the existing peak flows, for which the receiving system was designed. The receiving storm sewer systems within the project limits are City of Vaughan municipal systems, which would have been designed based on a 5 year design storm.

Watercourse Crossings

TRCA requires Control post-development peak flows to pre-development levels for all storms up to and including the 100 year storm (i.e. 2, 5, 10, 25, 50, and 100 year storms) using the established unit flow relationships. However, given the limited space within the ROW of the linear transportation corridor, it will be difficult to satisfy these criteria; therefore, a "best efforts" approach to provide sufficient storage to attenuate the post-development peak flows to the pre-development levels for all design storm event is recommended.

4.1.3 Water Balance and Erosion Control

The TRCA criteria for water balance and erosion control requires retention of the first 5 mm of rainfall. This is applicable to increased pavement area as a result of roadway widening/improvements.

4.2 Hydrologic Modelling

A hydrologic analysis has been conducted using the Rational Method to calculate the peak flows under the 2 year to 100 year storm events for both the existing and proposed condition scenarios. The Modified Rational Method was then used to calculate the storage volumes required to control the post-development peak flows for the design storm events to the allowable release rates (i.e. pre-development levels).

City of Vaughan Intensity Duration Frequency (IDF) curves were applied to calculate the existing and proposed condition peak flows, using a minimum inlet time (T_c) of 7 minutes. Details of the hydrologic analysis are provided in **Appendix C**.

4.3 Pavement Area Analysis

A pavement area analysis was performed to determine the increase in impervious surface, which will result from the roadway widening from 2 to 4 lanes, realignment of Kirby Road at the intersection of Jane Street, construction of new cycle tracks and sidewalks and design of an underpass at the Barrie GO Rail corridor crossing.

As a Low Impact Development measure, it is recommended that the boulevard and median areas outside of the active transportation facilities be covered with permeable material (e.g. grass, permeable pavement, etc.) to minimize the overall increase in impervious area along the Kirby Road corridor. Since these are not load bearing surfaces, the use of permeable material will not impact the functionality of the proposed design but will provide water quality and quantity control benefits through runoff reduction. Therefore, the proposed stormwater strategy was developed considering the boulevard and median areas as pervious. Additional details and specifications for the permeable material are to be included in the detailed design stage.

It was determined that the proposed roadway improvements will result in an additional 6.15 hectare increase in pavement area within the Kirby Road study corridor.

Table 4-1: Pavement Area Analysis

Study Corridor	Existing Pavement Area (ha)	Proposed Pavement Area (ha)	Increased Pavement Area (ha)	Percentage Increase
Kirby Rd.	4.38	10.53	6.15	140%

4.4 Water Balance Analysis

A water balance analysis for pre-development and post-development conditions has been completed in accordance with the MECP SWM Guideline (Table 3.1) to determine the net reduction in infiltration as a result of the proposed roadway widening. This is a high level water budget to quantify the existing infiltration, evapotranspiration and runoff from the site. Indirect impacts from runoff to the wetland or diversion of flow from the small, isolated wetland near the Kirby Road and Ravineview Drive intersection can be mitigated through implementation of stormwater management practices designed to mimic existing hydroperiods and runoff volumes. Feature-based water balance analysis would require additional hydrological monitoring at wetland to refine the characterization of existing groundwater and surface water contributions to the natural features which can be done in detail design stage.

Pre-development Conditions

The total project corridor site area is approximately 17.9 ha, comprised of 4.38 ha (25%) of pavement with zero infiltration and 13.52 ha (43%) urban lawns (shallow rooted crops) with an average annual infiltration of 220.8 mm/yr based on an annual rainfall volume of 661.6 mm/yr (Canadian Climate Normals 1971-2000, Lester B. Pearson) and sandy and gravelly soils (Hydrologic Soil Group A), or approximately 29,518 m^3/yr.

Post-development Conditions

The total increase in pavement area would be 6.15 ha (20%). Therefore, the urban lawn area will be reduced to 7.27 ha with an average annual infiltration of approximately 15,872 m^3/yr. There would be a net reduction in infiltration of approximately 13,646 m^3/yr, which would need to be infiltrated annually using the proposed SWM measures. This is discussed in more detail in the following sections.

4.5 Stormwater Best Management Practice Options

Various Best Management Practices (BMPs) for stormwater management were reviewed and assessed for their applicability on this project. Due to the nature of this facility (i.e. linear transportation corridor) and the limited space within the roadway right-of-way, a series of bioretention cells that can be integrated with the proposed streetscaping and parallel to storm sewers are proposed for catchments discharging directly to a watercourse to provide quality treatment, erosion control, and water balance. To provide quantity control throughout the Kirby Road corridor, online storage pipes are proposed. For catchments discharging to the storm sewer system, Oil-Grit Separator (OGS) units are proposed to provide pre-treatment.

4.5.1 Bioretention Cells

Bioretention systems allow for stormwater filtration, infiltration, and evapotranspiration from tree and vegetative plantings. For roadway applications, these can take the form of optional sub-surface modular units that are filled with lightly compacted soil within a trench situated beneath the roadway boulevard areas. The trench unit consists of a filter bed which is a mixture of sand, fines and organic material to support vegetation and promote evapotranspiration by allowing surface runoff to route through a distribution pipe via gravity within the trench. Soil filtration, bioremediation, infiltration, and evapotranspiration will occur as water filtrates through the soil from the perforated distribution pipe.

The facility will also be lined with geotextile fabric and clean granular fill (20 mm clear stone) below the filter bed for storage and infiltration of roadway runoff. In addition to removing TSS particles, the granular filter within the trench reduces water temperature impact and enhances water balance through infiltration. A perforated underdrain pipe can be incorporated in the granular layer for soils with low infiltration rate to collect and direct the excess runoff to a storm sewer system. The bioretention cell also contributes to controlling downstream erosion through extended detention and reducing flow velocities.

Discharging the runoff into the bioretention systems has the following advantages:

- Boulevard landscaping will receive a supply of rainwater during every rainfall event, thus sustaining the health of the plants;
- Stormwater runoff from the roadways could potentially see significant detention within the bioretention systems, which will result in runoff reduction;
- Water quality treatment will be achieved since stormwater can be routed through the bioretention filter media; and
- For smaller rainfall events, the soil trenches can provide (in the long-term) for complete capture of the runoff through infiltration and evapotranspiration.

The design criteria specified in the SWM Planning and Design Guide (MECP, 2003) and LID SWM Planning and Design Guide (STEP, 2020) were applied to determine the depth and footprint area for the bioretention cells. The maximum allowable depth of the stone reservoir below the underdrain pipe can be calculated using the following formula:

$$d_{r\,max} = i * t_s / V_r$$

where *i* is the infiltration rate of the native soils, which was estimated to be 31.4 mm/hr within the project limits based on the Hydrogeological Investigation (Section **2.3**); t_s is time to drain, which is recommended to be 48 hours; and V_r is void space ratio of the aggregate used, which is typically 0.4 for clear stone. Accordingly, the maximum allowable depth of the reservoir can be calculated to be d_{max} = 3767 mm.

For this project, 1.5 m and 3 m wide bioretention cells with a 0.75 m deep filter bed layer, 0.1 m pea gravel choking layer, and 0.3 m deep gravel storage layer are proposed, for a total facility depth of 1.15 m. Conceptual plan and profiles of the proposed bioretention cells are provided in **Appendix E**. The footprint area of the bioretention cells can be calculated using the following formula:

$$A_f = WQV / (d_c * V_r)$$

where *WQV* is the required water quality volume to meet the ‘Enhanced’ level protection (80% TSS removal), which is determined based on the contributing drainage area and the imperviousness using Table 3.2 of the SWM Planning and Design Manual (MECP, 2003); d_c is the depth of the bioretention cell, and V_r is the void space ratio for the filter bed and gravel storage layer, which is typically 0.4. In addition to providing quality treatment, the provided gravel storage volume beneath the invert of the underdrain pipe will retain water to meet the water balance and erosion control targets. Additionally, the ratio of the impervious drainage area to footprint area of the bioretention cells should be between 5:1 and 20:1 to limit the rate of accumulation of fine sediments and thereby prevent clogging.

The bottom of the bioretention cells should be one (1) meter above the seasonally high goundwater table. According to the Hydrogeological Investigation (**Section 2.3**), the groundwater was not observed where LID measures are generally proposed. This should provide adequate separation between the groundwater table and the bottom of the proposed facilities. Further investigation should be completed during the detailed design stage to confirm adequate separation from the proposed facilities at each location and determine the percolation rate of the native soils using in-situ infiltration testing to ensure the maximum allowable depth of the reservoir is not exceeded.

The bioretention cells can only be proposed for Drainage Areas A and C, where runoff discharges directly into a natural watercourse. However, the bioretention cells are designed to provide water quality treatment for pavement areas equivalent to the total increase in pavement area along the Kirby Road corridor per MECP requirements. For Drainage Areas C, the bioretention cells are sized to provide treatment for the entire pavement area. For Drainage Areas A and E, the bioretention cells are sized to provide treatment for the increased paved area to meet the total increase in pavement area within the project limits. In addition to providing 'Enhanced' level protection (80% TSS removal), the provided storage volume within the bioretention cells includes the volume required to retain the first 5 mm of rainfall to meet the TRCA target. The TRCA erosion control target will be achieved through extended detention within the bioretention cells. Pre-treatment of the runoff directed to the bioretention cells using catchbasin inserts (e.g. CB Shield) is recommended.

Table 4-2 lists the details of the bioretention cells proposed along the Kirby Road corridor. For locations of the proposed bioretention cells, refer to the Drainage Plans provided in **Appendix A**. Detailed calculations are provided in **Appendix D**.

Table 4-2: Summary of Proposed Water Quality Treatment Strategy

Drainage Area ID	Additional Pavement Area (ha)	Req'd Water Quality Volume (m^3)	Req'd Water Balance Storage[1] (m^3)	Proposed Length (m)	Treated Area (ha)	Provided Water Balance Volume[2] (m^3)	Provided Quality and Erosion Control Volume (m^3)
A	0.22	9	11	73	0.22	14	55
B	0.23	9	12	-	0.00	-	-
C	2.82	116	141	733	4.40	274	1049
D	0.95	33	47	-	0.00	-	-
E	1.92	76	96	321	1.92	122	469
Total	**6.15**	**243**	**307**	**1127**	**6.54**	**410**	**1573**

[1] Based on the retention of the first 5 mm of rainfall
[2] Provided storage volume

Through the proposed water quality treatment strategy, a total of 6.54 ha of pavement area will receive water quality control through the use of the bioretention facilities, which exceeds the 6.15 ha increase in pavement area across the Kirby Road corridor. A total of 410 m^3 and 1573 m^3 of water balance and water quality/erosion control storage volumes, respectively, are proposed using the facilities, which exceeds the required storage volumes based on TRCA criteria.

The total provided storage volume of 410 m^3 is equivalent to the retention of 6.7 mm of runoff over the entire pavement area of 6.54 ha. This corresponds to retaining the 55th percentile rainfall volume, which is equivalent to 23,798 m^3/yr, well exceeding the required 13,646 m^3/yr infiltration needed to meet the pre-development water balance. During Detailed Design, the location and performance characteristics of the bioretention facilities should to be confirmed to ensure that all bioretention cell design criteria are met.

4.5.2 Oil-Grit Separator Units

Oil/grit separator (OGS) units combine a storage chamber for sediment trapping and oil separation with drainage inlets for intercepting or receiving roadway stormwater runoff. At locations where the roadway drainage area is less than 2.0 ha, oil-grit separator units can be used for water quality control. OGS units are generally accepted to provide a maximum sediment removal efficiency of 50%. Consequently, additional mitigation measures shall be considered in series with each oil-grit separator to achieve the "Enhanced" protection (Level 1) water quality target.

For the drainage areas that ultimately discharge to a storm sewer system (B and D), pre-treatment using catchbasin inserts (e.g. CB Shield) and OGS units is recommended, to achieve the required quality control in combination with the existing end-of-pipe facilities.

4.5.3 Online Storage Pipes

At existing storm system connections, consideration should be given to providing over-sized storage pipes with flow control devices (e.g. orifice plate) upstream of the discharge location to provide storage volume and peak flow control.

Quantity control is required for the outfalls to Don River. At these locations, the required storage can be provided as a combination of underground storage and surface ponding. The required storage is considered as the largest of the storage required to control the peak flow from all storm events, up to the 100 year storm event, to the existing levels. As previously discussed, due to the linear nature of the corridor and limited space for stormwater management facilities within the Kirby Road right-of-way, the unit-flow rates established by the TRCA cannot be met for Drainage Areas A to D, and a "best-efforts" approach is proposed by controlling post-development peak flows for the 2 year to 100 year events to the existing levels.

The required storage volumes to achieve the quantity control targets for each catchment are summarized in **Table 4-3**. Online storage pipes shall be designed to provide the required storage in the detailed design stage. Detailed calculations are provided in **Appendix D**.

Table 4-3: Summary of Proposed Water Quantity Treatment Strategy

Drainage Area ID	Drainage Area (ha)	Existing Pavement Area (ha)	Additional Pavement Area (ha)	Required Storage to Control Minor Flows[1] (m^3)	Required Unitary storage volume (5 year) (m3)	Required Storage to Control Major Flows[2] (m^3)	Required Unitary storage volume (100 year) (m^3)
A	0.89	0.26	0.22	23	178	52	363
B	0.97	0.27	0.23	24	188	54	383
C	6.64	1.58	2.82	294	1543	664	3161
D	3.35	0.70	0.95	99	630	223	1277
E	6.05	1.58	1.92	200	1275	452	2601
Total	**17.90**	**4.38**	**6.15**	**640**	**3814**	**1445**	**7784**

[1] Based on the capacity of the receiving storm sewer system (up to 5 year storm)
[2] TRCA requirements (up to 100 year storm)

Through the proposed water quantity control strategy, a total of 6.15 ha of pavement area will receive quantity control through the proposed online storage pipes. A total of 640 m^3 of storage volume will need to be provided to attenuate minor peak flows and a total of 1445 m^3 will need to be provided to attenuate major peak flows to existing levels. During Detailed Design, the location, pipe sizing, and orifice sizing of the online storage pipes will need to be determined to ensure that the water quantity control criteria can be met.

4.5.4 Supplemental BMP Measures

Through discussions with TRCA, opportunities to implement supplemental stormwater best management practice (BMP) measures to augment the treatment proposed by the bioretention systems and OGS units may be considered.

The supplemental BMP measures shall be designed based on the site conditions and further geotechnical and hydrogeological investigations are to be undertaken during the next phase of design. Any low impact development measures shall meet the design criteria per the STEP Low Impact Development Stormwater Management Planning and Design Guide (2020).

A list of potential LID measures that may be considered for implementation within the study corridor during the Detailed Design is provided as follows.

Infiltration Trenches

Infiltration trenches are linear conveyance facilities lined with geotextile fabric and clean granular fill (50 mm clear stone) for quality treatment of roadway runoff. In addition to removing TSS particles, the granular filter within the trench reduces water temperature impact and enhances water balance through infiltration. It also contributes to controlling downstream erosion by reducing flow velocities.

Vegetated Filter Strips and Plunge Pool

Vegetated filter strips operate through a combination of sedimentation and infiltration. Shallow flows are routed over grassed areas, which allow the filter strips to function by slowing down the runoff velocity and filter out suspended sediment and associated pollutants and allowing infiltration into underlying soils. Filter strips are applicable where there are low, flat vegetated areas that will allow runoff to disperse over a wide area.

Plunge pools are designated depression areas at the base of storm outfalls to prevent scouring and erosion due to the high velocity of the flow at the outfall pipe locations. The plunge pool also functions as a level spreader that reduces the concentrated flow from the outfall and spreads the flow onto a natural vegetated floodplain area.

Vegetative filter strips and plunge pools should be considered at the storm outfall locations to disperse the energy of the flow and to provide additional water quality control in series with the bioretention cells as a treatment train system.

4.6 Erosion and Sediment Control during Construction

Erosion and sediment control measures should be implemented and monitored through the construction period. Construction activities should be conducted during periods that are least likely to result in in-stream impacts to fish habitat.

Detailed erosion and sediment control plans will be required as part of the detailed design component for all phases of the construction. The erosion and sediment control plans will be subject to review and approval by the various external agencies involved in the project, including TRCA.

During construction, disturbances to watercourse riparian vegetation should be minimized. If riparian vegetation is removed or disturbed, erosion and sediment control measures such as silt fences, rock flow check dams, and sedimentation ponds should be utilized to provide a maximum protection of local and downstream aquatic resources. These measures should be maintained during construction and until disturbed areas have been stabilized with seed and mulch. Additionally, topsoil should not be stockpiled close to the watercourses and water should not be withdrawn from these sensitive streams for construction purposes.

The site engineer and contractor will be responsible for delineating work areas and ensuring that erosion and sediment control measures are functional. In addition, the engineer will ensure that if required, provisions related to fisheries and watercourse protection is met and that any required fish habitat compensation measures are implemented in accordance with the terms and conditions of the Fisheries Act Authorization.

4.7 Stormwater Management Plan Summary

The proposed stormwater management plan for the project has been developed by examining the opportunities and constraints within the entire study corridor. Runoff from the paved roadway area will be conveyed to the proposed oil-grit separators and bioretention system through the roadway storm sewer systems and discharge into either existing storm sewer systems or natural watercourses. As mentioned in **Section 4.3**, the total roadway pavement area will increase by 6.15 ha, including cycle tracks and sidewalks within the boulevard areas. Enhanced level water quality, water balance, and erosion control treatment will be provided for 6.54 ha of pavement area, exceeding the MECP requirement of providing treatment to the increased pavement area. The stormwater management plan for this project is presented on the Drainage Plans in **Appendix A**. **Table 4-4** provides a summary of the water quality treatment and quantity control strategies proposed to mitigate the increase in impervious surface within the project limits, where road widening is proposed.

Table 4-4: Summary of Stormwater Management Plan

Drainage Area ID	Existing Pavement Area (ha)	Additional Pavement Area (ha)	Pavement Area Receiving Quality Treatment (ha)	Water Balance Storage Volume Provided (m^3)	Required Quantity Control Storage[3] (m^3)
A	0.26	0.22	0.22	14	52
B[1]	0.27	0.23	0.00	-	54
C[2]	1.58	2.82	4.40	274	664
D[1]	0.70	0.95	0.00	-	223
E	1.58	1.92	1.92	122	452
Total	**4.38**	**6.15**	**6.54**	**410**	**1445**

[1] Areas discharging to municipal systems will be pre-treated using catchbasin inserts and OGS units
[2] Total pavement area is treated in order to meet MECP requirements of treating the overall increased pavement area in the corridor
[3] Based on TRCA requirement (up to 100 year storm)

5 Conclusions

The Kirby Road corridor between Jane Street and Dufferin Street is proposed to be widened from 2 to 4 lanes and urbanized with the addition of cycle tracks and sidewalks on both sides of the road. The proposed design will also include improvement to the existing subsurface road drainage system, as well as new storm sewer systems for urbanized cross-sections, consisting of storm sewer systems with catchbasins along the curb lines, to convey stormwater runoff to the various outfall locations along the corridor.

The study area is within the area regulated by TRCA. There is one (1) watercourse crossing within the Kirby Road study corridor, which is at West Don River. Culvert extension is required to accommodate roadway improvements. Hydraulic assessment of the crossing using available TRCA model indicated that it does not meet the MTO design criteria with respect to freeboard and the Regional Storm event results in overtopping Kirby Road at the crossing.

Under proposed conditions, extension of the twin CSP culvert is one option considered to accommodate the proposed roadway widening, and the angle of the culvert is proposed to be straightened from a skewed position. Kirby Road is overtopped by the Regional storm event by approximately 0.44 m at this location under existing conditions, and 0.45 m under proposed conditions with the culvert extension option. Extending the length of the culvert to accommodate the proposed road widening will result in a 0.01 m increase in the Regional upstream flood level, which can be considered negligible. The preliminary hydraulic assessment indicated that the overtopping could be eliminated at this crossing and the MTO freeboard and clearances met by raising the road profile and increasing the hydraulic capacity,. This approach is recommended by TRCA to utilize this opportunity to improve the safety of the crossing. A more detailed analysis using a HEC-RAS model based on available information at the time of Detailed Design will be required to confirm the results of the preliminary assessment and assess the impact along the upstream reach of the watercourse.

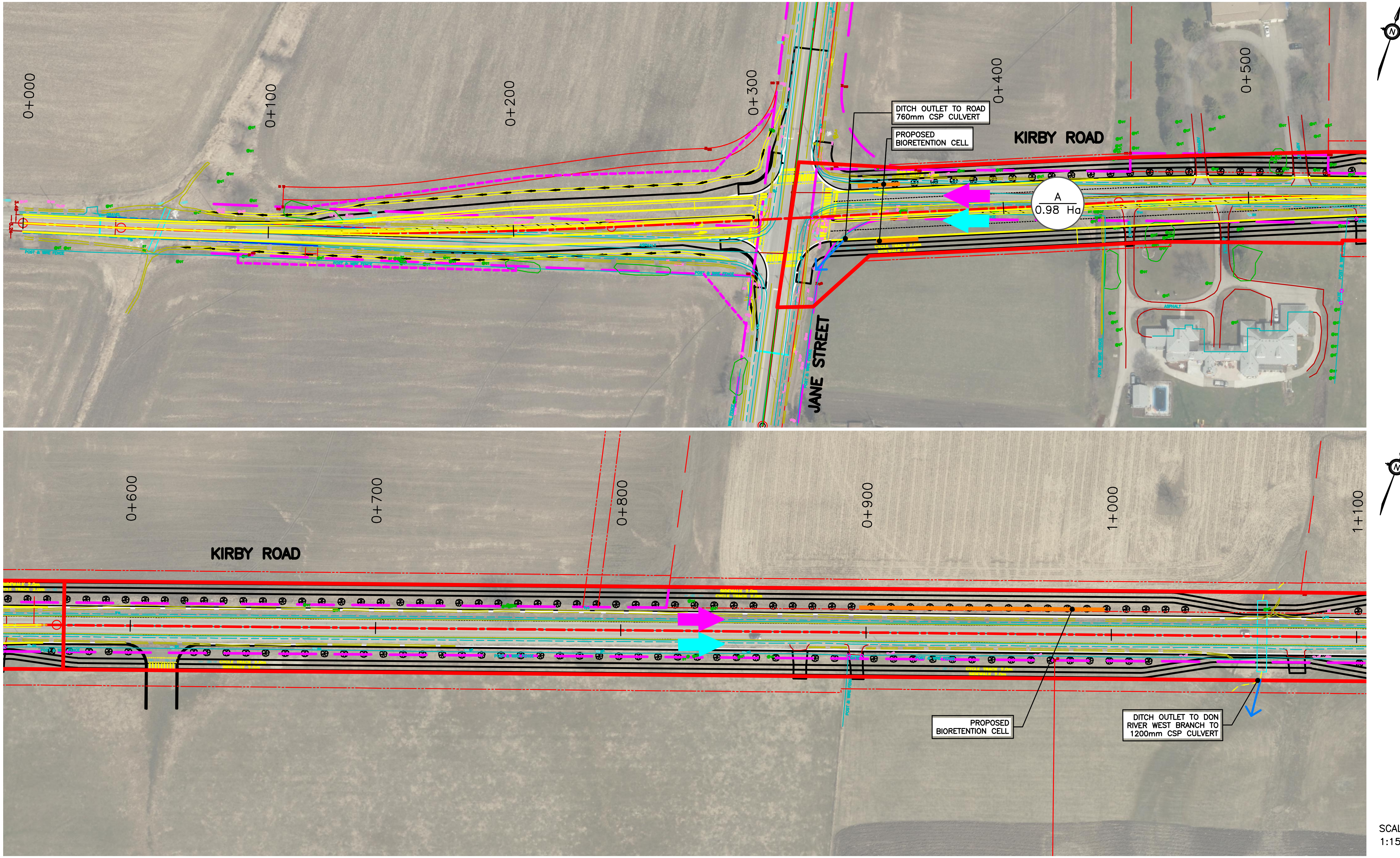
A grade separation is proposed at the Barrie GO line crossing west of Keele Street, which will potentially result in Kirby Road being constructed as an underpass beneath the GO Rail crossing. This will result in the disruption of surface flow and the subsurface storm sewer system at this location, as the roadway profile will be lowered by approximately 7.3 meters. Based on the available information of the existing catchment outlet location, it may be feasible to drain the surface runoff generated within the underpass area by connecting it to Don River culvert, located approximately 1 km west of the underpass, using a long stretch of storm sewer. This approach may be more cost effective compared to constructing a pumping station to provide drainage during both minor and major storm events. Further investigation and design details, including required water quality and quantity control measures, will need to be completed in the detailed design of the underpass. The proposed design will also address the existing floodplain spill north of the proposed Metrolinx Railway underpass.

The proposed road improvements will result in an additional pavement area of 6.15 ha. Stormwater best management practices, including catchbasin inserts, oil-grit separators, bioretention systems, and online storage pipes, are proposed to provide storm water quality treatment, water balance, erosion control, and quantity control for the increased runoff from the roadway right-of-way. As part of the SWM strategy, a total of 6.54 ha of pavement area will receive quality treatment through the proposed bioretention cells, which exceeds the MECP requirement of providing treatment to the increased pavement area. The bioretention cells will also provide 410 m^3 of water balance storage and 1231 m^3 of water quality and erosion control storage volume, which exceeds the required volumes to meet the TRCA criteria. A total of 6.15 ha of pavement area will receive quantity control through the proposed online storage pipes. Opportunities to implement supplemental BMP measures may be considered during the next phases of design in series with the proposed measures to augment the overall water quality treatment.

Appendix A: Drainage Area Plans

100 York Boulevard, Suite 300, Richmond Hill, ON, CA L4B 1J8
(289) 695-4600

METRIC



SCALES
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LEGEND

PROPOSED R.O.W.
EXISTING PROPERTY LINE
EXISTING CL ALIGNMENT
PROPOSED CL ALIGNMENT
PROPOSED CATCHMENT BOUNDARY
PROPOSED STORM SEWER

ROADWAY DESIGN AND GRADING
PROPOSED BIORETENTION CELL
PROPOSED ONLINE STORAGE PIPES

DRAINAGE AREA ID
AREA (ha)

PROPOSED OVERLAND FLOW DIRECTION
EXISTING OVERLAND FLOW DIRECTION

HDR

VAUGHAN
Infrastructure Delivery

KIRBY ROAD
(JANE STREET TO DUFFERIN STREET)
ENVIRONMENTAL ASSESSMENT
DRAINAGE PLAN
STA. 0+000 TO 1+120

SHEET NO.
ST-01

JAN, 2022

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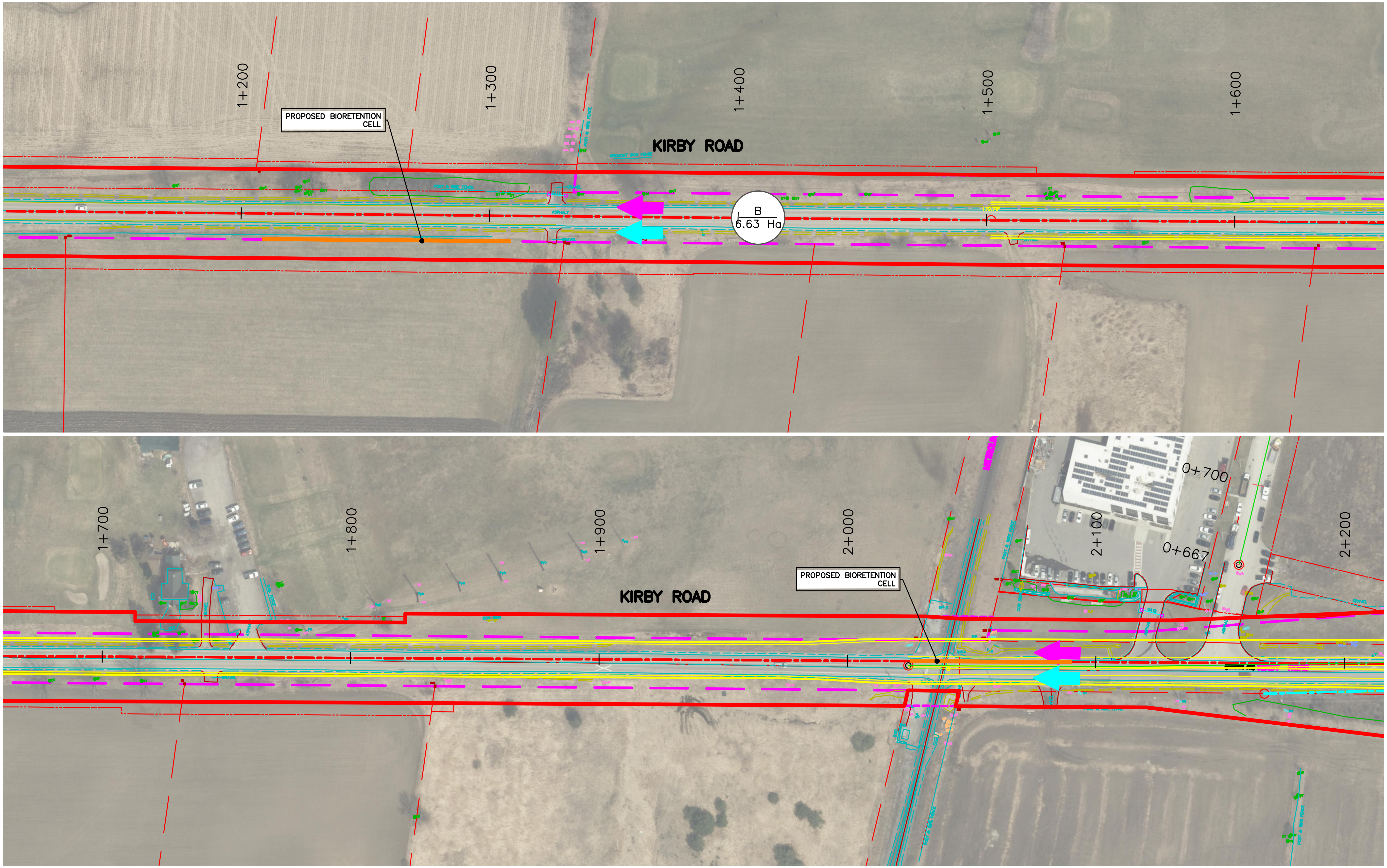

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LEGEND

- PROPOSED R.O.W.
- EXISTING PROPERTY LINE
- EXISTING CL ALIGNMENT
- PROPOSED CL ALIGNMENT
- PROPOSED CATCHMENT BOUNDARY
- PROPOSED STORM SEWER
- ROADWAY DESIGN AND GRADING
- PROPOSED BIORETENTION CELL
- PROPOSED ONLINE STORAGE PIPES
- A — DRAINAGE AREA ID
- xx ha — AREA (ha)
- PROPOSED OVERLAND FLOW DIRECTION
- EXISTING OVERLAND FLOW DIRECTION

HDR

VAUGHAN
Infrastructure Delivery

KIRBY ROAD
(JANE STREET TO DUFFERIN STREET)
ENVIRONMENTAL ASSESSMENT

DRAINAGE PLAN
STA. 1+120 TO 2+230

SHEET NO.
ST-02

JAN, 2022

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METRIC

SCALES
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LEGEND

- PROPOSED R.O.W.
- EXISTING PROPERTY LINE
- EXISTING CL ALIGNMENT
- PROPOSED CL ALIGNMENT
- PROPOSED CATCHMENT BOUNDARY
- PROPOSED STORM SEWER
- ROADWAY DESIGN AND GRADING
- PROPOSED BIORETENTION CELL
- PROPOSED ONLINE STORAGE PIPES
- A — DRAINAGE AREA ID
- xx ha — AREA (ha)
- PROPOSED OVERLAND FLOW DIRECTION
- EXISTING OVERLAND FLOW DIRECTION

VAUGHAN
Infrastructure Delivery

KIRBY ROAD
(JANE STREET TO DUFFERIN STREET)
ENVIRONMENTAL ASSESSMENT
DRAINAGE PLAN
STA. 2+230 TO 3+340

SHEET NO.
ST-03

JAN, 2022

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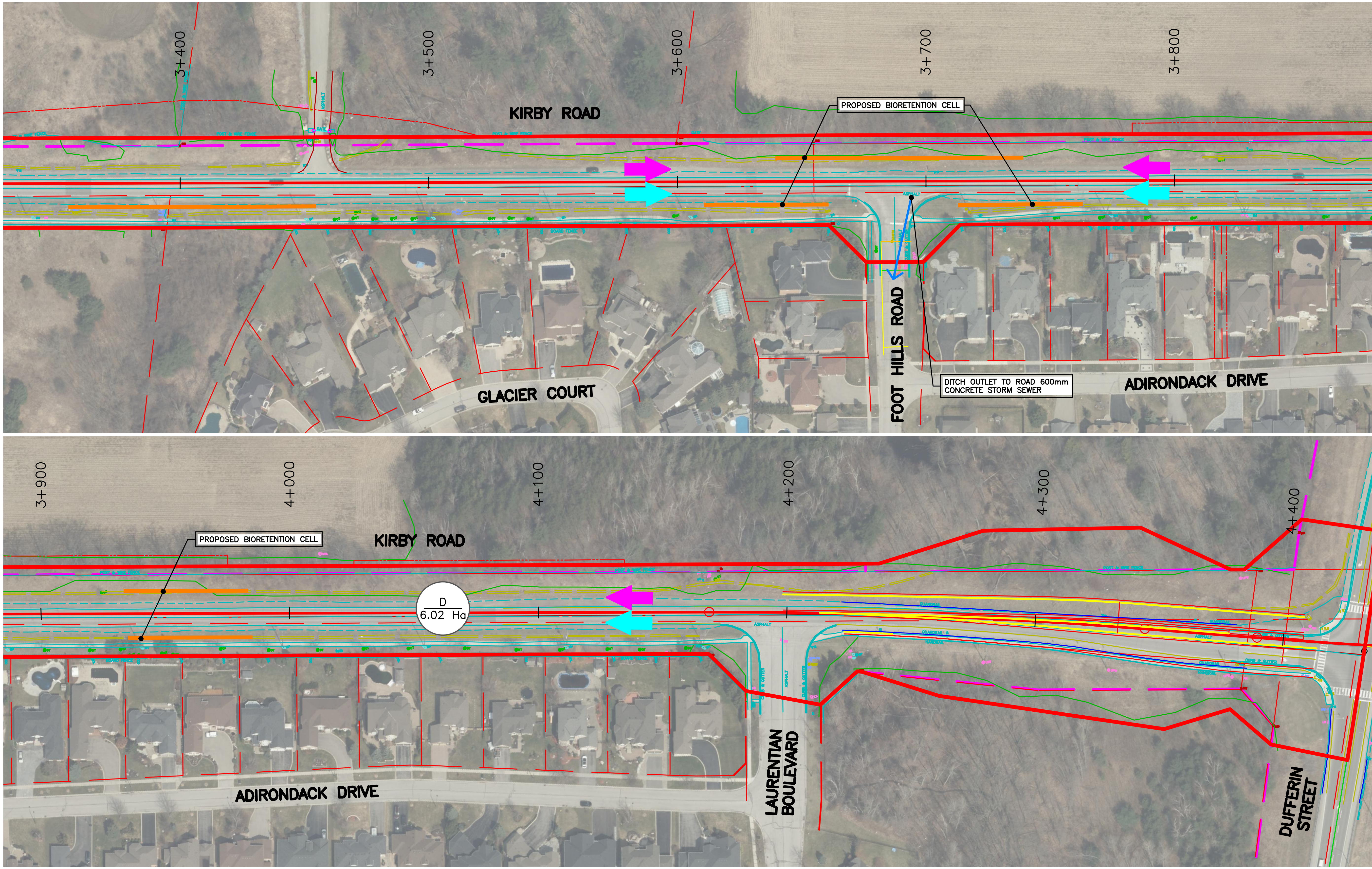

SCALES
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LEGEND

PROPOSED R.O.W.
EXISTING PROPERTY LINE
EXISTING CL ALIGNMENT
PROPOSED CL ALIGNMENT
PROPOSED CATCHMENT BOUNDARY
PROPOSED STORM SEWER

ROADWAY DESIGN AND GRADING
PROPOSED BIORETENTION CELL
PROPOSED ONLINE STORAGE PIPES

A / xx ha — DRAINAGE AREA ID / AREA (ha)

PROPOSED OVERLAND FLOW DIRECTION
EXISTING OVERLAND FLOW DIRECTION

HDR

VAUGHAN
Infrastructure Delivery

KIRBY ROAD
(JANE STREET TO DUFFERIN STREET)
ENVIRONMENTAL ASSESSMENT
DRAINAGE PLAN
STA. 3+340 TO 4+450

SHEET NO.
ST-04

JAN, 2022

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Appendix B: Hydraulic Assessment Output Files

HEC-RAS Locations: User Defined

Reach	River Sta	Profile	Plan	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl
Reach20	3479	Regional	DonPhaseII_Final	14.53	272.48	273.25	273.25	273.42	0.012984	2.58	14.55	41.93	0.98
Reach20	3479	Regional	Proposed	14.53	272.48	273.25	273.25	273.42	0.012984	2.58	14.55	41.93	0.98
Reach20	3479	Regional	SC-A	14.53	272.48	273.25	273.25	273.42	0.012984	2.58	14.55	41.93	0.98
Reach20	3479	Regional	SC-B	14.53	272.48	273.25	273.25	273.42	0.012984	2.58	14.55	41.93	0.98
Reach20	3479	Regional	SC-C	14.53	272.48	273.25	273.25	273.42	0.012984	2.58	14.55	41.93	0.98
Reach20	3479	Regional	SC-D	14.53	272.48	273.25	273.25	273.42	0.012984	2.58	14.55	41.93	0.98
Reach20	3479	100 Year	DonPhaseII_Final	0.77	272.48	272.78	272.7	272.8	0.004769	0.75	1.57	10.82	0.49
Reach20	3479	100 Year	Proposed	0.77	272.48	272.78	272.7	272.8	0.004769	0.75	1.57	10.82	0.49
Reach20	3479	100 Year	SC-A	0.77	272.48	272.78	272.7	272.8	0.004769	0.75	1.57	10.82	0.49
Reach20	3479	100 Year	SC-B	0.77	272.48	272.78	272.7	272.8	0.004769	0.75	1.57	10.82	0.49
Reach20	3479	100 Year	SC-C	0.77	272.48	272.78	272.7	272.8	0.004769	0.75	1.57	10.82	0.49
Reach20	3479	100 Year	SC-D	0.77	272.48	272.78	272.7	272.8	0.004769	0.75	1.57	10.82	0.49
Reach20	3479	50 Year	DonPhaseII_Final	0.69	272.48	272.77		272.79	0.004587	0.71	1.45	10.44	0.48
Reach20	3479	50 Year	Proposed	0.69	272.48	272.77		272.79	0.004587	0.71	1.45	10.44	0.48
Reach20	3479	50 Year	SC-A	0.69	272.48	272.77		272.79	0.004587	0.71	1.45	10.44	0.48
Reach20	3479	50 Year	SC-B	0.69	272.48	272.77		272.79	0.004587	0.71	1.45	10.44	0.48
Reach20	3479	50 Year	SC-C	0.69	272.48	272.77		272.79	0.004587	0.71	1.45	10.44	0.48
Reach20	3479	50 Year	SC-D	0.69	272.48	272.77		272.79	0.004587	0.71	1.45	10.44	0.48
Reach20	3428.83	Regional	DonPhaseII_Final	19.39	272.06	272.87	272.47	272.88	0.000865	0.67	72.69	133.81	0.25
Reach20	3428.83	Regional	Proposed	19.39	272.06	272.88	272.47	272.88	0.000848	0.67	73.18	133.98	0.25
Reach20	3428.83	Regional	SC-A	19.39	272.06	272.8	272.47	272.81	0.001253	0.75	63.62	127.87	0.3
Reach20	3428.83	Regional	SC-B	19.39	272.06	272.86	272.47	272.87	0.000901	0.68	71.23	131.9	0.26
Reach20	3428.83	Regional	SC-C	19.39	272.06	272.47	272.47	272.51	0.014871	1.61	26.37	90.27	0.92
Reach20	3428.83	Regional	SC-D	19.39	272.06	272.87	272.47	272.87	0.000867	0.67	72.14	133.53	0.25
Reach20	3428.83	100 Year	DonPhaseII_Final	0.77	272.06	272.31	272.31	272.38	0.019951	1.17	0.8	66.24	0.94
Reach20	3428.83	100 Year	Proposed	0.77	272.06	272.31	272.31	272.38	0.019951	1.17	0.8	66.24	0.94
Reach20	3428.83	100 Year	SC-A	0.77	272.06	272.31	272.31	272.38	0.019951	1.17	0.8	66.24	0.94
Reach20	3428.83	100 Year	SC-B	0.77	272.06	272.31	272.31	272.38	0.019951	1.17	0.8	66.24	0.94
Reach20	3428.83	100 Year	SC-C	0.77	272.06	272.31	272.31	272.38	0.019951	1.17	0.8	66.24	0.94
Reach20	3428.83	100 Year	SC-D	0.77	272.06	272.31	272.31	272.38	0.019951	1.17	0.8	66.24	0.94
Reach20	3428.83	50 Year	DonPhaseII_Final	0.69	272.06	272.3	272.3	272.36	0.022042	1.16	0.7	64.97	0.98
Reach20	3428.83	50 Year	Proposed	0.69	272.06	272.3	272.3	272.36	0.022042	1.16	0.7	64.97	0.98
Reach20	3428.83	50 Year	SC-A	0.69	272.06	272.3	272.3	272.36	0.022042	1.16	0.7	64.97	0.98
Reach20	3428.83	50 Year	SC-B	0.69	272.06	272.3	272.3	272.36	0.022042	1.16	0.7	64.97	0.98
Reach20	3428.83	50 Year	SC-C	0.69	272.06	272.3	272.3	272.36	0.022042	1.16	0.7	64.97	0.98

Reach20	3428.83	50 Year	SC-D	0.69	272.06	272.3	272.3	272.36	0.022042	1.16	0.7	64.97	0.98
Reach20	3330.15	Regional	DonPhaseII_Final	23.2	271.38	272.86		272.86	0.000151	0.45	162.35	217.17	0.12
Reach20	3330.15	Regional	Proposed	23.2	271.38	272.86		272.86	0.000149	0.45	163.2	217.37	0.12
Reach20	3330.15	Regional	SC-A	23.2	271.38	272.78		272.78	0.000178	0.47	146.51	213.63	0.13
Reach20	3330.15	Regional	SC-B	23.2	271.38	272.84		272.85	0.000158	0.46	159.81	216.91	0.12
Reach20	3330.15	Regional	SC-C	23.2	271.38	272.38		272.38	0.000756	0.78	83.69	133.72	0.25
Reach20	3330.15	Regional	SC-D	23.2	271.38	272.85		272.85	0.000154	0.46	161.41	217.08	0.12
Reach20	3330.15	100 Year	DonPhaseII_Final	0.77	271.38	272.14		272.14	0.000003	0.04	53.31	117.78	0.02
Reach20	3330.15	100 Year	Proposed	0.77	271.38	272.14		272.14	0.000003	0.04	53.31	117.78	0.02
Reach20	3330.15	100 Year	SC-A	0.77	271.38	271.59		271.59	0.002614	0.49	3.68	39.06	0.35
Reach20	3330.15	100 Year	SC-B	0.77	271.38	271.59		271.59	0.002614	0.49	3.68	39.06	0.35
Reach20	3330.15	100 Year	SC-C	0.77	271.38	271.59		271.6	0.002513	0.48	3.76	39.79	0.35
Reach20	3330.15	100 Year	SC-D	0.77	271.38	271.59		271.6	0.002513	0.48	3.76	39.79	0.35
Reach20	3330.15	50 Year	DonPhaseII_Final	0.69	271.38	272.08		272.08	0.000003	0.04	47.37	115.03	0.02
Reach20	3330.15	50 Year	Proposed	0.69	271.38	272.08		272.08	0.000003	0.04	47.37	115.03	0.02
Reach20	3330.15	50 Year	SC-A	0.69	271.38	271.58		271.59	0.002456	0.47	3.45	37.03	0.34
Reach20	3330.15	50 Year	SC-B	0.69	271.38	271.58		271.59	0.002456	0.47	3.45	37.03	0.34
Reach20	3330.15	50 Year	SC-C	0.69	271.38	271.58		271.59	0.002456	0.47	3.45	37.03	0.34
Reach20	3330.15	50 Year	SC-D	0.69	271.38	271.58		271.59	0.002456	0.47	3.45	37.03	0.34
Reach20	3326.42*	Regional	DonPhaseII_Final	24.48	271.35	272.85	272.08	272.86	0.000171	0.48	160.66	213.44	0.13
Reach20	3326.42*	Regional	Proposed	24.48	271.35	272.86	272.08	272.86	0.000168	0.48	161.5	213.49	0.13
Reach20	3326.42*	Regional	SC-A	24.48	271.35	272.78	272.08	272.78	0.000231	0.54	144.94	211.86	0.15
Reach20	3326.42*	Regional	SC-B	24.48	271.35	272.84	272.08	272.85	0.000179	0.49	158.15	213.19	0.13
Reach20	3326.42*	Regional	SC-C	24.48	271.35	272.08	272.08	272.35	0.019858	3.19	14.75	114.65	1.21
Reach20	3326.42*	Regional	SC-D	24.48	271.35	272.85	272.08	272.85	0.000174	0.49	159.73	213.37	0.13
Reach20	3326.42*	100 Year	DonPhaseII_Final	0.82	271.35	272.14	271.52	272.14	0.000017	0.1	16.2	118.52	0.04
Reach20	3326.42*	100 Year	Proposed	0.82	271.35	272.14	271.52	272.14	0.000017	0.1	16.2	118.52	0.04
Reach20	3326.42*	100 Year	SC-A	0.82	271.35	271.54	271.52	271.57	0.010671	0.89	1.44	21.76	0.7
Reach20	3326.42*	100 Year	SC-B	0.82	271.35	271.54	271.52	271.57	0.010671	0.89	1.44	21.76	0.7
Reach20	3326.42*	100 Year	SC-C	0.82	271.35	271.52	271.52	271.57	0.015485	1.01	1.17	19.63	0.83
Reach20	3326.42*	100 Year	SC-D	0.82	271.35	271.52	271.52	271.57	0.015485	1.01	1.17	19.63	0.83
Reach20	3326.42*	50 Year	DonPhaseII_Final	0.74	271.35	272.08	271.51	272.08	0.000017	0.1	14.92	114.87	0.04
Reach20	3326.42*	50 Year	Proposed	0.74	271.35	272.08	271.51	272.08	0.000017	0.1	14.92	114.87	0.04
Reach20	3326.42*	50 Year	SC-A	0.74	271.35	271.51	271.51	271.56	0.01993	1.06	0.89	14.99	0.92
Reach20	3326.42*	50 Year	SC-B	0.74	271.35	271.51	271.51	271.56	0.01993	1.06	0.89	14.99	0.92
Reach20	3326.42*	50 Year	SC-C	0.74	271.35	271.51	271.51	271.56	0.01993	1.06	0.89	14.99	0.92
Reach20	3326.42*	50 Year	SC-D	0.74	271.35	271.51	271.51	271.56	0.01993	1.06	0.89	14.99	0.92

Reach20	3307.12			Culvert									
Reach20	3284.18*	Regional	DonPhaseII_Final	30.83	270.45	271.36	271.36	271.66	0.022337	3.54	17.02	102.97	1.23
Reach20	3284.18*	Regional	Proposed	30.83	270.45	271.36	271.36	271.66	0.022337	3.54	17.02	102.97	1.23
Reach20	3284.18*	Regional	SC-A	30.83	270.45	271.36	271.36	271.66	0.022337	3.54	17.02	102.97	1.23
Reach20	3284.18*	Regional	SC-B	30.83	270.45	271.36	271.36	271.66	0.022337	3.54	17.02	102.97	1.23
Reach20	3284.18*	Regional	SC-C	30.83	270.45	271.36	271.36	271.66	0.022337	3.54	17.02	102.97	1.23
Reach20	3284.18*	Regional	SC-D	30.83	270.45	271.36	271.36	271.66	0.022337	3.54	17.02	102.97	1.23
Reach20	3284.18*	100 Year	DonPhaseII_Final	1.31	270.45	270.73	270.73	270.8	0.017001	1.24	1.77	17.51	0.86
Reach20	3284.18*	100 Year	Proposed	1.31	270.45	270.73	270.73	270.8	0.017001	1.24	1.77	17.51	0.86
Reach20	3284.18*	100 Year	SC-A	1.31	270.45	270.73	270.73	270.8	0.017001	1.24	1.77	17.51	0.86
Reach20	3284.18*	100 Year	SC-B	1.31	270.45	270.73	270.73	270.8	0.017001	1.24	1.77	17.51	0.86
Reach20	3284.18*	100 Year	SC-C	1.31	270.45	270.73	270.73	270.8	0.017001	1.24	1.77	17.51	0.86
Reach20	3284.18*	100 Year	SC-D	1.31	270.45	270.73	270.73	270.8	0.017001	1.24	1.77	17.51	0.86
Reach20	3284.18*	50 Year	DonPhaseII_Final	0.89	270.45	270.7	270.7	270.75	0.017058	1.1	1.19	14.64	0.83
Reach20	3284.18*	50 Year	Proposed	0.89	270.45	270.7	270.7	270.75	0.017058	1.1	1.19	14.64	0.83
Reach20	3284.18*	50 Year	SC-A	0.89	270.45	270.7	270.7	270.75	0.017058	1.1	1.19	14.64	0.83
Reach20	3284.18*	50 Year	SC-B	0.89	270.45	270.7	270.7	270.75	0.017058	1.1	1.19	14.64	0.83
Reach20	3284.18*	50 Year	SC-C	0.89	270.45	270.7	270.7	270.75	0.017058	1.1	1.19	14.64	0.83
Reach20	3284.18*	50 Year	SC-D	0.89	270.45	270.7	270.7	270.75	0.017058	1.1	1.19	14.64	0.83

Reach	River Sta	Profile	Plan	E.G. US. (m)	W.S. US. (m)	E.G. IC (m)	E.G. OC (m)	Min El W (m)	Q Culv Group (m3/s)	Q Weir (m3/s)	Delta W (m)	Culv Vel U (m/s)	Culv Vel DS (m/s)
Reach20	3307.12 C	Regional	DonPhase	272.86	272.85	272.87	272.86	272.62	1.75	22.69	1.49	2.99	2.99
Reach20	3307.12 C	Regional	Proposed	272.86	272.86	272.86	272.86	272.62	1.17	23.26	1.5	2.01	2.01
Reach20	3307.12 C	Regional	SC-A	272.78	272.78	272.78	272.72	272.62	10.23	14.25	1.42	2.86	3.88
Reach20	3307.12 C	Regional	SC-B	272.85	272.84	272.85	272.77	272.65	10.87	13.61	1.48	2.92	3.96
Reach20	3307.12 C	Regional	SC-C	272.05	272.08	272.05	271.96	272.94	24.48		0.72	2.39	2.58
Reach20	3307.12 C	Regional	SC-D	272.85	272.85	273.1	272.76	273.05	10.28		1.49	3.17	3.17
Reach20	3307.12 C	Regional	SC-D	272.85	272.85	272.92	272.52	273.05	14.2		1.49	3.03	3.3
Reach20	3307.12 C	100 Year	DonPhase	272.14	272.14	272	272.14	272.62	0.82		1.4	1.92	3.22
Reach20	3307.12 C	100 Year	Proposed	272.14	272.14	272.02	272.14	272.62	0.82		1.4	1.92	2.03
Reach20	3307.12 C	100 Year	SC-A	271.58	271.54	271.58	271.56	272.62	0.82		0.8	1.23	0.58
Reach20	3307.12 C	100 Year	SC-B	271.58	271.54	271.58	271.56	272.65	0.82		0.8	1.23	0.58
Reach20	3307.12 C	100 Year	SC-C	270.8	271.52	270.65	270.8	272.94	0.82		0.79	0.28	0.2
Reach20	3307.12 C	100 Year	SC-D	270.83	271.52	270.84	270.84	273.05	0.05		0.79	0.29	0.1
Reach20	3307.12 C	100 Year	SC-D	270.83	271.52	270.77	270.83	273.05	0.77		0.79	0.63	0.48
Reach20	3307.12 C	50 Year	DonPhase	272.08	272.08	271.95	272.08	272.62	0.74		1.39	1.84	3.14
Reach20	3307.12 C	50 Year	Proposed	272.08	272.08	271.97	272.08	272.62	0.74		1.39	1.84	1.98
Reach20	3307.12 C	50 Year	SC-A	271.56	271.51	271.56	271.55	272.62	0.74		0.81	1.19	0.61
Reach20	3307.12 C	50 Year	SC-B	271.56	271.51	271.56	271.55	272.65	0.74		0.81	1.19	0.61
Reach20	3307.12 C	50 Year	SC-C	270.76	271.51	270.64	270.76	272.94	0.74		0.81	0.29	0.2
Reach20	3307.12 C	50 Year	SC-D	270.8	271.51	270.8	270.81	273.05	0.01		0.81	0.14	0.02
Reach20	3307.12 C	50 Year	SC-D	270.8	271.51	270.76	270.8	273.05	0.73		0.81	0.68	0.51

Appendix C: Stormwater Management Calculations

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By	M.Khodadadi	Checked	S. Khorshid		

Stormwater Management Calculations

TABLE 01A
DRAINAGE AREA QUANTITY CONTROL REQUIREMENT CALCULATION

Drainage Area ID	**A**	
Existing Drainage Area	0.89	ha
Existing Pavement Area	0.26	ha
Existing Runoff Coefficient	0.44	*Assume pavement C = 0.9, landscaped C = 0.25*
Proposed Drainage Area	0.89	ha
Proposed Pavement Area	0.48	ha
Proposed Runoff Coefficient	0.60	*Assume pavement C = 0.9, landscaped C = 0.25*
Time of Concentration	7	minute

Rainfall Parameter

Return Period	IDF Parameters (Vaughan) $i = C_f \times A / (Tc + B)^C$ A	B	C	C_f	Rainfall Intensity (mm/hr)	Allowable Release Rate (L/s)
2-yr	647.7	4	0.784	1	98.84	107.57
5-yr	**929.6**	**4**	**0.798**	**1**	**137.17**	**149.29**
10-yr	1021	3	0.787	1	166.73	181.47
25-yr	1100	2	0.776	1.1	219.93	239.37
50-yr	1488	3	0.803	1.2	281.05	305.89
100-yr	**1770**	**4**	**0.82**	**1.25**	**309.70**	**337.07**

Storage Volume Calculation - 5 Year Post to 5 Year Pre

Time (minutes)	Rainfall Intensity (mm/hr)	Peak Flow (L/s)	Storm Runoff Volume (m^3)	Ex. Discharge Flow Vol. (m^3)	Required Storage Volume (m^3)
7	137.17	203.82	85.61	62.70	22.90
15	88.69	131.78	118.60	134.36	0.00
20	73.60	109.37	131.24	179.15	0.00
25	63.29	94.04	141.05	223.94	0.00
30	55.74	82.83	149.09	268.73	0.00
40	45.38	67.42	161.82	358.30	0.00
50	38.53	57.26	171.77	447.88	0.00
60	33.65	50.00	179.99	537.46	0.00
70	29.97	44.53	187.02	627.03	0.00
80	27.08	40.25	193.18	716.61	0.00
90	24.76	36.79	198.67	806.19	0.00
100	22.84	33.94	203.63	895.76	0.00
120	19.85	29.49	212.36	1074.91	0.00
360	8.40	12.49	269.76	3224.74	0.00
720	4.86	7.21	311.67	6449.49	0.00
1440	2.80	4.16	359.31	12898.97	0.00
Required Storage Volume:			**22.90**		

Storage Volume Calculation - 100 Year Post to 100 Year Pre

Time (minutes)	Rainfall Intensity (mm/hr)	Peak Flow (L/s)	Storm Runoff Volume (m^3)	Ex. Discharge Flow Vol. (m^3)	Required Storage Volume (m^3)
7	309.70	460.19	193.28	141.57	51.71
15	197.84	293.97	264.57	303.36	0.00
20	163.35	242.72	291.26	404.48	0.00
25	139.87	207.83	311.75	505.60	0.00
30	122.76	182.42	328.35	606.72	0.00
40	99.37	147.65	354.37	808.96	0.00
50	84.01	124.83	374.48	1011.20	0.00
60	73.08	108.59	390.94	1213.45	0.00
70	64.88	96.41	404.91	1415.69	0.00
80	58.48	86.89	417.07	1617.93	0.00
90	53.32	79.23	427.86	1820.17	0.00
100	49.08	72.93	437.58	2022.41	0.00
120	42.49	63.13	454.57	2426.89	0.00
360	17.57	26.11	563.93	7280.67	0.00
720	10.00	14.86	641.76	14561.35	0.00
1440	5.68	8.43	728.69	29122.70	0.00
Required Storage Volume:			**51.71**		

Required Storage Summary

Uncontrolled Discharge Flow Rate	**0.204**	m^3/s	5 Year Proposed Condiitions
Controlled Discharge Flow Rate	**0.149**	m^3/s	5 Year Existing Flow
Required Storage	**22.90**	m^3	
Uncontrolled Discharge Flow Rate	**0.460**	m^3/s	100 Year Proposed Condiitions
Controlled Discharge Flow Rate	**0.337**	m^3/s	100 Year Existing Flow
Required Pipe Storage	**51.71**	m^3	

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Stormwater Management Calculations

TABLE 1B
DRAINAGE AREA QUANTITY CONTROL REQUIREMENT CALCULATION

Drainage Area ID	**A**	
Existing Drainage Area	0.89	ha
Existing Pavement Area	0.26	ha
Existing Runoff Coefficient	0.44	*Assume pavement C = 0.9, landscaped C = 0.25*
Proposed Drainage Area	0.89	ha
Proposed Pavement Area	0.48	ha
Proposed Runoff Coefficient	0.60	*Assume pavement C = 0.9, landscaped C = 0.25*
Time of Concentration	7.00	minute

Rainfall Parameters

Return Period	IDF Parameters (Vaughan) $i = A / (Tc + B)^C$ A	B	C	C_f	Rainfall Intensity (mm/hr)	Allowable Release Rate (L/s)
2-yr	647.70	4.00	0.78	1	98.84	2.94
5-yr	**929.60**	**4.00**	**0.80**	**1**	**137.17**	**4.72**
10-yr	1021.00	3.00	0.79	1	166.73	6.14
25-yr	1100.00	2.00	0.78	1.1	219.93	7.12
50-yr	1488.00	3.00	0.80	1.2	281.05	10.32
100-yr	**1770.00**	**4.00**	**0.82**	**1.25**	**309.70**	**12.73**

TRCA Don River Unit flow Requirement (TRCA SWM Criteria, 2012)

Return Period	Unit Flow Rate (m3/s/ha)	Allowable Release Rate, q (L/s)
2-yr	0.0033	2.94
5-yr	**0.0053**	**4.72**
10-yr	0.0069	6.14
25-yr	0.0080	7.12
50-yr	0.0116	10.32
100-yr	**0.0143**	12.73

Storage Volume Calculation - 5 Year Post to 5 Year Pre (Unit Flow)

Time (minutes)	Rainfall Intensity (mm/hr)	Peak Flow (L/s)	Storm Runoff Volume (m^3)	Ex. Discharge Flow Vol. (m^3)	Required Storage Volume (m^3)
7	137.17	203.82	85.61	1.98	83.63
15	88.69	131.78	118.60	4.25	114.35
20	73.60	109.37	131.24	5.66	125.58
25	63.29	94.04	141.05	7.08	133.98
30	55.74	82.83	149.09	8.49	140.60
40	45.38	67.42	161.82	11.32	150.50
50	38.53	57.26	171.77	14.15	157.62
60	33.65	50.00	179.99	16.98	163.01
70	29.97	44.53	187.02	19.81	167.21
80	27.08	40.25	193.18	22.64	170.54
90	24.76	36.79	198.67	25.47	173.20
100	22.84	33.94	203.63	28.30	175.33
120	19.85	29.49	212.36	33.96	178.40
360	8.40	12.49	269.76	101.89	167.88
720	4.86	7.21	311.67	203.77	107.90
1440	2.80	4.16	359.31	407.55	0.00
Required Storage Volume:			**178.40**		

Storage Volume Calculation - 100 Year Post to 100 Year Pre (Unit Flow)

Time (minutes)	Rainfall Intensity (mm/hr)	Peak Flow (L/s)	Storm Runoff Volume (m^3)	Ex. Discharge Flow Vol. (m^3)	Required Storage Volume (m^3)
7	309.70	460.19	193.28	5.35	187.93
15	197.84	293.97	264.57	11.45	253.12
20	163.35	242.72	291.26	15.27	275.99
25	139.87	207.83	311.75	19.09	292.66
30	122.76	182.42	328.35	22.91	305.44
40	99.37	147.65	354.37	30.54	323.82
50	84.01	124.83	374.48	38.18	336.30
60	73.08	108.59	390.94	45.82	345.12
70	64.88	96.41	404.91	53.45	351.45
80	58.48	86.89	417.07	61.09	355.98
90	53.32	79.23	427.86	68.73	359.14
100	49.08	72.93	437.58	76.36	361.22
120	42.49	63.13	454.57	91.63	362.94
360	17.57	26.11	563.93	274.90	289.03
720	10.00	14.86	641.76	549.81	91.96
1440	5.68	8.43	728.69	1099.61	0.00
Required Storage Volume:			**362.94**		

Required Storage Summary

Uncontrolled Discharge Flow Rate	**0.204**	m^3/s	5 Year Proposed Condiitions
Controlled Discharge Flow Rate	**0.005**	m^3/s	5 Year Existing Flow
Required Storage	**178.40**	m^3	
Uncontrolled Discharge Flow Rate	**0.460**	m^3/s	100 Year Proposed Condiitions
Controlled Discharge Flow Rate	**0.013**	m^3/s	100 Year Existing Flow
Required Pipe Storage	**362.94**	m^3	

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Stormwater Management Calculations

TABLE 02A
DRAINAGE AREA QUANTITY CONTROL REQUIREMENT CALCULATION

Drainage Area ID	**B**	
Existing Drainage Area	0.97	ha
Existing Pavement Area	0.27	ha
Existing Runoff Coefficient	0.43	*Assume pavement C = 0.9, landscaped C = 0.25*
Proposed Drainage Area	0.97	ha
Proposed Pavement Area	0.50	ha
Proposed Runoff Coefficient	0.59	*Assume pavement C = 0.9, landscaped C = 0.25*
Time of Concentration	7	minute

Rainfall Parameter

Return Period	IDF Parameters (Vaughan) $i = C_f \times A / (Tc + B)^C$ A	B	C	C_f	Rainfall Intensity (mm/hr)	Allowable Release Rate (L/s)
2-yr	647.7	4	0.784	1	98.84	114.85
5-yr	**929.6**	**4**	**0.798**	**1**	**137.17**	**159.40**
10-yr	1021	3	0.787	1	166.73	193.75
25-yr	1100	2	0.776	1.1	219.93	255.57
50-yr	1488	3	0.803	1.2	281.05	326.59
100-yr	**1770**	**4**	**0.82**	**1.25**	**309.70**	**359.88**

Storage Volume Calculation - 5 Year Post to 5 Year Pre

Time (minutes)	Rainfall Intensity (mm/hr)	Peak Flow (L/s)	Storm Runoff Volume (m^3)	Ex. Discharge Flow Vol. (m^3)	Required Storage Volume (m^3)
7	137.17	216.41	90.89	66.95	23.94
15	88.69	139.91	125.92	143.46	0.00
20	73.60	116.12	139.34	191.28	0.00
25	63.29	99.84	149.76	239.10	0.00
30	55.74	87.94	158.29	286.92	0.00
40	45.38	71.59	171.81	382.56	0.00
50	38.53	60.79	182.38	478.20	0.00
60	33.65	53.09	191.11	573.84	0.00
70	29.97	47.28	198.57	669.48	0.00
80	27.08	42.73	205.10	765.12	0.00
90	24.76	39.06	210.93	860.76	0.00
100	22.84	36.03	216.20	956.39	0.00
120	19.85	31.32	225.47	1147.67	0.00
360	8.40	13.26	286.42	3443.02	0.00
720	4.86	7.66	330.92	6886.04	0.00
1440	2.80	4.42	381.49	13772.08	0.00
Required Storage Volume:			**23.94**		

Storage Volume Calculation - 100 Year Post to 100 Year Pre

Time (minutes)	Rainfall Intensity (mm/hr)	Peak Flow (L/s)	Storm Runoff Volume (m^3)	Ex. Discharge Flow Vol. (m^3)	Required Storage Volume (m^3)
7	309.70	488.60	205.21	151.15	54.06
15	197.84	312.12	280.90	323.90	0.00
20	163.35	257.70	309.24	431.86	0.00
25	139.87	220.66	330.99	539.83	0.00
30	122.76	193.68	348.62	647.79	0.00
40	99.37	156.77	376.25	863.72	0.00
50	84.01	132.54	397.61	1079.65	0.00
60	73.08	115.30	415.08	1295.58	0.00
70	64.88	102.36	429.91	1511.51	0.00
80	58.48	92.25	442.82	1727.44	0.00
90	53.32	84.13	454.28	1943.37	0.00
100	49.08	77.43	464.60	2159.30	0.00
120	42.49	67.03	482.64	2591.16	0.00
360	17.57	27.72	598.75	7773.49	0.00
720	10.00	15.77	681.38	15546.98	0.00
1440	5.68	8.95	773.68	31093.96	0.00
Required Storage Volume:			**54.06**		

Required Storage Summary

Uncontrolled Discharge Flow Rate	**0.216**	m^3/s	5 Year Proposed Condiitions
Controlled Discharge Flow Rate	**0.159**	m^3/s	5 Year Existing Flow
Required Storage	**23.94**	m^3	
Uncontrolled Discharge Flow Rate	**0.489**	m^3/s	100 Year Proposed Condiitions
Controlled Discharge Flow Rate	**0.360**	m^3/s	100 Year Existing Flow
Required Pipe Storage	**54.06**	m^3	

Stormwater Management Calculations

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TABLE 2B
DRAINAGE AREA QUANTITY CONTROL REQUIREMENT CALCULATION

Drainage Area ID	**B**	
Existing Drainage Area	0.97	ha
Existing Pavement Area	0.27	ha
Existing Runoff Coefficient	0.43	*Assume pavement C = 0.9, landscaped C = 0.25*
Proposed Drainage Area	0.97	ha
Proposed Pavement Area	0.50	ha
Proposed Runoff Coefficient	0.59	*Assume pavement C = 0.9, landscaped C = 0.25*
Time of Concentration	7	minute

Rainfall Parameters

Return Period	IDF Parameters (Vaughan) $i = A / (Tc + B)^C$ A	B	C	C_f	Rainfall Intensity (mm/hr)	Allowable Release Rate (L/s)
2-yr	647.70	4.00	0.78	1	98.84	3.20
5-yr	**929.60**	**4.00**	**0.80**	**1**	**137.17**	**5.14**
10-yr	1021.00	3.00	0.79	1	166.73	6.69
25-yr	1100.00	2.00	0.78	1.1	219.93	7.76
50-yr	1488.00	3.00	0.80	1.2	281.05	11.25
100-yr	**1770.00**	**4.00**	**0.82**	**1.25**	**309.70**	**13.87**

TRCA Don River Unit flow Requirement (TRCA SWM Criteria, 2012)

Return Period	Unit Flow Rate (m3/s/ha)	Allowable Release Rate, q (L/s)
2-yr	0.0033	3.20
5-yr	**0.0053**	**5.14**
10-yr	0.0069	6.69
25-yr	0.0080	7.76
50-yr	0.0116	11.25
100-yr	**0.0143**	13.87

Storage Volume Calculation - 5 Year Post to 5 Year Pre (Unit Flow)

Time (minutes)	Rainfall Intensity (mm/hr)	Peak Flow (L/s)	Storm Runoff Volume (m^3)	Ex. Discharge Flow Vol. (m^3)	Required Storage Volume (m^3)
7	137.17	216.41	90.89	2.16	88.73
15	88.69	139.91	125.92	4.63	121.30
20	73.60	116.12	139.34	6.17	133.17
25	63.29	99.84	149.76	7.71	142.05
30	55.74	87.94	158.29	9.25	149.04
40	45.38	71.59	171.81	12.34	159.47
50	38.53	60.79	182.38	15.42	166.96
60	33.65	53.09	191.11	18.51	172.60
70	29.97	47.28	198.57	21.59	176.98
80	27.08	42.73	205.10	24.68	180.43
90	24.76	39.06	210.93	27.76	183.17
100	22.84	36.03	216.20	30.85	185.36
120	19.85	31.32	225.47	37.02	188.45
360	8.40	13.26	286.42	111.05	175.37
720	4.86	7.66	330.92	222.09	108.83
1440	2.80	4.42	381.49	444.18	0.00
Required Storage Volume:			**188.45**		

Storage Volume Calculation - 100 Year Post to 100 Year Pre (Unit Flow)

Time (minutes)	Rainfall Intensity (mm/hr)	Peak Flow (L/s)	Storm Runoff Volume (m^3)	Ex. Discharge Flow Vol. (m^3)	Required Storage Volume (m^3)
7	309.70	488.60	205.21	5.83	199.39
15	197.84	312.12	280.90	12.48	268.42
20	163.35	257.70	309.24	16.65	292.60
25	139.87	220.66	330.99	20.81	310.19
30	122.76	193.68	348.62	24.97	323.65
40	99.37	156.77	376.25	33.29	342.96
50	84.01	132.54	397.61	41.61	355.99
60	73.08	115.30	415.08	49.94	365.14
70	64.88	102.36	429.91	58.26	371.65
80	58.48	92.25	442.82	66.58	376.24
90	53.32	84.13	454.28	74.90	379.38
100	49.08	77.43	464.60	83.23	381.37
120	42.49	67.03	482.64	99.87	382.77
360	17.57	27.72	598.75	299.61	299.14
720	10.00	15.77	681.38	599.23	82.16
1440	5.68	8.95	773.68	1198.45	0.00
Required Storage Volume:			**382.77**		

Required Storage Summary

Uncontrolled Discharge Flow Rate	**0.216**	m^3/s	5 Year Proposed Condiitions
Controlled Discharge Flow Rate	**0.005**	m^3/s	5 Year Existing Flow
Required Storage	**188.45**	m^3	
Uncontrolled Discharge Flow Rate	**0.489**	m^3/s	100 Year Proposed Condiitions
Controlled Discharge Flow Rate	**0.014**	m^3/s	100 Year Existing Flow
Required Pipe Storage	**382.77**	m^3	

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Stormwater Management Calculations

TABLE 03A
DRAINAGE AREA QUANTITY CONTROL REQUIREMENT CALCULATION

Drainage Area ID	**C**	
Existing Drainage Area	6.64	ha
Existing Pavement Area	1.58	ha
Existing Runoff Coefficient	0.40	*Assume pavement C = 0.9, landscaped C = 0.25*
Proposed Drainage Area	6.64	ha
Proposed Pavement Area	4.40	ha
Proposed Runoff Coefficient	0.68	*Assume pavement C = 0.9, landscaped C = 0.25*
Time of Concentration	7	minute

Rainfall Parameter

Return Period	IDF Parameters (Vaughan) $i = C_f \times A / (Tc + B)^C$				Rainfall Intensity (mm/hr)	Allowable Release Rate (L/s)
	A	B	C	C_f		
2-yr	647.7	4	0.784	1	98.84	737.59
5-yr	**929.6**	**4**	**0.798**	**1**	**137.17**	**1023.66**
10-yr	1021	3	0.787	1	166.73	1244.28
25-yr	1100	2	0.776	1.1	219.93	1641.29
50-yr	1488	3	0.803	1.2	281.05	2097.38
100-yr	**1770**	**4**	**0.82**	**1.25**	**309.70**	**2311.18**

Storage Volume Calculation - 5 Year Post to 5 Year Pre

Time (minutes)	Rainfall Intensity (mm/hr)	Peak Flow (L/s)	Storm Runoff Volume (m^3)	Ex. Discharge Flow Vol. (m^3)	Required Storage Volume (m^3)
7	137.17	1723.77	723.98	429.94	294.05
15	88.69	1114.46	1003.02	921.30	81.72
20	73.60	924.92	1109.90	1228.39	0.00
25	63.29	795.28	1192.91	1535.49	0.00
30	55.74	700.47	1260.85	1842.59	0.00
40	45.38	570.21	1368.51	2456.79	0.00
50	38.53	484.24	1452.72	3070.99	0.00
60	33.65	422.84	1522.24	3685.18	0.00
70	29.97	376.59	1581.66	4299.38	0.00
80	27.08	340.36	1633.72	4913.58	0.00
90	24.76	311.14	1680.15	5527.78	0.00
100	22.84	287.02	1722.15	6141.97	0.00
120	19.85	249.44	1795.95	7370.37	0.00
360	8.40	105.62	2281.42	22111.11	0.00
720	4.86	61.02	2635.87	44222.22	0.00
1440	2.80	35.17	3038.72	88444.44	0.00
Required Storage Volume:			**294.05**		

Storage Volume Calculation - 100 Year Post to 100 Year Pre

Time (minutes)	Rainfall Intensity (mm/hr)	Peak Flow (L/s)	Storm Runoff Volume (m^3)	Ex. Discharge Flow Vol. (m^3)	Required Storage Volume (m^3)
7	309.70	3891.85	1634.58	970.69	663.88
15	197.84	2486.11	2237.50	2080.06	157.44
20	163.35	2052.70	2463.24	2773.41	0.00
25	139.87	1757.65	2636.47	3466.77	0.00
30	122.76	1542.71	2776.89	4160.12	0.00
40	99.37	1248.73	2996.94	5546.83	0.00
50	84.01	1055.69	3167.06	6933.53	0.00
60	73.08	918.40	3306.23	8320.24	0.00
70	64.88	815.32	3424.35	9706.95	0.00
80	58.48	734.83	3527.20	11093.65	0.00
90	53.32	670.09	3618.49	12480.36	0.00
100	49.08	616.78	3700.69	13867.07	0.00
120	42.49	533.94	3844.37	16640.48	0.00
360	17.57	220.80	4769.24	49921.43	0.00
720	10.00	125.64	5427.46	99842.87	0.00
1440	5.68	71.33	6162.64	199685.74	0.00
Required Storage Volume:			**663.88**		

Required Storage Summary

Uncontrolled Discharge Flow Rate	**1.724**	m^3/s	5 Year Proposed Condiitions
Controlled Discharge Flow Rate	**1.024**	m^3/s	5 Year Existing Flow
Required Storage	**294.05**	m^3	
Uncontrolled Discharge Flow Rate	**3.892**	m^3/s	100 Year Proposed Condiitions
Controlled Discharge Flow Rate	**2.311**	m^3/s	100 Year Existing Flow
Required Pipe Storage	**663.88**	m^3	

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Stormwater Management Calculations

TABLE 03B
DRAINAGE AREA QUANTITY CONTROL REQUIREMENT CALCULATION

Drainage Area ID	**C**	
Existing Drainage Area	6.64	ha
Existing Pavement Area	1.58	ha
Existing Runoff Coefficient	0.40	*Assume pavement C = 0.9, landscaped C = 0.25*
Proposed Drainage Area	6.64	ha
Proposed Pavement Area	4.40	ha
Proposed Runoff Coefficient	0.68	*Assume pavement C = 0.9, landscaped C = 0.25*
Time of Concentration	7.00	minute

Rainfall Parameters

Return Period	IDF Parameters (Vaughan) $i = A / (Tc + B)^C$ A	B	C	C_f	Rainfall Intensity (mm/hr)	Allowable Release Rate (L/s)
2-yr	647.70	4.00	0.78	1	98.84	21.91
5-yr	**929.60**	**4.00**	**0.80**	**1**	**137.17**	**35.19**
10-yr	1021.00	3.00	0.79	1	166.73	45.82
25-yr	1100.00	2.00	0.78	1.1	219.93	53.12
50-yr	1488.00	3.00	0.80	1.2	281.05	77.02
100-yr	**1770.00**	**4.00**	**0.82**	**1.25**	**309.70**	**94.95**

TRCA Don River Unit flow Requirement (TRCA SWM Criteria, 2012)

Return Period	Unit Flow Rate (m3/s/ha)	Allowable Release Rate, q (L/s)
2-yr	0.0033	21.91
5-yr	**0.0053**	**35.19**
10-yr	0.0069	45.82
25-yr	0.0080	53.12
50-yr	0.0116	77.02
100-yr	0.0143	94.95

Storage Volume Calculation - 5 Year Post to 5 Year Pre (Unit Flow)

Time (minutes)	Rainfall Intensity (mm/hr)	Peak Flow (L/s)	Storm Runoff Volume (m^3)	Ex. Discharge Flow Vol. (m^3)	Required Storage Volume (m^3)
7	137.17	1723.77	723.98	14.78	709.20
15	88.69	1114.46	1003.02	31.67	971.34
20	73.60	924.92	1109.90	42.23	1067.67
25	63.29	795.28	1192.91	52.79	1140.12
30	55.74	700.47	1260.85	63.35	1197.50
40	45.38	570.21	1368.51	84.46	1284.05
50	38.53	484.24	1452.72	105.58	1347.14
60	33.65	422.84	1522.24	126.69	1395.54
70	29.97	376.59	1581.66	147.81	1433.85
80	27.08	340.36	1633.72	168.92	1464.80
90	24.76	311.14	1680.15	190.04	1490.12
100	22.84	287.02	1722.15	211.15	1510.99
120	19.85	249.44	1795.95	253.38	1542.56
360	8.40	105.62	2281.42	760.15	1521.28
720	4.86	61.02	2635.87	1520.29	1115.57
1440	2.80	35.17	3038.72	3040.59	0.00
Required Storage Volume:			**1542.56**		

Storage Volume Calculation - 100 Year Post to 100 Year Pre (Unit Flow)

Time (minutes)	Rainfall Intensity (mm/hr)	Peak Flow (L/s)	Storm Runoff Volume (m^3)	Ex. Discharge Flow Vol. (m^3)	Required Storage Volume (m^3)
7	309.70	3891.85	1634.58	39.88	1594.70
15	197.84	2486.11	2237.50	85.46	2152.04
20	163.35	2052.70	2463.24	113.94	2349.30
25	139.87	1757.65	2636.47	142.43	2494.04
30	122.76	1542.71	2776.89	170.91	2605.97
40	99.37	1248.73	2996.94	227.88	2769.06
50	84.01	1055.69	3167.06	284.86	2882.21
60	73.08	918.40	3306.23	341.83	2964.40
70	64.88	815.32	3424.35	398.80	3025.55
80	58.48	734.83	3527.20	455.77	3071.43
90	53.32	670.09	3618.49	512.74	3105.75
100	49.08	616.78	3700.69	569.71	3130.97
120	42.49	533.94	3844.37	683.65	3160.71
360	17.57	220.80	4769.24	2050.96	2718.27
720	10.00	125.64	5427.46	4101.93	1325.53
1440	5.68	71.33	6162.64	8203.85	0.00
Required Storage Volume:			**3160.71**		

Required Storage Summary

Uncontrolled Discharge Flow Rate	**1.724**	m^3/s	5 Year Proposed Condiitions
Controlled Discharge Flow Rate	**0.035**	m^3/s	5 Year Existing Flow
Required Storage	**1542.56**	m^3	
Uncontrolled Discharge Flow Rate	**3.892**	m^3/s	100 Year Proposed Condiitions
Controlled Discharge Flow Rate	**0.095**	m^3/s	100 Year Existing Flow
Required Pipe Storage	**3160.71**	m^3	

Stormwater Management Calculations

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TABLE 04A
DRAINAGE AREA QUANTITY CONTROL REQUIREMENT CALCULATION

Drainage Area ID	**D**	
Existing Drainage Area	3.35	ha
Existing Pavement Area	0.70	ha
Existing Runoff Coefficient	0.39	*Assume pavement C = 0.9, landscaped C = 0.25*
Proposed Drainage Area	3.35	ha
Proposed Pavement Area	1.65	ha
Proposed Runoff Coefficient	0.57	*Assume pavement C = 0.9, landscaped C = 0.25*
Time of Concentration	7	minute

Rainfall Parameter

Return Period	IDF Parameters (Vaughan) $i = C_f \times A / (Tc + B)^C$ A	B	C	C_f	Rainfall Intensity (mm/hr)	Allowable Release Rate (L/s)
2-yr	647.7	4	0.784	1	98.84	354.42
5-yr	**929.6**	**4**	**0.798**	**1**	**137.17**	**491.89**
10-yr	1021	3	0.787	1	166.73	597.90
25-yr	1100	2	0.776	1.1	219.93	788.67
50-yr	1488	3	0.803	1.2	281.05	1007.82
100-yr	**1770**	**4**	**0.82**	**1.25**	**309.70**	**1110.56**

Storage Volume Calculation - 5 Year Post to 5 Year Pre

Time (minutes)	Rainfall Intensity (mm/hr)	Peak Flow (L/s)	Storm Runoff Volume (m^3)	Ex. Discharge Flow Vol. (m^3)	Required Storage Volume (m^3)
7	137.17	727.35	305.49	206.59	98.90
15	88.69	470.25	423.23	442.70	0.00
20	73.60	390.27	468.33	590.26	0.00
25	63.29	335.57	503.35	737.83	0.00
30	55.74	295.57	532.02	885.40	0.00
40	45.38	240.60	577.45	1180.53	0.00
50	38.53	204.33	612.98	1475.66	0.00
60	33.65	178.42	642.31	1770.79	0.00
70	29.97	158.90	667.39	2065.93	0.00
80	27.08	143.62	689.35	2361.06	0.00
90	24.76	131.29	708.95	2656.19	0.00
100	22.84	121.11	726.67	2951.32	0.00
120	19.85	105.25	757.81	3541.59	0.00
360	8.40	44.57	962.66	10624.77	0.00
720	4.86	25.75	1112.21	21249.53	0.00
1440	2.80	14.84	1282.20	42499.06	0.00
Required Storage Volume:			**98.90**		

Storage Volume Calculation - 100 Year Post to 100 Year Pre

Time (minutes)	Rainfall Intensity (mm/hr)	Peak Flow (L/s)	Storm Runoff Volume (m^3)	Ex. Discharge Flow Vol. (m^3)	Required Storage Volume (m^3)
7	309.70	1642.18	689.72	466.44	223.28
15	197.84	1049.02	944.12	999.50	0.00
20	163.35	866.14	1039.37	1332.67	0.00
25	139.87	741.65	1112.47	1665.84	0.00
30	122.76	650.95	1171.72	1999.01	0.00
40	99.37	526.90	1264.57	2665.34	0.00
50	84.01	445.45	1336.35	3331.68	0.00
60	73.08	387.52	1395.08	3998.02	0.00
70	64.88	344.03	1444.92	4664.35	0.00
80	58.48	310.07	1488.32	5330.69	0.00
90	53.32	282.75	1526.84	5997.03	0.00
100	49.08	260.25	1561.52	6663.36	0.00
120	42.49	225.30	1622.15	7996.03	0.00
360	17.57	93.17	2012.40	23988.10	0.00
720	10.00	53.01	2290.14	47976.20	0.00
1440	5.68	30.10	2600.35	95952.40	0.00
Required Storage Volume:			**223.28**		

Required Storage Summary

Uncontrolled Discharge Flow Rate	**0.727**	m^3/s	5 Year Proposed Condiitions
Controlled Discharge Flow Rate	**0.492**	m^3/s	5 Year Existing Flow
Required Storage	**98.90**	m^3	
Uncontrolled Discharge Flow Rate	**1.642**	m^3/s	100 Year Proposed Condiitions
Controlled Discharge Flow Rate	**1.111**	m^3/s	100 Year Existing Flow
Required Pipe Storage	**223.28**	m^3	

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Stormwater Management Calculations

TABLE 04B
DRAINAGE AREA QUANTITY CONTROL REQUIREMENT CALCULATION

Drainage Area ID	**D**	
Existing Drainage Area	3.35	ha
Existing Pavement Area	0.70	ha
Existing Runoff Coefficient	0.39	*Assume pavement C = 0.9, landscaped C = 0.25*
Proposed Drainage Area	3.35	ha
Proposed Pavement Area	1.65	ha
Proposed Runoff Coefficient	0.57	*Assume pavement C = 0.9, landscaped C = 0.25*
Time of Concentration	7.00	minute

Rainfall Parameters

Return Period	IDF Parameters (Vaughan) $i = A / (Tc + B)^C$ A	B	C	C_f	Rainfall Intensity (mm/hr)	Allowable Release Rate (L/s)
2-yr	647.70	4.00	0.78	1	98.84	11.06
5-yr	**929.60**	**4.00**	**0.80**	**1**	**137.17**	**17.76**
10-yr	1021.00	3.00	0.79	1	166.73	23.12
25-yr	1100.00	2.00	0.78	1.1	219.93	26.80
50-yr	1488.00	3.00	0.80	1.2	281.05	38.86
100-yr	**1770.00**	**4.00**	**0.82**	**1.25**	**309.70**	**47.91**

TRCA Don River Unit flow Requirement (TRCA SWM Criteria, 2012)

Return Period	Unit Flow Rate (m3/s/ha)	Allowable Release Rate, q (L/s)
2-yr	0.0033	11.06
5-yr	**0.0053**	**17.76**
10-yr	0.0069	23.12
25-yr	0.0080	26.80
50-yr	0.0116	38.86
100-yr	**0.0143**	47.91

Storage Volume Calculation - 5 Year Post to 5 Year Pre (Unit Flow)

Time (minutes)	Rainfall Intensity (mm/hr)	Peak Flow (L/s)	Storm Runoff Volume (m^3)	Ex. Discharge Flow Vol. (m^3)	Required Storage Volume (m^3)
7	137.17	727.35	305.49	7.46	298.03
15	88.69	470.25	423.23	15.98	407.25
20	73.60	390.27	468.33	21.31	447.02
25	63.29	335.57	503.35	26.63	476.72
30	55.74	295.57	532.02	31.96	500.06
40	45.38	240.60	577.45	42.61	534.84
50	38.53	204.33	612.98	53.27	559.72
60	33.65	178.42	642.31	63.92	578.40
70	29.97	158.90	667.39	74.57	592.82
80	27.08	143.62	689.35	85.22	604.13
90	24.76	131.29	708.95	95.88	613.07
100	22.84	121.11	726.67	106.53	620.14
120	19.85	105.25	757.81	127.84	629.97
360	8.40	44.57	962.66	383.51	579.15
720	4.86	25.75	1112.21	767.02	345.20
1440	2.80	14.84	1282.20	1534.03	0.00
Required Storage Volume:			**629.97**		

Storage Volume Calculation - 100 Year Post to 100 Year Pre (Unit Flow)

Time (minutes)	Rainfall Intensity (mm/hr)	Peak Flow (L/s)	Storm Runoff Volume (m^3)	Ex. Discharge Flow Vol. (m^3)	Required Storage Volume (m^3)
7	309.70	1642.18	689.72	20.12	669.60
15	197.84	1049.02	944.12	43.11	901.01
20	163.35	866.14	1039.37	57.49	981.89
25	139.87	741.65	1112.47	71.86	1040.61
30	122.76	650.95	1171.72	86.23	1085.49
40	99.37	526.90	1264.57	114.97	1149.60
50	84.01	445.45	1336.35	143.72	1192.64
60	73.08	387.52	1395.08	172.46	1222.62
70	64.88	344.03	1444.92	201.20	1243.71
80	58.48	310.07	1488.32	229.94	1258.37
90	53.32	282.75	1526.84	258.69	1268.15
100	49.08	260.25	1561.52	287.43	1274.09
120	42.49	225.30	1622.15	344.92	1277.23
360	17.57	93.17	2012.40	1034.75	977.65
720	10.00	53.01	2290.14	2069.50	220.64
1440	5.68	30.10	2600.35	4138.99	0.00
Required Storage Volume:			**1277.23**		

Required Storage Summary

Uncontrolled Discharge Flow Rate	**0.727**	m^3/s	5 Year Proposed Condiitions
Controlled Discharge Flow Rate	**0.018**	m^3/s	5 Year Existing Flow
Required Storage	**629.97**	m^3	
Uncontrolled Discharge Flow Rate	**1.642**	m^3/s	100 Year Proposed Condiitions
Controlled Discharge Flow Rate	**0.048**	m^3/s	100 Year Existing Flow
Required Pipe Storage	**1277.23**	m^3	

Stormwater Management Calculations

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By	M.Khodadadi	Checked	S. Khorshid	

TABLE 05A

DRAINAGE AREA QUANTITY CONTROL REQUIREMENT CALCULATION

Drainage Area ID	**E**	
Existing Drainage Area	6.05	ha
Existing Pavement Area	1.58	ha
Existing Runoff Coefficient	0.42	*Assume pavement C = 0.9, landscaped C = 0.25*
Proposed Drainage Area	6.05	ha
Proposed Pavement Area	3.50	ha
Proposed Runoff Coefficient	0.63	*Assume pavement C = 0.9, landscaped C = 0.25*
Time of Concentration	7	minute

Rainfall Parameter

Return Period	IDF Parameters (Vaughan) $i = C_f \times A / (Tc + B)^C$ A	B	C	C_f	Rainfall Intensity (mm/hr)	Allowable Release Rate (L/s)
2-yr	647.7	4	0.784	1	98.84	697.77
5-yr	**929.6**	**4**	**0.798**	**1**	**137.17**	**968.41**
10-yr	1021	3	0.787	1	166.73	1177.11
25-yr	1100	2	0.776	1.1	219.93	1552.70
50-yr	1488	3	0.803	1.2	281.05	1984.16
100-yr	**1770**	**4**	**0.82**	**1.25**	**309.70**	**2186.42**

Storage Volume Calculation - 5 Year Post to 5 Year Pre

Time (minutes)	Rainfall Intensity (mm/hr)	Peak Flow (L/s)	Storm Runoff Volume (m^3)	Ex. Discharge Flow Vol. (m^3)	Required Storage Volume (m^3)
7	137.17	1445.37	607.06	406.73	200.32
15	88.69	934.47	841.02	871.57	0.00
20	73.60	775.54	930.64	1162.09	0.00
25	63.29	666.83	1000.25	1452.61	0.00
30	55.74	587.34	1057.21	1743.13	0.00
40	45.38	478.12	1147.48	2324.18	0.00
50	38.53	406.03	1218.10	2905.22	0.00
60	33.65	354.55	1276.38	3486.26	0.00
70	29.97	315.76	1326.21	4067.31	0.00
80	27.08	285.39	1369.86	4648.35	0.00
90	24.76	260.89	1408.80	5229.40	0.00
100	22.84	240.67	1444.01	5810.44	0.00
120	19.85	209.15	1505.89	6972.53	0.00
360	8.40	88.56	1912.96	20917.58	0.00
720	4.86	51.16	2210.16	41835.17	0.00
1440	2.80	29.49	2547.94	83670.34	0.00

Required Storage Volume: 200.32

Storage Volume Calculation - 100 Year Post to 100 Year Pre

Time (minutes)	Rainfall Intensity (mm/hr)	Peak Flow (L/s)	Storm Runoff Volume (m^3)	Ex. Discharge Flow Vol. (m^3)	Required Storage Volume (m^3)
7	309.70	3263.29	1370.58	918.30	452.28
15	197.84	2084.59	1876.13	1967.78	0.00
20	163.35	1721.17	2065.41	2623.71	0.00
25	139.87	1473.78	2210.66	3279.64	0.00
30	122.76	1293.56	2328.40	3935.56	0.00
40	99.37	1047.05	2512.92	5247.42	0.00
50	84.01	885.19	2655.56	6559.27	0.00
60	73.08	770.07	2772.25	7871.12	0.00
70	64.88	683.64	2871.29	9182.98	0.00
80	58.48	616.15	2957.54	10494.83	0.00
90	53.32	561.87	3034.08	11806.69	0.00
100	49.08	517.17	3103.00	13118.54	0.00
120	42.49	447.71	3223.48	15742.25	0.00
360	17.57	185.14	3998.97	47226.75	0.00
720	10.00	105.34	4550.89	94453.50	0.00
1440	5.68	59.81	5167.33	188906.99	0.00

Required Storage Volume: 452.28

Required Storage Summary

Uncontrolled Discharge Flow Rate	**1.445**	m^3/s	5 Year Proposed Condiitions
Controlled Discharge Flow Rate	**0.968**	m^3/s	5 Year Existing Flow
Required Storage	**200.32**	m^3	
Uncontrolled Discharge Flow Rate	**3.263**	m^3/s	100 Year Proposed Condiitions
Controlled Discharge Flow Rate	**2.186**	m^3/s	100 Year Existing Flow
Required Pipe Storage	**452.28**	m^3	

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Stormwater Management Calculations

TABLE 05B
DRAINAGE AREA QUANTITY CONTROL REQUIREMENT CALCULATION

Drainage Area ID	**E**
Existing Drainage Area	6.05 ha
Existing Pavement Area	1.58 ha
Existing Runoff Coefficient	0.42 *Assume pavement C = 0.9, landscaped C = 0.25*
Proposed Drainage Area	6.05 ha
Proposed Pavement Area	3.50 ha
Proposed Runoff Coefficient	0.63 *Assume pavement C = 0.9, landscaped C = 0.25*
Time of Concentration	7.00 minute

Rainfall Parameters

Return Period	IDF Parameters (Vaughan) $i = A / (Tc + B)^C$ A	B	C	C_f	Rainfall Intensity (mm/hr)	Allowable Release Rate (L/s)
2-yr	647.70	4.00	0.78	1	98.84	19.97
5-yr	**929.60**	**4.00**	**0.80**	**1**	**137.17**	**32.07**
10-yr	1021.00	3.00	0.79	1	166.73	41.75
25-yr	1100.00	2.00	0.78	1.1	219.93	48.40
50-yr	1488.00	3.00	0.80	1.2	281.05	70.18
100-yr	**1770.00**	**4.00**	**0.82**	**1.25**	**309.70**	**86.52**

TRCA Don River Unit flow Requirement (TRCA SWM Criteria, 2012)

Return Period	Unit Flow Rate (m3/s/ha)	Allowable Release Rate, q (L/s)
2-yr	0.0033	19.97
5-yr	**0.0053**	**32.07**
10-yr	0.0069	41.75
25-yr	0.0080	48.40
50-yr	0.0116	70.18
100-yr	**0.0143**	86.52

Storage Volume Calculation - 5 Year Post to 5 Year Pre (Unit Flow)

Time (minutes)	Rainfall Intensity (mm/hr)	Peak Flow (L/s)	Storm Runoff Volume (m^3)	Ex. Discharge Flow Vol. (m^3)	Required Storage Volume (m^3)
7	137.17	1445.37	607.06	13.47	593.59
15	88.69	934.47	841.02	28.86	812.16
20	73.60	775.54	930.64	38.48	892.17
25	63.29	666.83	1000.25	48.10	952.15
30	55.74	587.34	1057.21	57.72	999.50
40	45.38	478.12	1147.48	76.96	1070.53
50	38.53	406.03	1218.10	96.20	1121.90
60	33.65	354.55	1276.38	115.43	1160.95
70	29.97	315.76	1326.21	134.67	1191.54
80	27.08	285.39	1369.86	153.91	1215.95
90	24.76	260.89	1408.80	173.15	1235.65
100	22.84	240.67	1444.01	192.39	1251.62
120	19.85	209.15	1505.89	230.87	1275.02
360	8.40	88.56	1912.96	692.60	1220.35
720	4.86	51.16	2210.16	1385.21	824.95
1440	2.80	29.49	2547.94	2770.42	0.00
Required Storage Volume:			**1275.02**		

Storage Volume Calculation - 100 Year Post to 100 Year Pre (Unit Flow)

Time (minutes)	Rainfall Intensity (mm/hr)	Peak Flow (L/s)	Storm Runoff Volume (m^3)	Ex. Discharge Flow Vol. (m^3)	Required Storage Volume (m^3)
7	309.70	3263.29	1370.58	36.34	1334.25
15	197.84	2084.59	1876.13	77.86	1798.26
20	163.35	1721.17	2065.41	103.82	1961.59
25	139.87	1473.78	2210.66	129.77	2080.89
30	122.76	1293.56	2328.40	155.73	2172.67
40	99.37	1047.05	2512.92	207.64	2305.28
50	84.01	885.19	2655.56	259.55	2396.02
60	73.08	770.07	2772.25	311.45	2460.80
70	64.88	683.64	2871.29	363.36	2507.93
80	58.48	616.15	2957.54	415.27	2542.26
90	53.32	561.87	3034.08	467.18	2566.90
100	49.08	517.17	3103.00	519.09	2583.91
120	42.49	447.71	3223.48	622.91	2600.57
360	17.57	185.14	3998.97	1868.72	2130.25
720	10.00	105.34	4550.89	3737.45	813.44
1440	5.68	59.81	5167.33	7474.90	0.00
Required Storage Volume:			**2600.57**		

Required Storage Summary

Uncontrolled Discharge Flow Rate	**1.445**	m^3/s	5 Year Proposed Condiitions
Controlled Discharge Flow Rate	**0.032**	m^3/s	5 Year Existing Flow
Required Storage	**1275.02**	m^3	
Uncontrolled Discharge Flow Rate	**3.263**	m^3/s	100 Year Proposed Condiitions
Controlled Discharge Flow Rate	**0.087**	m^3/s	100 Year Existing Flow
Required Pipe Storage	**2600.57**	m^3	

Project	Kirby Road Class EA, City of Vaughan	No.	--
By	M.Khodadadi	Date	10-Aug-21
Checked	S.Khorshid	Checked	--

Stormwater Management Calculations

TABLE 06

QUANTITY CONTROL REQUIREMENT CALCULATION

Drainage Area ID	Existing			Proposed			Increased Paved Area (ha)	5 Year				100 Year				Discharge Location
	Drainage Area (ha)	Paved Area (ha)	Runoff Coefficient	Drainage Area (ha)	Paved Area (ha)	Runoff Coefficient		Existing Flow (m^3/s)	Proposed Flow (m^3/s)	Req'd Storage Vol. (m^3)	Req'd Unitary Storage Vol.[1] (m^3)	Existing Flow (m^3/s)	Proposed Flow (m^3/s)	Req'd Storage Vol. (m^3)	Req'd Unitary Storage Vol.[1] (m^3)	
A	0.89	0.26	0.44	0.89	0.48	0.60	0.22	0.15	0.20	23	178	0.34	0.46	52	363	
B	0.97	0.27	0.43	0.97	0.50	0.59	0.23	0.16	0.22	24	188	0.36	0.49	54	383	
C	6.64	1.58	0.40	6.64	4.40	0.68	2.82	1.02	1.72	294	1543	2.31	3.89	664	3161	
D	3.35	0.70	0.39	3.35	1.65	0.57	0.95	0.49	0.73	99	630	1.11	1.64	223	1277	
E	6.05	1.58	0.42	6.05	3.50	0.63	1.92	0.97	1.45	200	1275	2.19	3.26	452	2601	
Total	**17.90**	**4.38**		**17.90**	**10.53**		**6.15**			**640**	**3814**			**1445**	**7784**	

[1] Required unitary storage volumes calculated based on TRCA Stormwater Management Criteria (2012) Unitary Flow Rates

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Stormwater Management Calculations

TABLE 07
QUALITY CONTROL REQUIREMENT CALCULATION

Drainage Area ID	Drainage Area (ha)	Existing			Proposed			Increased Paved Area (ha)	Contributing Pavement Area (ha)	Required Treatment Volume[1] (m^3)	Required Water Balance Storage[3] (m^3)	Total Required Storage (m^3)	Bioretention Area[2] (m^2)	Required Bioretention Length (m)	Bioretention Facilities Width (m)	Proposed Bioretention Cell Length (m)	Provided Water Balance Storage Volume (m^3)	Required Erosion Control Storage Volume[4] (m^3)	Provided Water Quality and Erosion Control Storage Volume (m^3)
		Paved Area (ha)	% Impervious	Req. Volume (m^3)	Paved Area (ha)	% Impervious	Req. Volume (m^3)												
A	0.89	0.26	29%	5.94	0.48	54%	14.54	0.22	0.22	9	11	11	110	73	1.5	80	14	44	43
B	0.97	0.27	28%	6.06	0.50	52%	14.79	0.23	0.00	9	12	12	-	-		-	-	-	-
C	6.64	1.58	24%	33.40	4.40	66%	149.68	2.82	4.40	116	141	141	2200	733	3.0	760	274	880	821
D	3.35	0.70	21%	14.13	1.65	49%	47.48	0.95	0.00	33	47	47	-	-	-	-	-	-	-
E	6.05	1.58	26%	34.62	3.50	58%	110.37	1.92	1.92	76	96	96	962	321	3.0	340	122	385	367
Total	**17.90**	**4.38**	**24%**		**10.53**	**59%**		**6.15**	**6.54**	**243**	**307**	**307**	**3272**	**1127**		**1180**	**410**	**1309**	**1231**

[1] From Table 3.2 of MOE SWM Planning and Design Manual (2003)
[2] 5% of the contributing pavement area
[3] Based on TRCA target of 5 mm retention
[4] Storage volume in addition to water balance volume to meet 25 mm retention

MOE Table 3.2

Impervious Level (%)	W.Q. Storage Volume (m^3/ha)
35%	25
55%	30
70%	35
85%	40

Bioretention Cell Dimensions

Hydraulic Conductivity[5]	3.30E-03 cm/s
Infiltration Rate, i =	94 mm/hr
Safety Factor =	3
Infilt. with Safety Factor	31.4 mm/hr
d_p =	100 mm
t_s =	48 hr
V_r =	0.4
$d_{r\ max}$ =	3767 mm
d_r =	0.3 m
Perforated Pipe	0.00 m
$d_{filter} = d_{f\ minimum}$	0.50 m
$d_{pea\ gravel}$ =	0.1 m
d_{total} =	0.90 m

LID SWM GUIDE Table C1

Kfs cm/s	T min/cm	1/T mm/hr
0.1	2	300
0.01	4	150
0.001	8	75
0.0001	12	50
0.00001	20	30
0.000001	50	12

Appendix D: Bioretention Cell Schematic

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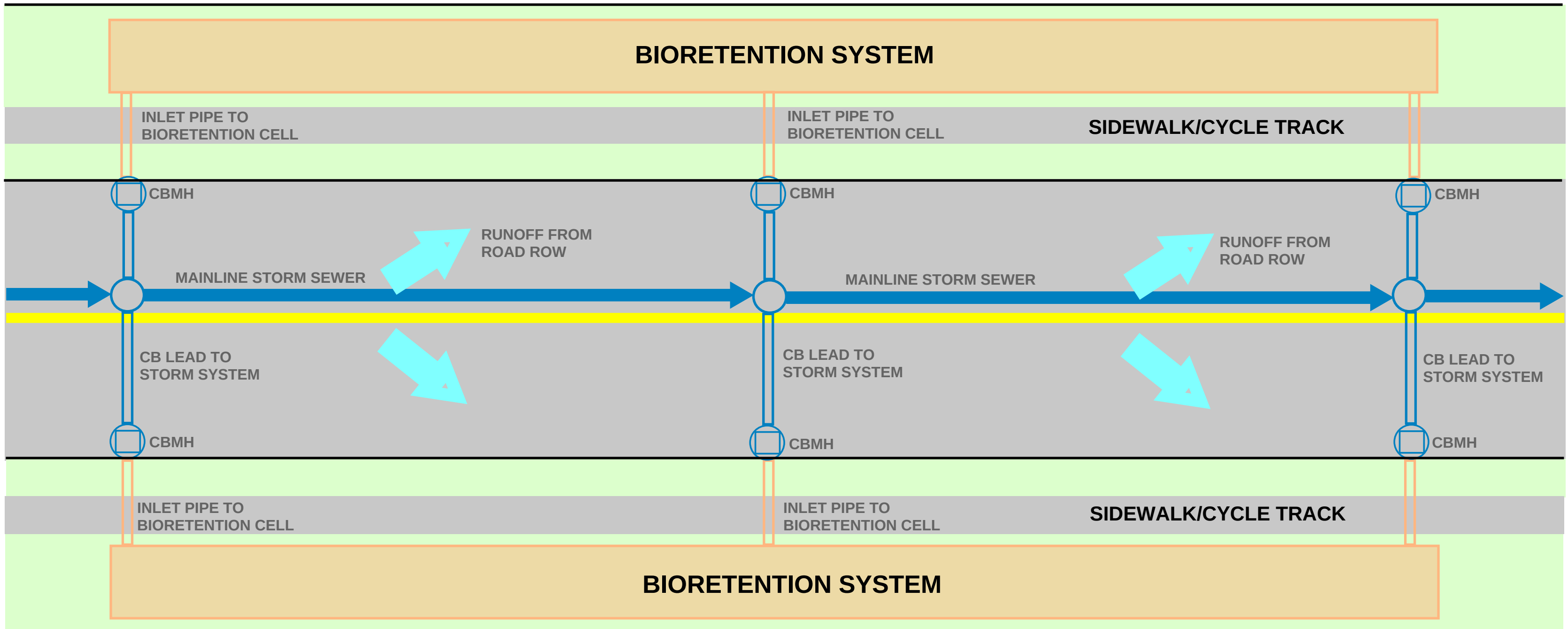
SCHEMATIC OF LINEAR LID BIORETENTION CELL FEATURE - FIGURE NOT TO SCALE

PLAN VIEW: ROAD RIGHT-OF-WAY LID IMPLEMENTATION



SECTION VIEW: SUBSURFACE DESIGN

NOTE: BIORETENTION SYSTEM CAN POTENTIALLY INCLUDE VEGETATIVE PLANTINGS OR STREETCAPING TREES, DESIGN TO BE DETERMINED