APPENDIX 'A'
Summary of Potential Factors of Basement Water Infiltration

APPENDIX ‘A’ - SUMMARY OF ASSESSMENT OF POTENTIAL FACTORS OF BASEMENT WATER INFILTRATION (MARCH 2015)

Potential Factor	Level of Influence	Notes
Stormwater to Utility Trench	Primary Cause	Validated by 2013 storm sewer leakage tests. 2014 impermeable collar test excavations confirmed significant amount of water in bedding material.
FDC and Utility Trench Depths	May increase risk of basement water infiltration at specific locations	Not a cause of basement water infiltration, but locations with shallower FDC depths (and thus utility trench depths) in relation to adjacent weeping tile systems would be expected to increase the risk of basement water infiltration.
Groundwater	May contribute additional/excess flows to the FDC and utility trench (Not sufficient to cause problem)	Groundwater in part contributes to water accumulation within utility trench bedding material but not viewed as a cause of the basement water infiltration experienced since 2008.
Creek Backwater		May contribute water to utility trench within bedding material, increased residence time within storm sewers but not viewed as a cause of the basement water infiltration experienced since 2008.
Osprey Marsh Pond (SWM) Backwater		Osprey Marsh Pond not a direct cause of surcharging or basement water infiltration, but may contribute to water within utility trench bedding material, increased residence time within storm sewers, however not viewed as a cause of the basement water infiltration experienced since 2008.
Basement Walkouts		Current hydraulic modelling efforts indicate an insufficient number to generate observed FDC flows and volumes under surcharge events; may still be a potential contributor to surcharging or basement water infiltration at specific locations however not viewed as a cause of the basement water infiltration experienced since 2008.
Inflow/Infiltration to FDC		Some contribution to FDC pipe flow due to amount of water within surrounding bedding material through cracks in pipes/MHs, but insufficient to be a cause of the basement water infiltration experienced since 2008.
FDC Hydraulics	May impair conveyance capacity of FDC system (Not sufficient to cause problem)	Sections of the FDC sewer system have been identified as undersized or poorly graded (flat) which exacerbates FDC surcharging, but not viewed as a cause of the basement water infiltration experienced since 2008
FDC Design		Analysis work indicates a number of deficiencies in FDC system using original design criteria, which may exacerbate FDC surcharging at specific locations. FDC system was however designed according to the approved criteria of that time. The deficiencies, while impairing the overall efficiency of the system, are not viewed as a cause of the basement water infiltration experienced since 2008.
FDC Tailwater		Receiving storm sewer has not surcharged during monitoring period; water levels have been above FDC outlet invert but for only brief periods and does not appear to directly correlate with observed FDC surcharge (and does not explain surcharge at upstream limits of system), thus not considered to be the cause of basement water infiltration experienced since 2008.
FDC Maintenance		FDC system flushed since study start-up; FDC systems are closed, hence would typically only require nominal maintenance. CCTV showed some issues with respect to debris accumulation, but generally minimal and not sufficient to cause persistent/widespread surcharge or the basement water infiltration experienced since 2008.
FDC Construction		Detailed information not available for all of the FDC system. Sections of trunk FDC along Ninth Line may have been constructed flatter than design, larger number of residences ultimately connected to FDC system than originally designed, however these discrepancies are not considered to be the primary cause of FDC surcharging or the cause of basement water infiltration experienced since 2008.
Cross-Connections	Not Applicable	Known cross-connections repaired; very few found
Creek Maintenance		Monitoring data do not indicate any correlation to FDC surcharge. Lands regulated by Conservation Halton; work needs to balance ecological impacts. City forces have cleared creek (sediment / vegetation) since study start-up with rapid re-growth noted.
GO Station		Monitoring data do not currently indicate any correlation between GO Station water infiltration and instances of observed FDC surcharge
Sanitary System		Region of Peel monitoring data indicated no sanitary system surcharging or correlation with identified FDC surcharging events
Lot Grading	Insufficient information	Insufficient information available to assess level of influence
Basement Construction / Changes		Insufficient information available to assess level of influence

APPENDIX 'B'
Summary of Potential Mitigation Measures

APPENDIX 'B' - SUMMARY OF POTENTIAL MITIGATION MEASURES (MARCH 2015)

Items	Action	Description	Analytical Support / Theory	Technical Considerations	Policy and Implementation Considerations	Effectiveness	Feasibility	Priority	Potential Further Investigation related to uncertainties and information gaps

1	**Strategic Lining of Storm Sewers**	Sealing the inside surface of storm sewers in strategic locations with an impermeable liner to reduce/eliminate leakage into bedding (and ultimately into FDC)	• Storm sewer leakage tests (2013) confirmed that storm sewers leak into the FDC system
			• Impermeable collar tests (2014) confirmed a significant amount of water in bedding material; water quality typing suggests surface water as source
			• Rapid FDC surcharge and temperature signal data strongly suggest a stormwater input; storm sewers largest likely contributor
			• Preventing storm sewer leakage would directly limit FDC surcharge potential
				• Several key preliminary locations based on historic basement infiltration and computer modelling:
				  ◦ Black Walnut Trail (BWT) north of Smoke Tree (32.9 ha – 3.6 km of storm sewer) – Highest priority area
				  ◦ Doug Leavens Boulevard (4.3 ha – 0.5 km of storm sewer)
				  ◦ Alderwood Trail (9.2 ha – 1.0 km of storm sewer)
				  ◦ Osprey Boulevard (16.4 ha – 1.8 km of storm sewer)
					• Work would all be done within public right-of-way, minimal disruption
					• Some loss in storm sewer capacity due to lining, generally nominal (5% +\-)
					• Preferred methodology to seal MHs and CBs
					• Need to seal catchbasin leads as well.
					• Lining of rear-yard catchbasin leads is a potential future work item; private property access may be required
						Moderate to High	High	High ***(Recommended)***	• Further potential refinement to locations of lining; test effectiveness in select locations before doing widespread lining (additional monitoring)
									• Need to further explore alternative technologies to determine the optimal lining material

2	**Construction of Utility Trench Dewatering System**	Dewater bedding material around the FDC to limit accumulation of water and provide additional storage volume during storm events	• Impermeable collar tests (2014) confirmed a significant amount of water in bedding material
			• Would limit excess water accumulation in bedding material and restore storage capacity
				• Given depth of FDC sewer bedding relative to surface water, a pumping system would be required
				• Given that pumping would be quasi-continuous (i.e. during non-storm and storm periods) back-up pumps and power less necessary
				• Consider several preliminary locations based on historic basement infiltration and forensic modelling:
				  ◦ BWT at Cactus Gate
				  ◦ BWT at Scotch Pine Gate
				  ◦ Along trunk between Derry and Osprey
				  ◦ Osprey Boulevard
					• Work would all be done within public right-of-way, minimal disruption
					• Uncertainty related to available public land to construct; lands would need to be in close proximity to problem areas
					• Approach to discharge pumped water will need to consider impacts to receivers (storm sewer or creek)
						Moderate to High	Moderate to High	High ***(Recommended)***	• Variable cost of pumping systems; would need to confirm locations and determine sizing and feasibility before proceeding further. Requires a pre-engineering study
									• Test effectiveness of a single installation before proceeding with others (additional monitoring); number and location of potential pumping systems to be confirmed based on effectiveness of highest priority pumping system and land ownership.

APPENDIX 'B' - SUMMARY OF POTENTIAL MITIGATION MEASURES (MARCH 2015)

Items	Action	Description	Analytical Support / Theory	Technical Considerations	Policy and Implementation Considerations	Effectiveness	Feasibility	Priority	Potential Further Investigation related to uncertainties and information gaps
3	**Construction of FDC Pumping Stations**	Provide pumping stations at key locations for the FDC system; activated once the system either approaches or reaches surcharge conditions; flows to be pumped to surface	• Computer modelling of a monitored surcharge event showed that pumping would be largely successful in reducing surcharge (depth and duration) for upper limits of the FDC system	• A larger pumping system would be required than for utility trench drains given amount and rate of water to be pumped during a storm • Given the need for the system to operate during storm events, back-up power and back-up pumps would be required which would increase costs • Potentially located at same preliminary locations as applied for utility trench drains to reduce costs	• Similar to utility trench drains	Moderate	Moderate to High	Moderate to High ***(Recommended)***	• Additional modelling should be completed to better confirm feasibility and preferred locations of FDC pumping

4	**FDC Sewer Upgrades**	Upsizing selected FDC sewers to increase their conveyance capacity and reduce surcharge	• FDC monitoring data indicate that the FDC system surcharges frequently, particularly in certain locations
			• Computer modelling of a monitored surcharge event showed that a FDC upgrade along a portion of BWT would eliminate surcharge in this location
				• Strategic upsizing by one standard pipe size in two key preliminary locations:
				  ◦ BWT (CNR to Scotch Pine Gate) – 1 km +\-
				  ◦ Along creek (Doug Leavens Blvd. to Ninth Line) – 2 km +\-
				• Focus on trunk FDC pipes; other smaller branches may also be required for upsizing
				• Would need to consider overall cost benefits and likely initiate the work once area infrastructure reaches its engineered lifetime
					• Works along BWT would be disruptive to residents (road reconstruction)
					• Potential synergy with other measures since excavation would be required regardless
					• Works along the FDC system within creek block would be much less disruptive
						Moderate	Moderate	Moderate ***(Recommended)***	• Further modelling assessment required to confirm benefit of FDC sewer upgrade along creek and required extents as well as Ninth Line, if shown to be effective
									• Would need to assess if upgrades negatively impact downstream areas
									• Assess whether additional costs likely given depth of excavation required in some locations (5 m +\-), particularly along BWT

5	**Sump Pumps**	Homeowner installs a new basement sump pump system to help to drain the weeping tile system around the home; sump pump would discharge to surface	• A sump pump should provide added relief for accumulated water within the residential weeping tile system, which should reduce the duration that water is around the home, and thus reduce the potential for basement water infiltration	• 187 homes (to-date) have reported basement water infiltration • Homeowner should confirm that a sump pump can be effectively installed in their basement; in particular that a clear outlet to the surface can be achieved (at least 2 m away from the foundation)	• Homeowner-led approach • City subsidy program in place for homes that have experienced basement water seepage to assist homeowners with cost of installation (up to 50% of invoiced total, up to a maximum of $3,000) • Applications must be reviewed and approved by City staff	Moderate	Moderate	Moderate ***(Recommended)***	• N/A

APPENDIX 'B' - SUMMARY OF POTENTIAL MITIGATION MEASURES (MARCH 2015)

Items	Action	Description	Analytical Support / Theory	Technical Considerations	Policy and Implementation Considerations	Effectiveness	Feasibility	Priority	Potential Further Investigation related to uncertainties and information gaps
6	**FDC Backflow Preventers**	Provide an impermeable collar around FDC lateral to prevent migration of bedding water, combined with a backflow valve on FDC lateral itself to eliminate surcharge impact to home	• Storm sewer leakage tests (2013) and impermeable collar tests (2014) confirm significant amount of water within bedding material and the potential for this material to transport water • Monitoring results show a correlation between FDC surcharge and reported instances of basement infiltration (ref. storm event of January 13, 2013) • Assumption that eliminating potential for FDC surcharge and duration to impact basement foundations (via either lateral or bedding material) would therefore eliminate primary cause of basement water infiltration	• Need to confirm least invasive method to install – would open cut excavation be the only solution?	• Likely that collars and backflow valves could be placed within City property (roadway limits) to maintain control • Inspection and maintenance needs may be challenging depending on access and location	Low to Moderate	Low to Moderate	Low to Moderate ***(Screened)***	• Further investigation would be required to identify priority areas • Potential impact to foundations given that no drainage outlet would be available during FDC surcharge events (backflow valve) – would this increase potential for basement water infiltration for certain weather/seasonal conditions? Magnitude of inflow/infiltration though likely significantly less.
7	**Storage**	Incorporate offline storage features (likely underground storage tanks) to detain excess FDC flows and reduce the resulting FDC surcharge	• Monitoring data suggest FDC surcharge continues to occur in several locations; storing some or all of the FDC surcharge would be expected to reduce potential for basement water infiltration • Forensic hydrologic/hydraulic modelling will assist in confirming observed flows and associated volumes within the FDC system	• Would depths of FDC permit gravity drainage or would pumping be required?	• Underground storage systems require significant land at depths to be effective, potentially necessitating the acquisition of private property • Significant additional costs if pumping is required	Moderate	Low to Moderate	Low to Moderate ***(Screened)***	• Additional modelling would be required to confirm observed and required storage volumes for more formative events • Where are preferred locations of storage based on FDC surcharge and available land? • Where would pumping be required?

APPENDIX 'B' - SUMMARY OF POTENTIAL MITIGATION MEASURES (MARCH 2015)

Items	Action	Description	Analytical Support / Theory	Technical Considerations	Policy and Implementation Considerations	Effectiveness	Feasibility	Priority	Potential Further Investigation related to uncertainties and information gaps
8	**Storm Sewer Outfall Collars**	Construct an impermeable barrier around storm sewer outfalls (including all other utilities) to prevent the movement of water from the receiving system back along the bedding material and potentially into the FDC or utility trench	• Storm sewer leakage tests (2013) indicated that storm sewers leak, and that bedding material is likely pathway • Subsequent analyses considered the potential that FDC inflows and elevated water in bedding (and duration) could be the result of storm flows backing up in the bedding material from receiving watercourses, which would have elevated levels during storm events • Two impermeable collars were designed and constructed in 2014 (Scotch Pine Gate and Pondview Way) along with additional monitoring devices • Limited monitoring data to date given construction timing, however initial results suggest that bedding water is primarily coming from upstream rather than downstream	• 42 identified storm sewer outfalls, 2 completed to-date = 40 remaining outfalls. Would it be necessary to install collars for all 40 storm sewer outfalls?	• Would all be within public property, along creeks and Osprey Marsh – minimal disruption to the public	Unknown	Moderate	Low to Moderate ***(Screened)***	• Further monitoring data required to confirm effectiveness at 2 test locations • If considering this alternative, need to strategically target specific locations; more field investigations may be required accordingly
9	**Basement Walkout Covers**	Construct covers over all identified basement walkouts so that rainfall does not contribute to walkout sumps (and potentially directly into the FDC system)	• City reconnaissance work (air photos) indicates a significant number of potential basement walkouts in FDC service area (377 total) which may contribute stormwater flows to FDC • Modelling work to date however indicates that for the area north of Derry Road, there are an insufficient number to be a significant cause of observed FDC surcharge; may be a potential contributor however	• What type of design would be required? Would need to ensure that water drains sufficiently far away from walkout structure (> 2 m?)	• Given that this work would be wholly on private property the only way this action would be difficult to implement. Work would need to be led by the homeowner given that home and walkout configuration would be unique	Low to Moderate	Low	Low ***(Screened)***	• Additional modelling work would be required to confirm potential impact of basement walkouts in other areas (between Derry Road and Britannia Road in particular) • Field confirmation would be required to confirm how many "potential" walkouts are actually present, but difficult to confirm if these features have a direct connection to FDC system or bedding material. Field confirmations would likely reduce numbers and potential contribution; private homeowner cooperation would be required • Are there potentially other walkouts which could not be identified on aerial mapping?

APPENDIX 'B' - SUMMARY OF POTENTIAL MITIGATION MEASURES (MARCH 2015)

Items	Action	Description	Analytical Support / Theory	Technical Considerations	Policy and Implementation Considerations	Effectiveness	Feasibility	Priority	Potential Further Investigation related to uncertainties and information gaps
10	**New FDC Outlet**	Re-direct FDC trunk sewer along Ninth Line to a free outfall (i.e. open channel rather than closed storm sewer)	• Monitoring data indicate water levels in receiving storm sewer do rise to level of invert of FDC outlet; however this is generally brief (10-15 minutes) and at lower depth (only a portion of FDC pipe) • Computer modelling indicates that tailwater conditions have a limited impact on performance of upstream FDC • FDC analysis spreadsheet indicates that trunk along Ninth Line is over-capacity using different design approaches, including the section along Erin Centre Boulevard which would be eliminated under this option	• Sewer cannot be re-directed to Sixteen Mile Creek due to significant depth of sewer (11 m +\- below grade at Ninth Line and Erin Centre Boulevard) • Based on a review of City's topographic mapping, the only likely feasible outlet is watercourse at Ninth Line just east of Hwy 407 EB on-ramp from Hwy 403 (Joshua's Creek watershed – Conservation Halton jurisdiction) • Would need to confirm this channel would have limited backwater influence (free-flowing) and has sufficient capacity • Assume re-direction would begin at Ninth Line and Erin Centre Boulevard • Would require 1.3 km of new FDC sewer; would offer a 0.1% (+\-) grade	• Outlet would appear to still be within the City of Mississauga boundary, but would likely include MTO lands given proximity to Highway 407 and 403; would require consultation and approval with MTO • Would require disruption to traffic along Ninth Line which is a major arterial for the City	Low	Low	Low ***(Screened)***	• Would need to further confirm benefit of re-direction, but monitoring data suggest this would be limited – outlet does not appear to be the source of observed FDC surcharge, although it may be a minor contributor • Further analyses would be required to confirm feasibility of grading, potential utility conflicts, and capacity of receiving watercourse to accept additional flows
11	**Creek Remediation**	Clearing of vegetation growth within Lisgar Creek (Sixteen Mile Creek tributary) to improve conveyance capacity of the channel and lower peak water levels	• Monitoring data to date generally indicate little to no correlation between elevated water levels in watercourses and FDC surcharging; watercourse levels typically peak later than FDC • Speculation has been that elevated water levels within watercourses may contribute to inflows to bedding material via storm sewer outfalls; or may prevent drainage of both bedding material and storm sewers, which increases residence time and accumulation (i.e. exfiltration from storm sewers) • Data collection from impermeable collars (2014) may further assist in assessing impact, and potential benefit of impermeable collars.	• Need to review to determine if a product or approach could limit vegetation re-growth, while still maintaining a natural aesthetic and obtaining approval from Conservation Halton	• Previous clean-out was time consuming and labour intensive • Vegetation grew back rapidly, negating the effort • Work would run counter to Conservation Halton objectives, would require on-going permit applications	Low	Low	Low ***(Screened)***	• Further monitoring data collection from impermeable collars may assist in assessing impact of elevated creek water levels on potential for stormwater movement through bedding material; however this is currently speculated to be of minimal benefit • How much could peak water levels be reduced through vegetation clearing? Additional hydraulic analyses would be required; need to factor in rapid re-growth of vegetation as noted

APPENDIX ‘C’
Details of Prioritized Action Plan

The following provides additional details related to the recommended potential actions:

1. Storm Sewer Lining

What's involved?

Re-line and seal the inside of storm sewers in priority areas.

Why will it help?

By preventing water from leaking out of the storm sewer system, the potential for leakage into the utility trench below should be significantly reduced, which should also reduce FDC surcharging frequency and extent.

How is it done?

There are several different methods available: one method involves inserting and attaching a liner; another method involves spraying sealant around the inside of the sewer

Where would it be done?

A number of priority areas have been identified based on:

- Locations of reported basement water infiltration;
- Locations where field monitoring data show the most frequent FDC surcharge; and
- Locations identified by computer modelling analysis.

The current list of locations includes the areas around:

- Black Walnut Trail (north of Smoke Tree Road);
- Doug Leavens Boulevard (west of the creek);
- Alderwood Trail; and
- Osprey Boulevard (east of the creek).

Based on an initial screening process, Black Walnut Trail (north of Smoke Tree Road) is considered to be a priority location.

2. Utility Trench Dewatering

What's involved?

Continuously drain water that has been accumulating in the utility trench at key locations.

Why will it help?

By draining the water from the utility trench as it accumulates, storage volume is restored which can be available during storm events if required, which should further reduce FDC surcharging.

How is it done?

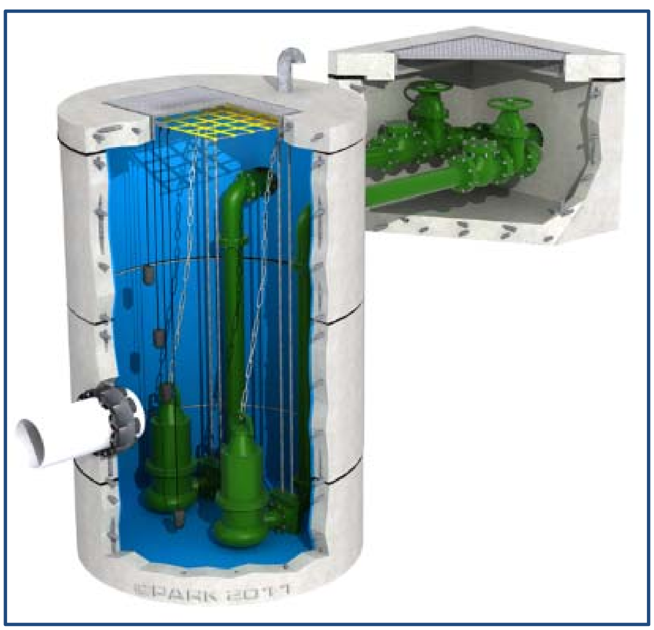
Because of the depth of the FDC system (in most locations), drainage by gravity is not possible. The water will therefore need to be pumped (using a system similar to a residential sump pump) to the surface, and then likely outlet to the creek.

Where would it be done?

A total of four different installations are currently considered; however, the precise number of installations required will need further study. The preliminary locations include:

- Black Walnut Trail (two different locations);
- Along the creek/trunk FDC between Derry Road and Osprey Boulevard; and
- Osprey Boulevard.

3. FDC Pumping Stations



What's involved?

Actively pump excess flow from the FDC sewer system during surcharge events.

Why will it help?

Pumping away the excess flow within the FDC system should reduce flows and therefore reduce the amount of FDC surcharge.

How is it done?

A permanent pumping station would need to be established which would be connected to the FDC system, likely by a new pipe at an existing FDC maintenance hole. The pumping station would involve an underground storage chamber with a "wet well" (to provide some depth of water to pump from) and one or more large pumps. These pumps would be triggered once water levels rise to a pre-set elevation, and would then turn on and pump the diverted water out of the FDC (likely to the surface and/or to the creek). The pumps would then shut off again once water levels drop enough

Where would it be done?

Further study and investigations would be required to confirm the precise number and locations of these pumping stations. Compared to dewatering of the utility trench, it should be noted that the FDC pumping costs will be significantly greater due to the requirements for larger pumps, backup units, backup power systems, more space and land.

4. FDC Sewer Upgrades

What's involved?

Increase the size and/or slope of existing FDC sewers.

Why will it help?

Larger and/or steeper sloped sewers can carry more water – by making the FDC sewers larger the amount of surcharging should be reduced.

How is it done?

The ground, including the roadway in most areas, is dug up to expose the existing FDC sewer pipe. The pipe is then removed piece by piece. A new larger pipe is installed including new larger maintenance holes, if required, and the ground and roadway are then restored.

Where would it be done?

No definite locations have been identified as of yet; further study and assessment would be required. Also, due to the disruption to the roadway, and the relative age of the FDC, storm and sanitary sewers, FDC upgrades should be coordinated with planned road works and/or when the sewer are approaching the end of their service life.

5. Sump Pumps

What's involved?

Homeowners in the Lisgar District with reported basement water infiltration installing a new sump pump system in their basement.

Why will it help?

Sump pumps would help to drain water from the weeping tile system around a home during a storm event, which should limit or reduce the potential for basement infiltration.

How is it done?

Part of the basement floor in a home would need to be cut and a sump pit created and connected in to the weeping tile system around the home. A sump pump is then installed, which begins pumping once water levels in the sump reach a pre-set water level. The water is then pumped out to the ground surface at a distance typically of at least 2 metres from the home.

Where would it be done?

The City of Mississauga is continuing to offer the Lisgar District Sump Pump Subsidy Program to homeowners in the Lisgar District with reported basement water infiltration. A financial subsidy is available to eligible homeowners of up to 50% of the sump pump installation cost, to a maximum of $3,000 per household.