INFORMATION REPORT

TO:	Chair and Members Public Works Committee
COMMITTEE DATE:	August 31, 2015
SUBJECT/REPORT NO:	Storm Event Response Group (SERG) and Flooding (PW15059) - (City Wide)
WARD(S) AFFECTED:	City Wide
PREPARED BY:	Dan McKinnon 905-546-2424, Extension 5941 Andrea Bazzard 905-546-2424, Extension 5605
SUBMITTED BY: **SIGNATURE:**	Gerry Davis, CPA, CMA General Manager Public Works Department

Council Direction:

Not applicable.

Information:

As a result of the changing climate Hamilton and other southern Ontario municipalities have experienced significant rainfall events with intensities, durations and frequency of re-occurrence that are unprecedented for the area. The City is committed to assessing, analysing and implementing storm water management improvements to mitigate these unprecedented events, however, it is important to note that flooding is a complex issue and will never be entirely eliminated.

This Information Report will serve as an update to the 2010 Information Update with respect to process and protocol improvements and solutions to address flooding, both complete and ongoing, that have been established through the Storm Event Response Group (SERG) committee and also collaboratively through the Public Works Department.

1.0 Executive Summary

To date, the City has inspected 85% of all its combined, sanitary and storm sewer mains, including all of the SERG focus flood areas, with a total of 450 km of inspections being completed since July, 2009 (section 2.1). In addition through the new sewer lateral inspection program 14,000 laterals (private drains) have also been inspected (section 2.2). These inspections have driven a rehabilitation program (section 2.3),

through which the City has addressed approximately 320km of sewer main, virtually eliminating pipes with conditions at the end of their service life from the system (section 2.4). While the inspection and rehabilitation program has been crucial to address Hamilton's aging infrastructure, these techniques will only ensure that the pipes are performing as to their original design.

Overall infrastructure network and flood analysis, through a thorough understanding of the existing major and minor systems design standards (section 2.5), hydraulic model simulations (section 2.6), analysis of rainfall gauges and radar data (section 2.7), and flow monitoring techniques (section 2.8), will collectively and ultimately lead to far more effective mitigation measures than condition inspections on their own.

In addition to overall network analysis, a number of studies have been completed for specific flooded areas (section 2.10), with remedial plans being brought forward as capital works. Other studies have been completed at the watershed level (section 2.11) to ensure the mitigation of impacts from existing and future developments.

Capital works, have been listed for the last five years totalling $160 million gross (section 3.1), and proposed capital works for the next five years totalling $407 million gross (section 3.2). A detailed listing of all capital works has been attached as Appendix A and Appendix B to Report PW15059, including an individual ward summary of all initiatives complete or planned.

Private property improvements are often the best option and most expedient solution to address flooding. Within this report there is an update on the successful roll out of the protective plumbing program (3P) (section 4.1), including the downspout disconnection program (4.2), and integration with the sewer lateral management program (section 4.3).

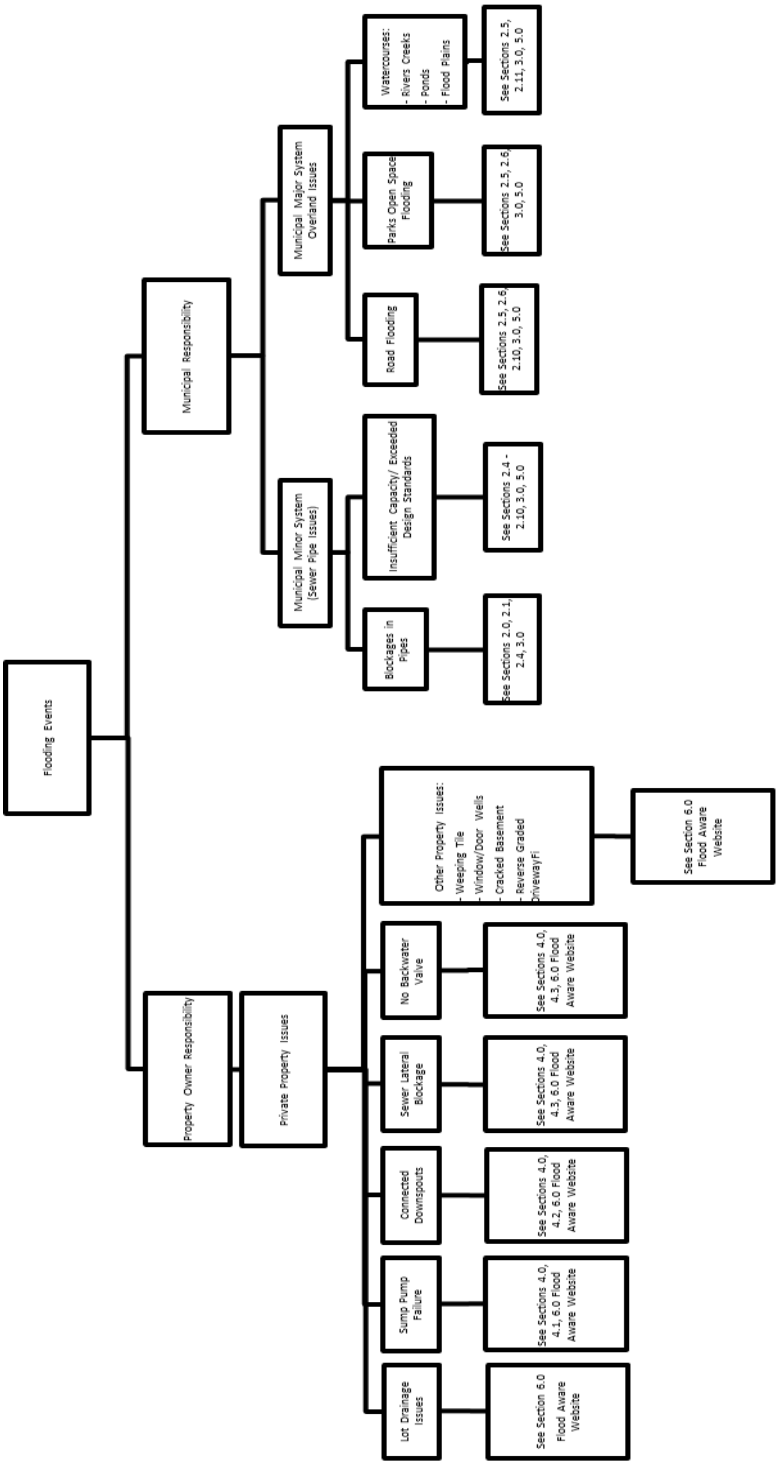
Prior to a storm event Water / Wastewater (WDWWC), and Road Operations and Maintenance (RO) staff ensure prioritized infrastructure sites such as inlets, outfalls, catch basins, and culverts are inspected and cleared as per standard procedures. Post event inspections and clean ups are also conducted (section 5.0).

Communications will also continue to play a vital role prior to and during storm events producing public service announcements and information for residents (section 6.0). Information has also been supplied through the City's web site - http://www.hamilton.ca/home-property-and-development/water-sewer/flood-preparedness - a convenient resource providing helpful tips for residents (section 6.0).

Finally, this report will outline some of the new techniques being promoted in the City to address future storm water management (section 7.0).

Figure 1 on the following page outlines the various types of flooding that can occur during a storm event, and outlines which section in this report has relevant information.

Figure 1.


Flooding Events
Municipal Responsibility
Municipal Major System Overland Issues
Watercourses: - Rivers Creeks - Ponds - Flood Plains
See Sections 2.5, 2.11, 3.0, 5.0
Parks Open Space Flooding
See Sections 2.5, 2.6, 3.0, 5.0
Road Flooding
See Sections 2.5, 2.6, 2.10, 3.0, 5.0
Municipal Minor System (Sewer Pipe Issues)
Insufficient Capacity/ Exceeded Design Standards
See Sections 2.4 - 2.10, 3.0, 5.0
Blockages in Pipes
See Sections 2.0, 2.1, 2.4, 3.0
Property Owner Responsibility
Private Property Issues
Other Property Issues: - Weeping Tile - Window/Door Wells - Cracked Basement - Reverse Graded Driveway Fi
See Section 6.0 Flood Aware Website
No Backwater Valve
See Sections 4.0, 4.3, 6.0 Flood Aware Website
Sewer Lateral Blockage
See Sections 4.0, 4.3, 6.0 Flood Aware Website
Connected Downspouts
See Sections 4.0, 4.2, 6.0 Flood Aware Website
Sump Pump Failure
See Sections 4.0, 4.1, 6.0 Flood Aware Website
Lot Drainage Issues
See Section 6.0 Flood Aware Website

2.0 Inspections, System Monitoring, Rehabilitation and Studies

2.1 CCTV and Zoom Camera inspections

The City of Hamilton has approximately 2,900 km of sewer mains within its wastewater and storm water collection system, made up of approximately 47,000 individual pipe segments. Since 2003 the City, through the Engineering Services and Hamilton Water Divisions of Public Works, has been very proactive with CCTV camera and zoom camera assessment. Through both the Capital Works and Operational programs approximately 85% of the system has been inspected since 2010. This includes inspections related to condition assessments, critical pipe assessments, rehabilitation projects, as well as emergency and risk management issues.

In the years following the 2009 flood events sewer inspection was prioritized to SERG areas for flood and capital analysis. For instance, since the flood events of July and August 2009, inspections were prioritized by the volume of flood complaints in many areas, with approximately 450 km of inspections completed, which have helped to determine the structural condition of the pipes, presence of blockages and/or any other operational issues present in those areas. It is important to note that through this entire inspection program, only a few minor maintenance issues were discovered, and staff have determined that none would have contributed to the flooding.

2.2 Lateral CCTV Inspections

In recent years the inspection technology has advanced to a point whereby laterals (private drains) can also be inspected from the City mainline pipe. Since 2008, with the inception of the lateral inspection program where laterals (private drains) are inspected and rehabilitated from the City mainline pipe, approximately 14,000 laterals have been inspected and 4,000 have been CIPP rehabilitated to date.

2.3 Cured in Place Pipe (CIPP) – Rehabilitation Program

To date approximately 320 km of sewer main have been rehabilitated through a cured in place lining process at a cost of approximately $82 million. This seamless cured in place pipe (liner) prevents infiltration and exfiltration, restores structural integrity (50 years plus life), and eliminates joints that can weaken and allow root intrusion. As a “no dig” technology the liner is applied via existing sewer manholes, and as such, the field work takes weeks as opposed to months and is completed at one third of the cost of traditional open cut replacement. While this strategy does not increase the size of the pipe there is a benefit of improved hydraulics of the new liner pipe relative to the deteriorated existing pipe.

Figure 2

Sewer CIPP - Length(m) by Year by Ward

	WARD																
	(Blank)	W01	W02	W03	W04	W05	W06	W07	W08	W09	W10	W11	W12	W13	W14	W15	Grand Total
YR																	
(Blank)	78.3	2125.35	6678.53	6436.4	2045.6	853.7	514	1816.1	1046.09	1646.2	523.5	112.9	216.8	2350.52		390.6	
	24																26,858.59
1992		132.5															132.50
1993			311.8														311.80
1994				72.2	88.9												161.10
1995		75.61															75.61
1996	81.3	484.1		210.7	34.4		96										906.50
1997		412.11												1271.9			1,684.01
1998			113.2	696			496	957									2,262.20
1999		1534.4			314.8		70	103						1542.3			3,564.50
2003		3528.1	282.8	1151.5	1337.1		1395.405	2027.3	1511.34	1276.1	373.9	85.1		132			13,100.65
2004		2847.08	888.7	1039.8	2016.27	691.4	3880.725	3823.3	1381.17	327.1		269.3		1708.1			18,872.95
2005		1028.38	2545.15	220.2	190.2	432.6	1994	1509.2	703.06	85	21.5	86	128.8	6406.6			15,350.69
2006		846.2	1300.39	2803.4	6198.83	2007.9	3447.5	4687.2	4596.31	2212.39	723.9	135.6	79.3	2064.5		265.6	31,369.02
2007		2723.36	4630.7	7308.9	11474.8	521.9	815	5913	1478.76	849.8		207.9	180	1527.1			37,631.22
2008		2016.94	2640.23	8877.4	5717.4	3966.3	1627.5	4087.3	5376.57	3112.65	457.5		427.1	1089.3			39,396.19
2009		895.72	1644.8	5326.46	2886.9	953.8	1931.2	1866.2	1939.25	530	651.4		85	256.05		29.7	18,996.48
2010		1519.5	4034.6	4524.97	3423.6	1240.7	1891.5	4028.1	1494.36	1248.7	438.77	322.1	163.8	682.95		144.2	25,157.85
2011		678.69	2824.4	3398.65	2678.6	1093.3	3892.4	3679.75	1747.19	969.2	88.2		105.6	493.1		86.8	21,735.88
2012		1890.082	1493	5547.65	3618	2311.3	2188.9	784.75	2153.49	789.1	427.9		64.6	814.3		262.1	22,345.17
2013		4264.75	1624.1	3303.4	2357.15	1843.4	1012	2367.4	1596.17	1187.638	453.58	229.7	161.7	2091.84			22,492.83
2014		1801.45	1969.5	2918.2	3048.9	1056.5	3008.404	451.5	367.52	2689.3	59.6			347		72	17,789.87
Grand Total	183.60	28,804.32	32,981.90	53,835.83	47,431.45	16,972.80	28,260.53	38,101.10	25,391.28	16,923.18	4,219.75	1,448.60	1,612.70	22,777.56		1,251.00	320,195.60
Network Total	140,732.39	150,214.29	133,244.26	179,541.31	175,190.43	218,762.56	222,025.64	315,770.02	299,953.18	164,541.22	172,636.81	199,161.03	238,542.45	174,422.11	4,986.00	120,828.55	2,910,552.24
% of network Rehabilitated	0.13%	19.18%	24.75%	29.99%	27.07%	7.76%	12.73%	12.07%	8.47%	10.29%	2.44%	0.73%	0.68%	13.06%	0.00%	1.04%	11.00%

2.4 Overall Structural Condition Rating

Through CCTV and Zoom camera inspections, all sewer mains are graded from 1 - 5 using the WRc[3d] edition (Water Research Council) international engineering standard. A pipe rated condition grade "1" would be considered to be in excellent condition, while a pipe with a condition grade "5" would be considered to be at the end of its structural design life. While the zoom camera inspection program is very useful for identifying service related issues, it can only provide an indication on structural condition. The City continues to investigate sewer condition through a comprehensive CCTV inspection program. Through the CCTV and zoom camera inspection programs, and subsequent rehabilitation program, Hamilton has virtually eliminated all grade 5 pipes from the storm and wastewater collection system as can be seen in figures 3.1, 3.2 and 4.1, 4.2.

Figure 3.1 – 2010 Ratings

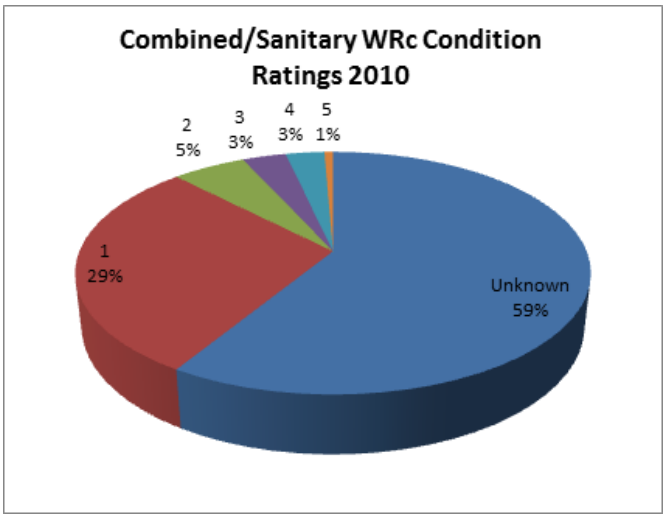


Figure 3.2 – 2010 Ratings

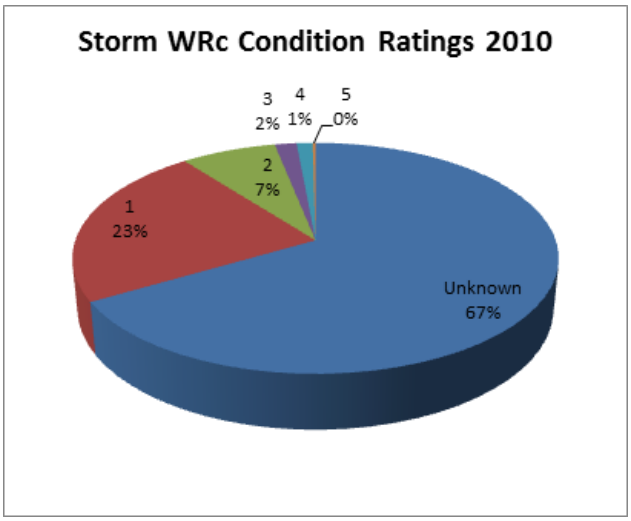


Figure 4.1 – 2015 Ratings

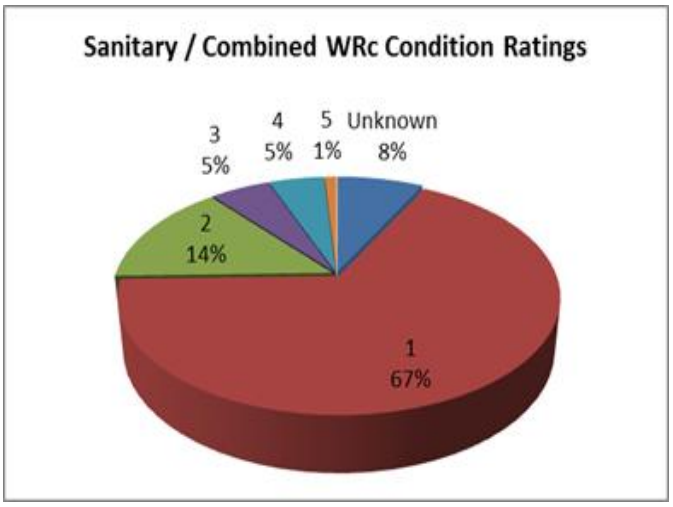
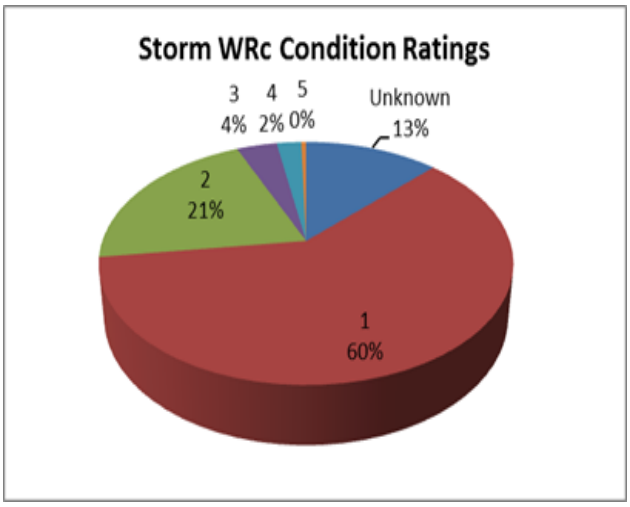


Figure 4.2 – 2015 Ratings



It should be noted that while the structural condition of the sewer network has increased significantly through the above program, post flooding inspections did not reveal pipe defects and/or design and operational issues that could be the cause of the flooding events. For example, following the flooding event of July 2009, approximately 450 km of sewer main were inspected but only a handful of minor defects, blockages, and operational issues were identified and none are believed to have contributed to the widespread flooding that occurred. It should also be noted that the above inspections provide an excellent record of condition, however, in the analysis of flooding it is the performance of the stormwater management, sanitary/combined sewer systems, including overall capacity and flow characteristics that are essential to understand. There are other performance modelling techniques far more adept for this as will be explained further in the sections below.

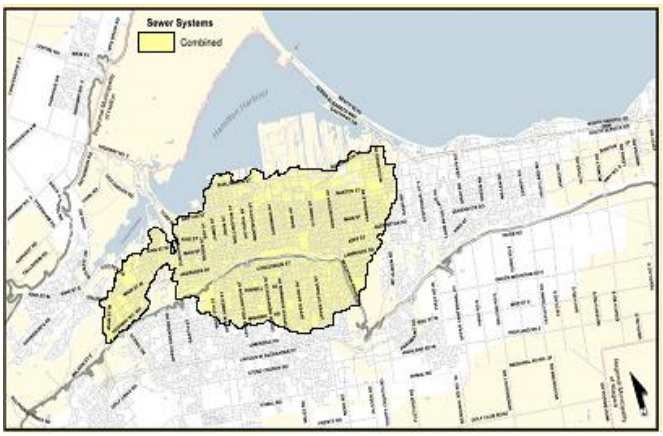
2.5 Existing Minor and Major Stormwater Management System Design Standards

The delivery of stormwater management services in Hamilton can be categorized in two ways depending on geographic area. Specifically, there is

a) the Combined Sewer Service Area, and
b) the Separated Storm Sewer Area.

Figure 5 shows the geographic delineation between the two areas in Hamilton. The area outlined in black is the combined sewer service area.

Figure 5



Common to both types of systems is the fact that the underground pipes (Minor System) have a limited carrying capacity by design. The engineered conveyance capacity of the sewers can be quantified by the design return period expressed as 1:5 year storm for example. This can be simply interpreted as the sewer pipes were sized to convey no more than the runoff generated by a 1:5 year rainfall event (~44.4 mm of rain in 2 hours). Rainfall greater than 44.5 mm event would cause the pipe to be full. The design return period for sewers in the various communities in Hamilton are generally summarized below.

Community	Design Return Period (year)	Total Depth of Rain (mm over 2 hours)
Ancaster	2	30
Flamborough, Stoney Creek, Glanbrook, Dundas	5	44.4
City of Hamilton (pre-amalgamation)	17	60.1

Uncommon between the Combined Sewer Service Area and the Separated Storm Sewer Area is the Major System. It is important to note that the combined sewer service area does not have an engineered Major System. Generally, the Major System is comprised of the components to manage rainfall volume that exceeds the capacity of the Minor System. These include channels and ditches, roadways, and ponds.

These Major System components are similarly engineered to a design return period. Generally, the 1:100 year rainfall event (~83.8 mm in 2 hours) is used to size the infrastructure.

It is important to understand that both the Minor System and Major System have their respective threshold servicing capacity. When the volume of rainfall exceeds the design capacity of the infrastructure, diminished services are experienced including flooding.

Additional conditions that cause hydraulic demand in sewer and overland flow systems to exceed the carrying capacity are listed below:

- Severe rainfall
- Changes in adjacent property characteristics
- Increased population
- Increased impervious land area (pavement)
- Illegal plumbing connections (i.e. downspouts connected to the sanitary system)
- Saturated and/or frozen ground causing excessive runoff
- Debris, obstructions and sedimentation in pipes, inlets and watercourses

Continual improvements are being made to the design standards for Stormwater since the adoption of the “Criteria and Guidelines for Stormwater Infrastructure Design” in 2007. Some of the recent changes include:

1. Incorporation of a minimum of 2m separation between foundation walls to provide a spillway/overland flow route from the RYCB (rear yard catch basin) to handle events larger of the 100 year storm or Hurricane Hazel storm.
2. Sump pump standard has been revised to include a secondary relief valve and a backup power.

Using the past fourteen (14) years of recorded rainfall data an assessment was undertaken that focused on the evaluation of the current rainfall and intensity duration frequency (IDF) curve data to determine if the current IDF standard is still reflective of the most recent rainfall events observed in the City. It was concluded the current IDF curve data is representative of the rainfall events and no changes were recommended.

The study also assessed how the City’s current IDF compares to other municipalities in the area. It was found that the City’s current IDF parameters generally generate more

rainfall than those of most other nearby municipalities. The study concluded that the City's IDF parameters results in relatively conservative storm infrastructure designs.

2.6 Computer Models

Computer models are utilized to compare the conveyance capacity of existing sewer infrastructure relative to the demand placed upon them from domestic and Industrial/Commercial/Institutional (ICI) sanitary flows as well as the system response to storms. This analysis can include historic (real) events and synthetic events including storms which might occur in the future; including the impact of Climate Change.

In a well designed sewer system where land use practice and private drainage are within originally designed limits, a computer model generally confirms that the system performance is as it was originally designed. Occasionally, a computer model will show that a sewer system is not able to convey the calculated flow indicating a change to original design loading characteristics. In this event staff may undertake forensic investigation to determine what has changed.

A robust and calibrated computer model can predict the location within a collection system where the capacity will be exceeded when applying progressively more demanding rainfall events. This approach was used to identify and validate known "hot spots" within the Lower East End Drainage Study (LEEDS) and the Fessenden Neighbourhood. With these findings a capital program has been initiated to improve the service levels.

2.6.1 Sanitary and Combined Sewer Systems

Currently, the City has assembled computer models for all sanitary sewers and combined sewers integrated with combined sewage overflow tanks; pumping stations and wastewater treatment plants.

In 2012 the City completed a City Wide Detailed Wastewater Model which provides a representation of land use, environmental processes (groundwater regime, evapotranspiration etc.,) and includes nearly every hydraulically relevant element in the combined and sanitary sewer system, including:

- pipes
- nodes
- pump stations
- CSO tanks
- Real Time Control facilities
- overflows

This model has been calibrated, leveraging the City's sewer flow and rainfall monitoring campaigns, has been independently peer reviewed, and is a powerful tool to assess the sewer system response to wet weather, growth, intensification and plan/design solutions to meet these demands.

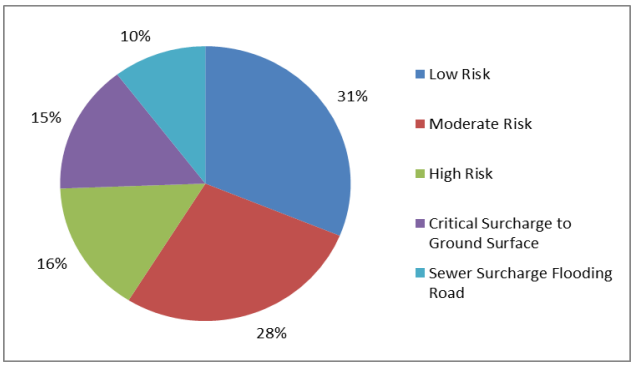
A robust and calibrated computer model can predict the location within a collection system where capacity will be exceeded when applying progressively more demanding rainfall events. This approach is used to identify and validate flooding "hot spots" within

the city, and is currently being leveraged to support flooding and wet weather studies across the system and for reporting to the Federal and Provincial governments on annual CSO control/performance. The Detailed Wastewater Model will also play a key role and be a powerful tool in the upcoming Flooding and Drainage Master Servicing Study.

By using the model, city staff may better understand the performance of the collection system, validate observed flooding and develop and design capital programs to improve level of service.

The following pie chart depicts Detailed Wastewater Model results indicating the risk of basement flooding in the combined service area of the city for a 5 yr 6hr Soil Conservation Service (SCS) storm (equivalent of 56.5 millimetres in 6 hours). This is a type of rainfall distribution that we use in computer models. This storm has a peak intensity of 88.14 mm/hr and differs from the IDF curve storms that are used for simple Rational and Modified Rational Method calculations. Specifically, this risk of basement flooding is calculated as the modeled level of surcharge in sewer pipes, relative to assumed basement elevation, or approximately 1.8 metres below the ground surface. Applying this storm in the Detailed Wastewater Model indicates that a large percentage (41%) of sewer pipes in the combined area would surcharge to levels where they could flood basements (High Risk – Critical Surcharge), and pipes that are so surcharged that dilute sewage is spilling from manholes and flooding roads. A large percentage of pipes are at moderate risk of flooding basements, meaning that they surcharge to a level that is just below or at assumed basement elevation.

Figure 6 – Modeled Risk of Sewer Surcharge Flooding Basements in the Combined Sewer System for a 5yr 6hr SCS Storm



2.6.1 – Storm Sewer Models

The storm sewer system "All Pipes Model" using MIKE URBAN software has been completed for the Stoney Creek and Dundas Areas. The development of the two models included some calibration and validation. Calibration and validation will continue into the future to ensure accuracy and enhance the predictive precision of these models.

Computer models for Ancaster, Waterdown, Hamilton Mountain and Binbrook are yet to be developed. Currently the delivery of these projects is not sustainable with the limited stormwater full time equivalent resource allocation.

Upon completion of each type of model, staff will better understand the performance of the collection systems, validate observed flooding and develop capital programs to ensure a common level of service across all property owners in the City.

2.7 Rainfall Data Systems

The City had a network of 19 rain gauges which was recently expanded to 30 rain gauges. This data is used to calibrate models, is coupled with sewer flow monitoring data to analyse response to wet weather and assess system hydraulic performance and is leveraged for the City's annual regulatory CSO reporting to the Federal and Provincial governments. The data from rain gauges can also be used in conjunction with RADAR data, as a "ground truth". When combined, this gauge adjusted RADAR rainfall analysis provides a detailed characterization of intensity, geographic extent, direction and speed of an event, and allows staff to better correlate flooding patterns with dynamic rainfall events. A characterization of events allows the City to better understand the performance of the collection system in terms of its designed service level versus the demand that nature puts on it.

This analysis is useful in understanding trends in the character of rainfall events, especially in the context of Climate Change and how the City designs Minor and Major Stormwater Management (SWM) Systems; Emergency Preparedness Planning and Education and Outreach.

2.8 Sewer Pipe Flow Monitoring

Over the last few years, Hamilton Water has installed 265 temporary flow monitors at key locations City-wide. Flow monitoring in the sanitary system allows staff to determine whether the collection system is performing as expected, as the monitors revealed whether sanitary sewers are receiving substantial amounts of rainwater inflow and groundwater infiltration (I/I) which can result in flooding. A reduction in I/I will reduce the total flow within a sanitary pipe and therefore reduce the chances of Sanitary Backups or unnecessary infrastructure upgrades. This data, along with the rainfall data, is also used to calibrate computer models.

2.9 Real Time Control

Real Time Control (RTC) refers to a system of infrastructure (E.g. gates, weirs, pumps etc.,) and controls which are automated and adjusted in real time based on flow, level or status measurements in the wastewater system. It improves the operation of the combined sewer system by hydraulically managing flows. Controlling stormwater flows through RTC optimizes conveyance capacity in portions of the system, thus improving conditions in the immediately upstream catchments. The primary benefit of RTC is environmental protection by decreasing overflows to Hamilton Harbour. In addition RTC provides system protection by managing flows to the wastewater treatment plant.

RTC is typically implemented to meet an operational goal or target such as reduction in combined sewer overflows (CSO), control of flooding to protect neighbourhoods, or management of peak flows to help protect treatment facilities during extreme events. Storms are dynamic but controls on flow and level in sewer systems have historically been static, meaning they don't respond to changing flow conditions. The replacement of static facilities with RTC provides better control and enhanced performance of the wastewater system, leverages spare capacity of existing infrastructure, and typically does this at a much lower cost and requires less land when compared with alternatives such as constructing new combined sewer overflow storage facilities or other infrastructure solutions.

The recent RTC implementation within the collection system is designed to enhance system performance by maximizing the volume of wet weather flow captured and treated within existing system infrastructure. In this manner, the investment in RTC is designed to maximize the investment already made within the collection system (within trunk sewer system and storage facilities) as well as at the Woodward Avenue WWTP (maximize the use of increased centralized treatment capacity). As such, it will be a key component in meeting the needs of the City's pollution control strategy for Hamilton Harbour.

The four facilities constructed for the first stage of RTC, operational in late 2012, increases the City's average annual CSO capture by over 500,000 cubic metres (equivalent to 200 Olympic sized swimming pools) near the West Harbour, provides enhanced flooding protection to neighbourhoods near the West Harbour and North End, and provides peak flow protection for the Woodward Avenue Wastewater Treatment Plant during extreme events.

Working with lessons learned and building upon the success of RTC Phase 1, a second phase of RTC is planned. This federally funded project will provide improved operation to existing CSO tank and control facilities which are tributary to sensitive receiving waters at Cootes Paradise and Red Hill Creek. The introduction of new sensor technology, a limited amount of new infrastructure and a coordinated and automated operating strategy will reduce the volume and frequency of combined sewer overflows. The design phase of this work is scheduled to start in Q4 2015.

2.10 Area Specific Stormwater Studies

These studies are undertaken to review the extent of the existing problem and to recommend actions to fix the problem or to implement mitigating measures to reduce the impact and frequency of the flood-events. These studies also consider situations up-stream and down-stream in order not to relocate problems to other neighbourhoods.

The recommendations of these studies include site specific improvements, i.e. the size of pipes through reconstruction, to a wide variety of storm water management technologies including controlling/delaying the flow of water to the sewers so they do not surcharge (back-up) or are directed to retention/detention ponds to control the flow and also improve the quality of the water that eventually ends up in the harbour or lake.

Since 2010 the following studies have been completed:

- Fessenden Neighbourhood Stormwater Project
- Rosedale Neighbourhood Flood Investigation and Remediation Project
- Churchill Park Neighbourhood Flood Assessment Project
- Winona Area Flood and Drainage Remediation Analysis Project
- Rothsay Ave Flood Remediation Project
- Sanatorium Rd SWM Review and Holbrook School Stormwater Recommendations Project
- Binbrook & Upper Stoney Creek Flood Stormwater Review Project
- Jasper drive and Bland Ave Flood Investigation Project
- Stoney Creek & Battlefield Creek Flood & Erosion Control Project
- Mill Street Bridge Scour & Erosion Assessment:
- Shrewsbury Flood Investigation and Remediation Project
- Assessment of Battlefield Creek Hydrology and Hydraulics at Centennial Pkwy and CPR Culvert Crossings
- Greenhill Avenue Area Storm Drainage EA Study
- Centennial Parkway Drainage EA
- Battlefield Creek Channel and Slope Stabilization
- Watercourse 5 & 6 Environmental Assessment
- Old Dundas Road – HC005 Basement Flooding Study (undertaken as an area specific Master Plan)
- Riverdale East Basement Flooding Study (ongoing)
- Binbrook Basement Flooding Study; Sewer System I/I Rehab; Master Plan Infrastructure Upgrades
- Upper Stoney Creek Flooding Investigations
- Vern Ames & Reno Neighbourhoods
- Kenilworth and Grenfell Avenue
- Assessment of Flooding in Binbrook and Upper Stoney Creek during the storm of July 22, 2012
- Investigation of Flooding in the Bolzano-Eaglewood-Gagliano area
- St. Elizabeth Village Stormwater Management Facilities Functional Design
- Waterdown North Master Drainage Plan Addendum
- West Central Mountain Drainage Assessment

2.10.1 The Lower East End Drainage Study (LEEDS)

The Lower East End Drainage Study (LEEDS) was initiated to address severe wide-spread basement flooding in the Lower East End of the City. The study area included an area with the highest concentration of reported flooding problems. The main purpose of the LEED study was to understand the causes of the flooding problems, and to investigate and recommend potential remedial measures. The area is serviced by a complex combined sewer system, which was originally designed to convey sanitary sewage as well as stormwater from the ground surface and roofs within one single sewer pipe. Historically, as part of road reconstruction projects, a number of storm sewers were added over time to the system in this area.

The scope of the LEED study included development of an "All-Pipes Model" using MOUSE / Mike Urban software, which was subsequently connected to the City-Wide Mike Urban Trunk Model. Due to the size of the study area and the complexity of the sewer system, the study area was broken into thirteen (13) focus areas of manageable size for modelling and assessment purposes.

The LEEDS model was used to test over 90 potential remedial measures identified to alleviate basement flooding in the reported problem areas. The types of measures tested with the model include:

- Upgrade combined/storm relief sewers with limited capacity (replace existing sewers with larger sewers)
- Redirect sewers away from problematic/over-utilized sewers (replace existing sewers with new sewers that connect to the system further downstream or to another part of the system)
- Extend storm relief sewers (extend storm relief sewers upstream and provide connections to the upstream combined sewers to expand the service area of the storm relief sewers, or extend the storm relief sewer to connect to an upstream storm relief sewer and fill in a "gap" in the storm relief sewer system)
- Modify or provide sewer connections (add CSO connections from combined sewers to storm relief sewers or modify existing connections to permit additional overflow)
- Modify weirs, orifices, gate settings (to increase local CSOs, to block or adjust problematic connections)

The benefits to the problem areas were rated based on the hydraulic benefits. Graphical illustrations were created to show the changes of the system performance for each measure that was tested. The illustrations showed the effects based on a 2-year 24-hour SCS design storm (52.8 mm over 24 hours), which produces a peak flow that has a return period greater than the 2 year event. Those measures that would provide the most benefit, in terms of number of hotspots benefitted, hydraulic system benefit, and least flooding risks were recommended for implementation in coordination with the City's yearly Road Reconstruction Program.

Many of these measures have already been constructed in the last 4 years, as per the following list, after obtaining Environmental Compliance Approvals for Municipal Sewage Works from the Ministry of Environment and Climate Change (MOECC).

- London – Maple to Roxborough
- Kenilworth Avenue Underpass Flooding Storm Relief
- Monterey – Province to Park Row
- Garside – Main to Dunsmure
- Barton/Ottawa – Barton St E, Agnes to Ottawa & Ottawa
- Maple - Huxley to Wexford
- Houghton, Wexford, Huxley – Main to Dunsmure
- Park Row - Main to Roxborough/Province & Graham
- Barnesdale - King to Cannon

To date the budget spent on the implementation of these projects is approximately $16 million dollars with approximately 3410 properties ("Hotspots Areas"), as well as the Kenilworth underpass benefitting from the recent improvements. Benefits of these implemented measures include:

- Reductions in hydraulic grade line (HGL – *the maximum water level inside a sewer pipe*) thereby reducing the risk of basement flooding; and
- Improved overall network performance both upstream and downstream of the project limits due to removal of bottlenecks

The City is going to continue programming the remaining recommended remedial measures as part of the Lower East End Drainage Study (LEEDS), subject to annual budget approval process and capital program coordination. A list of the proposed projects for the next five years is provided below.

- Gage Park Storm Water Management Facility
- Rosslyn – King to Roxborough
- Britannia/Oriole/Adair
- Edgemont – Maple to Main

2.10.2 The Fessenden Neighbourhood Class Environmental Assessment

The Fessenden Neighbourhood Class Environmental Assessment was initiated by the City of Hamilton to address flooding during major storm events and to reduce the risk of flooding within the neighbourhood.

In order to replicate the actual flooding events, the scope of Fessenden Class EA included development of a 1 dimensional and 2 dimensional (1D/2D) integrated drainage system model. An integrated MIKE FLOOD/ URBAN modelling software was selected for this purpose because of its capability to analyze sewer networks under surcharged conditions and the interaction between the sewer system flow and the surface (overland) flow. This model was developed to facilitate assessment of the storm sewer system and the overland drainage system capacities.

Various types of measures to alleviate flooding and mitigate storm drainage problems were investigated within the study area. Each of these measures has been tested on their effects to reduce the risk of flooding within the neighbourhood using the modelling tool. The modelled alternative solutions were compared to original conditions (flooding events) through the use of surface flooding maps and sewer profiles showing the system performance produced by the drainage system model.

The City has subsequently initiated the detailed design and construction of the preferred solutions in three phases as follows:

Phase 1: Underground stormwater detention tanks on Greencedar Drive.
Phase 2: A stormwater management facility on the Sir Allan MacNab School property, complete with storm sewer connection to a new control chamber at the intersection of Appleford Road and Forestgate Drive.
Phase 3: Increased storm sewer capacity from the depression area on Magnolia Drive to the new control chamber previously constructed in Phase 2.

To date the three major infrastructure components, as noted above, have been constructed at a total cost of $8.3 million dollars. The benefit is reduced surface flooding during the major storm events (i.e. 100 year storm). The majority of surface runoff experienced during a 100 year design storm (84.76 mm over 2 hours) is contained within the curbs. With this improved level of service it is expected that residents in the study area may now approach the insurance industry with a lower risk rating.

2.10.3 Assessment of future hydrology and hydraulic performance of the Lower Spencer Creek system considering Climate Change, including monitoring of Creek Sediments & Erosion

The City of Hamilton, the Great Lakes – St. Lawrence Cities Initiative (GLSLCI), the Hamilton Conservation Authority (HCA), and the Royal Bank of Canada (RBC) Blue Water Project has partnered to undertake this pilot showcasing study. The objective of the study is to complete an environmental and infrastructure vulnerabilities analysis in the Spencer Creek watershed under future climate change conditions.

2.11 Ongoing Flooding Studies

There can be multiple causes of basement flooding and each severe storm and neighbourhood flooding study requires a synthesis of information from a number of sources in order to determine root causes, including:

- Reported (and inferred) flooding occurrence
- Flow and rainfall monitoring
- Infiltration and Inflow Studies
- Smoke and dye testing
- Field inspections
- CCTV and zoom camera inspections
- Computer models
- Historic reports and design drawings
- Staff knowledge

2.11.1 Binbrook Flooding Study

The extreme event of July 26, 2012 was of a magnitude and intensity that is unprecedented in the historical record, with an extrapolated return period exceeding 1000 years. This storm overwhelmed drainage systems in Binbrook and resulted in basement flooding due to sewage backup as well as storm related flooding. Ongoing and regular flow monitoring in the sanitary system, intended to record the severity of infiltration and inflow, captured this storm and provided staff with a good basis for further assessment of the causes of flooding, and design of solutions.

Extensive field reconnaissance following the event included smoke testing, field inspection and CCTV review. This information was subsequently used to identify sources of extraneous flow in the sanitary system. To date a number of remedial measures have been implemented including; replacement of traditional manholes with solid lids (no pick-holes) to reduce the amount of stormwater that can infiltrate into the sanitary system during severe events and when street ponding occurs, rehabilitation of the sanitary sewer system by developers (in areas that are still under development control), and for defects in the city's right-of-way. In addition to the above works, a comprehensive study was completed which developed scope, cost and payback period scenarios for trenchless rehabilitation works. This work is required to help seal the sanitary system from excessive infiltration and inflow. These trenchless works are currently being scoped, budgeted and will be included in the upcoming 2016 rate budget. To help protect homes against catastrophic failures, a sanitary to storm emergency overflow in the collection system has been redesigned and, pending Ministry of the Environment and Climate Change approval, is scheduled for construction in 2016.

Pumping station and collection system upgrades required to service growth and full buildout in Binbrook were identified in the Water and Wastewater Master Plan (2005). Following the flooding and utilizing new information gathered about system response to wet weather, these upgrades were revisited and designs were modified. New designs are currently being advanced that will accommodate wet weather flows and address any operational issues. This work is being completed concurrently with the Upper Centennial trunk sewer tunnel which is currently under construction. This new tunnel will provide a new outlet for sanitary flows from Binbrook. This work is currently scheduled for completion in 2017.

2.11.2 Ancaster - Old Dundas Road (HC005) Sewage Pumping Station Flooding Study

The Old Dundas Road Sewage Pumping Station (HC005) was designed and constructed in the 1970's and services an area of approximately 180 hectares. The January 13th, 2013 rain on snow event and resulting basement flooding was the trigger for this study.

An Environmental Impact Statement study was completed in 1994 on the Old Dundas Road Sewage Pumping Station (HC005). The 1994 study investigated the option of providing an Emergency Overflow in order to reduce the risk of flooding of adjacent homes in the area during substantial rainfall or snowmelt events. The study was never formally approved by the Council of the day due to lack of agency support (Ministry of Environment, Ministry of Natural Resources, Niagara Escarpment Commission and Hamilton Conservation Authority), as it was the only alternative considered. In 1997 the City decided to no longer pursue this option and therefore authorized the release and abandonment of an overflow pipe easement which had been acquired and registered in 1992.

Over the years, the City has undertaken routine maintenance on both the sanitary sewer system and the Old Dundas Road Sewage Pumping Station (HC005). More recently, flooding of basements has occurred in 2005, 2006, and 2013. These ongoing

flooding events can be attributed to rainfall/snowmelt induced overloading of the sanitary sewer system and/or the Old Dundas Road Sewage Pumping Station.

Field investigations including sanitary manhole inspections, smoke testing, flow monitoring, and computer modelling and analysis were completed in 2013. These investigations were undertaken to determine the causes and extent of flooding in the study area. These investigations revealed that stormwater and groundwater are infiltrating significantly into the sanitary sewer system. As a result of excess infiltration/inflow, the collection system is unable to convey flows during significant precipitation events. As a result, basements in the area have flooded several times in recent years. Backwater valves installed by home-owners utilizing the 3P program have proven effective as an acute lot-level mitigation measure. To date 7 backwater valves have been installed by home owners in the study area. Also, storm manhole covers on sanitary manholes were immediately replaced (2 in total).

In 2014, the City completed a Municipal Class Environmental Assessment (MCEA) Master Plan to determine the preferred alternative to provide a 100 year+ level of protection against basement flooding for the study area. The wet weather relief alternatives considered varied from Private and Public Property upgrade works to building new infrastructure for flood mitigation. The preferred alternative for this station consists of a number of works and activities as follows:

- Private Property Works:

Private Property works will include disconnecting roof downspouts and private catchbasins which are likely connected to the sanitary sewer system. These illicit connections were identified during smoke testing of the system. Improving drainage adjacent to homes is also recommended. All works will befunded and implemented by the homeowner at their discretion. Work will commence in 2016.

- Public Property Works:

Public Property works include sealing maintenance hole covers to prevent inflow and rehabilitating underground sewer infrastructure that currently allows significant infiltration of groundwater into the sanitary sewer system. All works will be completed with the right-of-way. Work will commence in 2016.

- Inline/Offline Storage:

The Inline Storage component is currently in the design stage. Construction will commence in the spring of 2016.

- Provide an Emergency Overflow:

In the unlikely event of multiple concurrent failures of existing and proposed infrastructure, the implementation of an Emergency Overflow will provide a failsafe to ensure flooding relief to homeowners in the lower reaches of the catchment. It should be noted that in a case of multiple concurrent failures, a sanitary sewer overflow to the natural environment is inevitable. If no engineered overflow is constructed an overflow would still occur via sewer surcharge to the ground surface (flooding surrounding basements in the process) and overland flow across the road

would reach receiving waters. With an emergency overflow constructed, the overflow is engineered at a safe level relative to surrounding basement elevations, so an overflow to the environment would still occur, but basements would be protected.

Implementation of the Emergency Overflow will require completion of a Schedule "C" Environmental Study Report to evaluate impacts of any untreated sewage discharges to Ancaster Creek as a result of overflows. This project will commence in the summer of 2015.

2.11.3 Riverdale Area Flooding Study

Riverdale East and West Neighbourhoods in Stoney Creek are serviced by separate sanitary and storm sewers. There is a history of flooding, primarily in Riverdale East. In the past 14 years nearly 500 basement flooding incidents have been reported. The majority of basement backups have occurred during major events including; December 1, 2006, July 26, 2009 and most recently January 13, 2013. Residents have utilized the city's 3P program, and to date 343 back-water valves have been installed under this program. The January 13th 2013 rain on snow event and resulting flooding was the trigger for this study.

Early fieldwork included CCTV investigation and flow monitoring. Flow monitoring in the sanitary sewers indicates that this system is subject to high infiltration and inflow. Smoke testing completed in 2014 included 37 km of sewers. In total, 270 sources of infiltration and inflow were observed, including 225 downspout connections on private properties.

A consultant has been retained to perform a systematic review of flooding for this area. The scope of work includes synthesis of field data, computer modeling and recommendation of remedial measures to address sources and reduction strategies for infiltration and inflow and infrastructure upgrades which will provide flooding relief. Additional field data including flow, rainfall monitoring and system inspection is required to further advance the conceptual design of remedial works. A final report is scheduled for December 2016 following the additional field study. Depending on the outcome of the study an Environmental Assessment may be required for infrastructure works.

2.11.4 Berko Avenue/Vern Ames Park Flooding Study

In 2009, a former elementary school located at 205 Berko Avenue, Hamilton, Ontario was demolished and the land was purchased by the City of Hamilton with the intent of park and residential development. The City of Hamilton has proposed to redevelop a former Hamilton Wentworth District School Board (HWDSB) property with a full size (senior) soccer field on the west side of the property and twelve (12) single family residential dwellings along Edwina Place to the east. The current land parcels include the existing Lawfield Elementary School, Lawfield Arena, parkland and the former HWDSB property, now vacant. This area saddles both the combined and sanitary sewer service areas: flows from a portion of the neighbourhood drain by gravity to the north combined system and flows from the rest of the neighbourhood drain by gravity to the separated sanitary system to the south.

A subsequent infrastructure servicing review, including computer modeling and assessment of chronic historic flooding, indicated capacity constraints for the existing neighbourhood and constraints for any future intensification. Smoke testing, system inspection and flow monitoring in 2013/14 was used to determine the magnitude and nature of wet weather flows in the combined system and infiltration and inflow in the sanitary system.

Using this information, staff, along with a consultant, have designed infrastructure and source controls, including Low Impact Development (LID) stormwater solutions on the proposed new dwellings and existing school properties. LID for stormwater typically includes land treatment that controls stormwater runoff at the source via infiltration, storage and slow release; thereby reducing flow to sewers and reducing risk of basement flooding. The overall design includes concepts for LID on the existing school site, proposed intensification site and disconnection of illicit sources of infiltration and inflow to the sanitary system. Staff have engaged Lawfield School and other HWDSB staff gauge their willingness to participate and include LID construction on their lands and have also assisted with seeking funding. This work is ongoing.

The proposed LID will improve the level of service, reducing risk to existing homes in the combined area which experience basement flooding, control up to 100 year storm flows from part of the proposed intensification, and provide a source of water for irrigation. Staff are currently scoping smoke testing and system inspection for the sanitary catchment to better determine sources of infiltration inflow. This in order to determine appropriate remedial measure to accommodate all of the planned intensification while reducing existing risk of basement flooding is this sub-area.

The Provincial Places to Grow Plan requires municipalities to accommodate intensification within the urban area. The Berko Avenue/Vern Ames area wastewater capacity constraints are not unique. There are many neighbourhoods in Hamilton and surrounding municipalities slated for intensification, but with similar problems. The need to accommodate mandated intensification while reducing existing flood risk, and the magnitude of the problem, has the potential to overwhelm current resources.

2.12 Sub-Watershed & Related Studies

Sub-Watershed studies provide a basis for the protection, maintenance and enhancement of surface water and groundwater quality, and quantity through environmentally sound and responsive policy development. The resulting plan will provide recommendations as to where and how future development activity can occur so as to minimize flood risks, stream erosion, degradation of water quality, and negative impacts on natural systems, including groundwater.

Sub-watershed studies investigate the existing conditions of the subwatershed for hydrology, hydraulics, hydrogeology, fisheries, water quality, slope stability, and terrestrial ecology, and recommends management measures to mitigate impacts from existing and future development. The following is a list of studies complete or underway in this category:

- Stoney Creek urban Boundary Expansion (SCUBE) area Subwatershed studies "WEST and EAST"
- Lower Spencer Creek Integrated Subwatershed study
- Upper Hannon Creek Subwatershed Study
- Fruitland-Winona Block Servicing Strategy
- Mid-Spencer Creek/Greensville Rural Settlement Area Subwatershed Study
- Upper Hannon Creek Master Drainage and Servicing Study
- Elfrida Subwatershed Study
- Block Plan Servicing Strategy for Block 1 of the Fruitland-Winona Urban Expansion Lands
- Block Plan Servicing Strategy for Block 2 of the Fruitland-Winona Urban Expansion Lands

2.13 Rainfall Into Sanitary Sewers (Inflow & Infiltration)

Infiltration and Inflow (I/I) is the unintended entry of stormwater, snowmelt and groundwater into the sanitary sewer system. Separated sanitary sewers are designed to convey wastewater generated from home and business fixtures, and a certain amount of infiltration. I/I can enter sanitary sewers from defects in the city right of way (cracked pipes, manholes, poorly connected laterals etc.,) or on the private side (illegally connected downspouts, weeping tiles, driveway catch basins, uncapped cleanouts etc.).

When excessive I/I occur, sanitary sewers can become overloaded with stormwater runoff flows and groundwater which can surcharge and overwhelm the system. This can lead to basement flooding, sanitary sewer overflows to the environment, can impact the operation of sewage pumping stations, and cause treatment process upsets at the wastewater treatment plant. Infiltration and Inflow also robs capacity in sanitary pipes that is intended for growth and development. This can lead to placing development freezes on land while sources of I/I are tracked down and reduced and/or infrastructure upgrades to handle the excessive flows are completed. The flooding in Binbrook, Riverdale East and Old Dundas Road in Ancaster is caused by excessive I/I.

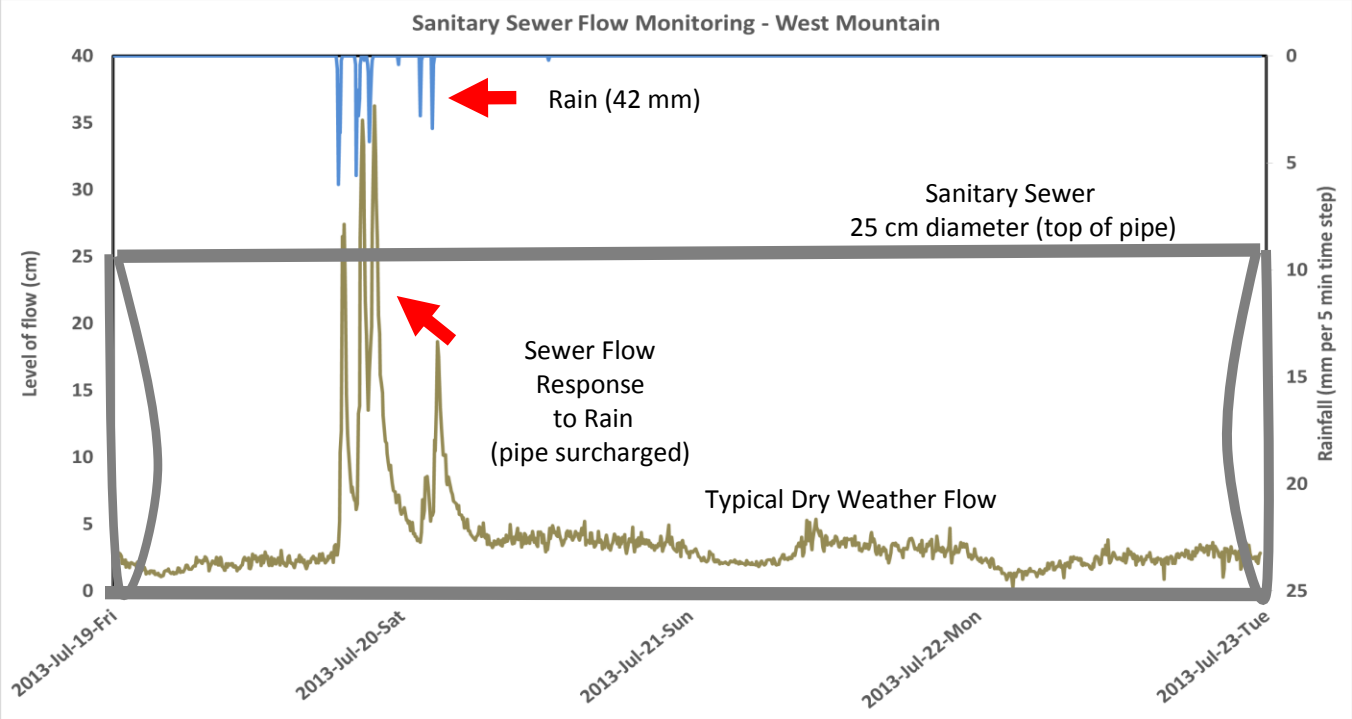
The City has a proactive I/I program and installs flow monitors and rain gauges (Sections 2.7 and 2.8) which are analysed to assess the severity of I/I across the system. This information is used to program and prioritize sanitary sewer evaluation studies which can include smoke testing, dye testing and in-the-field entry inspection. "Smoke" testing involves introducing a harmless vapour (similar to theatre smoke) into the sanitary pipes and noting where it escapes. This is a fast and efficient method of identifying sources of I/I. Since late 2012 the city has smoke tested 201km of sewers. To date, these inspections have identified over 1000 sources of I/I, many on private properties. Findings indicate the majority of these are downspouts either directly and illegally connected to the sanitary sewer system, or indirectly connected downspouts, whose flow finds its way into the sanitary system through soil to weeping tiles, cracked laterals and other sources. Current work includes smoke testing a large area of the West Mountain with over 8000 homes. This inspection data is leveraged to develop

rehabilitation plans including trenchless technologies, design infrastructure upgrades and to strategize an approach to private side disconnection.

The Detailed Wastewater Model (Section 2.6) is leveraged for I/I. It uses measured flows and rainfall for calibration. The model can be used to analyse rehabilitation and disconnection scenarios to assess the potential success/benefit of I/I rehabilitation and removal.

A sewer inflow vulnerability assessment was also completed in 2014. The scope of this work included identifying sanitary manholes located within floodplains, undertaking visual inspection and identifying remedial measures to ensure that these areas are appropriately sealed against rapid inflow.

Figure 7. Example of Infiltration/Inflow Response in a Sanitary Sewer



3.0 Capital Program – Improvements and Expenditures

Through the detailed analysis of inspections, system monitoring tools and various studies at the neighbourhood, community and city wide level; significant work has been completed and/or has been programmed within the capital budget to address storm water management and flooding within the City. SERG Initiatives and the prevention and mitigation of flooding is a priority within the capital process as per council's direction. The following summarizes capital works completed from 2005 until present (gross) and also capital works planned for the next 5 years (gross) that will have a direct or indirect impact on flooding. It should be noted that storm water sustainability analysis will be presented, along with information in regards to a storm water rate, at a future committee meeting.

3.1 Capital Works 2005 – 2015, $(000,000)

SERG Initiatives	$50.8
Pipe Upgrades/Replacements	$25.4
Inspection, Maintenance, & Rehabilitation	$21.9
CSO Upgrades	$50.6
Investigations	$8
Backwater Valve Pilot Project	$0.1
Total	**$157.7**

3.2 Capital Works Planned for Next 5 Years, $(000,000)

All proposed works are tentatively scheduled and subject to annual council approval as part of the standard capital process.

SERG Initiatives	$8.9
Inspection, Maintenance & Rehabilitation:	$19.3
Pipe Upgrades	$4.9
Total	**$33.1**

A detailed project listing of the above, actual and forecasted, capital expenditures can be found in Appendix A and Appendix B attached to Report PW15059.

4.0 Property Mitigation Measures

In addition to capital expenditure, the overall SERG analysis has determined that property improvements to mitigate future flooding is critical in many areas, and may often be the homeowner's best option. Property improvements are one of the most expedient solutions and through these initiatives the property owner has the ability to take proactive measures to protect their home from basement flooding. It was in recognition of this that the Protective Plumbing Program (3P) was created in 2009.

4.0.1 Residential Drainage Assistance Pilot Program (RDAPP)

In 2011 Council approved a pilot project to address residential drainage issues. The Residential Drainage Assistance Pilot Program (RDAPP) provides advice and financial assistance (in some cases) for drainage matters related to private property. Staff in the Planning and Economic Development Department would investigate drainage issues, provide recommendations on how to address drainage issues and would work closely with Municipal Law Enforcement when enforcement issues are identified. The RDAPP was extended to September 2015 to run concurrently with Pilot Program for Enforcement of Blocked Swales established by Municipal Law Enforcement (MLE).

The RDAPP has proven an effective method of resolving drainage issues and disputes in neighbourhoods where planned drainage methods were not developed and the intended routes for storm runoff are unknown. Additionally, the position has been valuable in providing support and expertise for more complex cases under the Enforcement of Blocked Swales program. Since the RDAPP was initiated in April 2012,

there have been 244 cases reviewed through the RDAPP process (as of the writing of this report). Of those, 97 are new cases since the extension of the program in October 2014. A summary of cases by year is provided in Table 1 below.

Table 1: RDAP Annual Case Summary

Year	Cases Resolved	Ongoing Cases	Total Number of Cases
2012	70	3	73
2013	72	1	73
2014	5	0	5
2015	71	22	93
Total	218	26	244

Since the inception of the program in 2012, seven engineering studies have been initiated as follows:

- Two projects completed including engineering investigations, permits, and construction to a total cost of approximately $75,000;
- Two preliminary engineering investigations have been completed with consultants at a cost of approximately $10,000. Recommendations included work on private property;
- Two engineering investigations by consultants at a cost of approximately $15,000 with expected City capital costs of approximately $25,000 each.
- One engineering investigation of a neighbourhood-scale drainage issue by a consultant at an approximate cost of $50,000, which will be presented to council for consideration in the second half of 2015.

A majority of the cases are resolved by providing guidance and advice to property owners and working with them to find solutions to either remedy or reduce the negative impact of existing storm runoff issues.

4.0.2 Lot Grading, Drainage and Site Alteration – Comprehensive Policy Review

In 2011 Planning completed a comprehensive review of its Grading Policy for Single and Semi-Detached and Site Alteration By-Law and provided enhancements/revisions. The recommended changes are aimed at improving long term sustainability of developed properties, and to reduce the potential number of grading and drainage complaints to the City, and to protect the interests of the neighbouring properties.

4.1 Protective Plumbing Program (3P)

The 3P program was approved by council on October 7, 2009. This program makes available grants and loans to qualified residential property owners with the purpose of taking proactive measures to protect their home from sewer backups. Since the original program was approved in 2009 council has approved a number of changes to the program. The following provides an overview of some of the major changes to the program:

July 2011 – council approved expanding the program to all residential property owners. Since providing a grant to rental income properties would have been considered "bonusing" under the Municipal Act residential rental properties continued to be excluded.

January 2012 - the building code requirements for Hamilton were updated to make the installation of a backwater valve mandatory for all new homes.

February 2013 – council approved the requirement for homeowners to obtain 3 independent quotes for work under the 3P program. The intent of this change was to derive increased value for property owners and work towards a financially sustainable program.

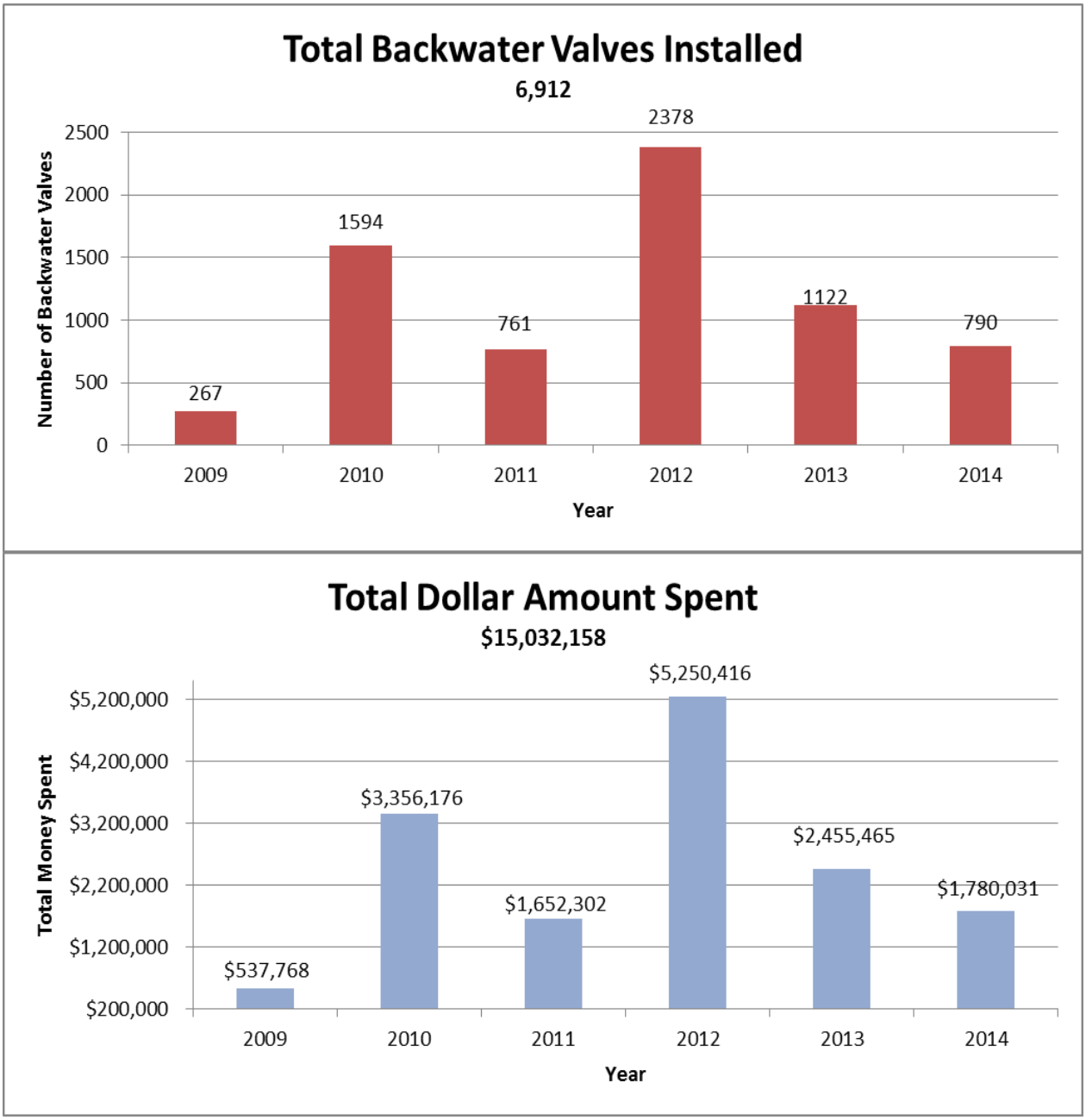
March 2013 - council approved a Community Improvement Plan (CIP) allowing owners of qualified residential rental properties to take advantage of the program.

Eligible property improvements included under the program include:

1) An assessment of the building's drainage system including a closed circuit television (CCTV) inspection;
2) Installation of a new approved backwater valve (replacements are not eligible);
3) Installation, of a sump pump, in conjunction with an approved backwater valve; and
4) Disconnection of downspouts.

Building permits are required for these works; however, residents who are eligible for funding under the 3P program have the building permit fee paid for under the 3P program. Reimbursement does not take place until all conditions have been met, including a satisfactory final inspection by the building department.

The 3P program has been viewed by many as the most successful grant program ever offered by the City. Since its inception in 2009 nearly 7,000 backwater valves have been installed across the City, and just over $15,000,000 in grants have been provided. The following charts show the programs progress from 2009 – 2014.



In August 2014 a customer satisfaction survey was developed and sent to those who had participated in the program during the previous 12 month period. Over 230 people responded to the survey. The results showed that the program scored 4.48 out of 5 in meeting our resident's expectations.

The 3P program continues to be an integral part of the City's strategy to mitigate the increased risk of basement flooding as a result of continuing climate change. While this program is not the answer to all of the problems and issues, it does allow homeowners to take positive action to protect their family, their home, and their investment from the effects of basement flooding.

We noticed a significant increase in program uptake in 2015, linked to contractor solicitation. We made need to take a closer look at program criteria/guidelines.

4.2 Downspout Disconnection Program

At the same time the 3P program was being developed UEM was retained to conduct a Pilot Downspout Disconnection Pilot Program beginning in October 2009 which ran to June 30, 2010. The program was implemented as an effort to provide some immediate relief against flooding basements during major rain storms for selected volunteer homes, while at the same time provide relief from surcharging the local sewer system. Table 2 outlines the results of that pilot program:

Table 2. Downspout Disconnection Pilot Program Results

Activities	Phase 1 Completion Date November 30, 2009	Phase 2 Completion Date June 30, 2010	Final
Number of houses reviewed within the study area	1329	1619	2947
Home owners directly contacted	794	1093	1887
Downspouts already disconnected	534	526	1060
Home owners willing to participate	105	265	370
Homes deemed not a candidate upon inspection	20	78	98
Property owners who “backed out” of the pilot	5	30	35
Actual number of homes who participated in the pilot	80	157	237
Number of downspouts disconnected	25	282	307

The results of the pilot program showed that approximately 50% of the downspouts investigated had already been disconnected. Homeowners in many cases had already understood the connection between basement flooding and downspout disconnection and as such had taken action on their own. Of the homes that were willing to participate just over 25% of them were not deemed suitable for disconnection as the disconnection would potentially cause greater issues such as tripping hazards or icy walkways in the winter. Based on the results of the pilot program as well as the creation of the 3P program, it was decided to include downspout disconnection as part of the 3P program. The 3P program provides up to $200 per eligible property for the disconnection of downspouts.

4.3 Integration with Sewer Lateral Management Program (SLMP)

Residents that are eligible for the Protective Plumbing Program are also deemed eligible to receive a CCTV inspection of their sewer lateral free of charge. Information on the SLMP Program, including integration with 3P, is available on the Internet and is

provided to customers in mailed/delivered information and eligibility packages. Eligible residents can request the City to arrange for a City contractor, or they can hire their own contractor, to perform their lateral inspection. Once reviewed, customers that have submitted adequate information are reimbursed an amount equal to the amount paid to City contractors for these services.

4.4 Sewer Lateral Cross Connection Control Program (SLXC)

The SLXC Program was initiated as a pilot study in 2010 to identify sources of sanitary discharge into the natural environment, specifically, the cross connection of residential sanitary plumbing systems to the municipal storm sewer system. The primary goal of the SLXC program is environmental protection with a secondary benefit being reduced flow to the Woodward Wastewater Treatment Plant, and by extension a benefit to basement flooding. The study has concentrated mainly on storm sewer sub-watersheds of Chedoke Creek, Red Hill Creek and Davis Creeks where elevated levels of E. Coli have been recorded at storm sewer outfalls and within the sub-sewer-sheds. Study results have revealed that 10% of the cross connections found are due to a single plumbing fixture incorrectly connected to the storm drain under the basement floor. 90% of the cross connections have been found to be sanitary drains from homes directly connected to the City's storm sewers (and storm drains from the same home connected to the City's sanitary sewers). Since the inception of the pilot study the City has identified more than 136 complete cross connections, of which 125 have been corrected.

As it relates to SERG, the SLXC Program redirects storm water from residential properties away from the sanitary sewer system and into the storm sewer system. This reduces the amount of wet weather flow that must be pumped by pumping stations, or treated at the WWTP and reduces sewer backups due to the overloading of sanitary sewers from rainwater.

SLXC investigations continue throughout the study areas and cross connections will continue to be corrected as they are identified.

5.0 Operations and Maintenance Measures

In an effort to address the many locations throughout the city that experience flooding each of the three Roads Operations Districts has a list of areas that require additional maintenance in the event of significant rainfall. These lists are updated frequently. The operations crews inspect between 500 and 600 historical drainage problem locations before, during and after significant rainfall events. These locations include catch basins, cross culverts and storm water inlet and outlets.

Roads Operations is currently responsible for the maintenance of the following storm drainage items throughout the City:

- Catch basins (not including main sewers)
- Roadside drainage

- Road cross culverts
- Stormwater management ponds and associated appurtenances
- Municipal Drain Program

Catch basin cleaning and inspections are carried out annually. Approximately half of the City's 45,000 catch basins are addressed each year. Any needed repairs identified in the cleaning operation result in a replacement or repair activity.

Drainage ditches and cross culverts are routinely inspected for deficiencies. Deficiencies which could contribute to flooding and which can be rectified are addressed.

The City has a large number of road cross culverts in various states of repair. An inventory is being created. Condition assessments have been carried out on a number of culverts and replacements are carried out in annual contracts.

The current assumed storm water management ponds are inspected annually. Normally throughout the year each location is visited twice by the stormwater management operations crew. Maintenance work is performed as needed using in-house resources or by contract if the work is major in nature.

The Municipal Drain Program, involving the assessment of needs and cost apportionment on the city's municipal drains is also administered by Operations

In addition to the above responsibilities there are new storm related facilities which will soon be included under the responsibility of Roads Operations. These are a flood control structure on the Lower Davis Creek and two storm pumping stations at other locations which are complete or nearing completion. It is planned to utilize a SCADA system through Hamilton Water to remotely monitor these locations to facilitate maintenance activities.

6.0 Communications / Education / Outreach

The Flood Aware outreach program was established in 2007 in response to the recommendations in the Independent Review Panel's report. The Flood Aware program included proactive outreach with seasonal Flood Aware brochures and ads, public service announcements, attendance at special events and an up-to-date website. The Flood Aware information provided residents with helpful tips about how to prepare for flooding during severe rain events and the measures that the City of Hamilton is taking to address flooding in the city. This included flood protection and prevention tips, insurance recommendations, the steps to take when making a property damage claim with the City of Hamilton, public health recommendations and an overview of ongoing studies and plans that the City of Hamilton is undertaking to address flooding. Due to a lack of dedicated resources the Flood Aware program has been discontinued.

Currently the City undertakes proactive outreach through media relations, social media and web updates when severe storms are anticipated as well as providing helpful "flood preparedness" tips for residents on the City's website - http://www.hamilton.ca/home-property-and-development/water-sewer/flood-preparedness.

Communication updates on the City's progress on SERG related programs and projects are shared through councillor newsletters, briefings and information updates.

Communications has been, and will continue to be, a key role in the roll out of SERG related programs such as the 3P Protective Plumbing Program. This information is also centralised on the City's web site.

6.0.1 – SERG Flooding Communication Strategy

The project is intended to assemble a proactive program to optimize flood related communications, awareness and preparedness. The development of this program is being undertaken in response to Recommendation 09-15 of the Independent Community Panel

> "*The City of Hamilton should devote more resources to its public communication program to ensure that its residents receive frequent, consistent communications with adequate visibility to reach the majority of them. Resources should also be devoted to formally evaluate the effectiveness of specific initiatives and the overall program*".

The scope of work includes development of a City-Wide Communication Framework to assist in optimizing the residents' participation in local drainage and flooding issue. Establish an integrated City-Wide communication plan and tools to support to the City's actions to mitigate flooding and drainage problems. The target audience for the Communication Framework includes the general public, city residents with flooding issues, local media, and members of Council. The Communication Framework will also consider internal communication processes between relevant City Departments and Sections to support the overall City-Wide communications in relation to flooding and storm water management.

7.0 New Storm Water Management Techniques

New development and re-development follow the storm drainage policy adopted in May 2004. This drainage policy contains specific requirements and procedures to manage storm runoff.

In addition to the above, Development Engineering Section in the Planning and Economic Development Department has engaged the development community with Low impact Development (LID) techniques that promote retention of stormwater runoff on site. Although this is a relatively new development in stormwater management, LID techniques which use infiltration, storage, evapotranspiration, reuse and other stormwater source controls to reduce the amount that runs off of a site have been used successfully in North America for more than two decades. There are projects where permeable pavement or rainwater cisterns have been proposed. i.e. the McMaster Innovation Park parking lot has permeable pavement proposed, and rainwater cisterns have been proposed for each lot in "The Graystones", rural subdivision in Greensville. LID techniques are also proposed in future development areas of the City including the Airport Employment Growth District. We have acknowledged the limitations that the City of Hamilton has to promote infiltration in various regions within the City due to the clay

nature of the existing soils. However, the goal of these techniques is to maintain the existing water balance model on the site for the new developments by promoting infiltration where possible, evaporation or re-use of rainwater.

Planning staff partnered with the Ministry of the Environment and Climate Change (MOECC) in a study on low impact development stormwater source controls (LID). The study "Innovate Stormwater Source Controls Study for Institutional, Commercial, and Industrial Developments" by AMEC (May 2012) reviewed past LID experiences and identified issues encountered.

Information from this study will serve in the development of LID source control guidelines to promote stormwater reuse, infiltration, and evaporation to reduce the total volume of runoff from the site. This approach Stormwater management is targeted for industrial, commercial, and institutional developments and alongside roadways where appropriate.

8.0 Strategic Alliances, previously known as Independent Community Panel (ICP)

As part of SERG, in 2006 City Council established an Independent Community Panel (ICP) to identify the impacts of storm events and to make recommendations to Council. The ICP panel consisted of five professionals from the community with stormwater expertise. The panel reported 26 recommended initiatives in 2006. The ICP reconvened again in 2009 to evaluate the City's progress on the 2006 recommendations. The review found that the City had achieved all 26 recommendations from the original report, and submitted another 23 recommendations to consider in future planning. A number of these recommendations were focused on developing the City of Hamilton's initiatives toward more climate change adaptation approaches.

9.0 Climate Change Working Groups

In the Community Climate Change Plan, the community has identified flooding and stormwater infrastructure as areas of concern and actions needed to improve to address extreme weather events from a changing climate. The Community Plan work began in July 2014 and the first draft of the Plan should be released this month.

On the Corporate front, we have formed a corporate working group under the ICLEI Canada's Building Adaptive & Resilient Communities Program to identify risks of climate change and bring forward recommendations on actions that can be taken to reduce these risks in operations and services. This work began in April 2015 the group is currently reviewing actions that identify impacts of a changing climate and extreme weather. Flooding has again been raised as an impact of concern.

Both of these initiatives build on the SERG work (and other work) that has helped identify current actions addressing stormwater and flooding concerns related to climate change and will continue to be informed by this work as new information and activities come to light.

10.0 FloodNet Program development and implementation, in conjunction with McMaster University, Waterloo University and other agencies

It's a Canada wide program to develop flood forecasting and warning systems in Canada. The main objective of this program is to create a vehicle for a concerted nation-wide effort to improve knowledge on flood processes and their impacts, and enhance flood forecasting and management capacity in Canada through the creation of a structured research network that brings together scientists/experts, users/operational forecasters, and the private sector to tackle the complex and fundamental research questions and the technological gaps that need to be addressed in order to significantly enhance flood forecasting and management in Canada. Some of the key research tasks include analyzing and characterizing extreme events (floods and storms) across Canada; quantifying and reducing predictive uncertainty of floods; developing an advanced flood alert system for Canada; assessing physical, socio-economic, and environmental impacts of floods to enhance flood management policies in Canada. The direct benefits of enhanced flood forecasts and management are tremendous and include the reduced cost of damages, the protection of people and livestock, the reduction of socio-economic impacts and human distress, and the protection of community water systems and the environment.

11.0 Hamilton's Climate Change and Storm Events Adaptation Plan

The work is intended to assemble a "Policy Document", with a proactive program to develop storm events adaptation and flood mitigation plans with the following components: Vulnerability Assessment, Future Climate-Risks Assessment, development of an executive framework summary for policy and decision-makers, Building adaptive capacity – getting ready for adaptation, discuss the findings with relevant project counterparts, stakeholders and the project staff, analysis and policy recommendations on adaptation options with a comprehensive plan for adaptation in Hamilton. Currently the continued delivery of these projects is not sustainable with the limited stormwater full time equivalent resource allocation.

12.0 Insurance Bureau of Canada - Municipal Risk Assessment Tool (MRAT)

Insured losses from flooding in the past few years have resulted in multibillion dollar pay-outs by Canadian insurers. In an effort to obtain better resolution of flood risk in cities, the Insurance Bureau of Canada (IBC) and its consultants are in the process of developing the Municipal Risk Assessment Tool (MRAT) which consists of risk models and city maps indicating relative risk of basement flooding-from an Insurer's perspective. The tool also has a forecasting utility that leverages information on the future impact of climate change on severe storms to help forecast potential future risk in 2020 and 2050. The Cities of Hamilton, Coquitlam, BC and Fredericton, NB have partnered with IBC on this initiative and have shared data on land use and infrastructure which is used for the risk analysis, and staff resources who are providing comment on the tool. The future intended use of MRAT is to indicate to cities where Insurers feel there is a risk of basement flooding. At the present time MRAT is still in the pilot/development stage and city staff are actively working with IBC.

13.0 City-Wide Flooding and Drainage Master Servicing Strategy

The Flooding and Drainage Master Servicing Strategy is an upcoming project which will focus on identifying the root causes of flooding in the core combined area of the city (ie. the combined area of the city not serviced by a major overland flow route). Specifically this study will:

- Determine an appropriate and sustainable level of service (LOS) for the City's urban drainage systems, including piped and surface drainage.
- Recommend opportunities for flooding and drainage system improvement and scope projects, programs and a resource strategy (staff and finances) to meet this LOS.
- Develop conceptual designs for capital works for the preferred alternatives.

The overall intention of this study is to develop solutions to subsurface and surface flooding in the most vulnerable area of the city. These solutions will provide widespread relief and increase the LOS above that which is currently provided, where feasible. This work will consider the impact of growth, intensification and climate change on the system and is an opportunity to realize capacity and create resilience for the City over the longer term. Given the scale and magnitude of potential capital works and programs, a long term implementation horizon (25 yrs +) is anticipated.

While the budget for this work has been approved by Council in the Rate Budget for 2015, the delivery of these projects is progressing slowly due to the limited stormwater full time equivalent resource allocation.