STORM SEWER MASTER PLAN
PHASE 1 Final REPORT
TOWN OF OAKVILLE

Submitted to:

Town of Oakville

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1.0 INTRODUCTION

Town of Oakville is located in Halton Region in Southern Ontario, North West of the Lake Ontario. It is considered to be a part of the Greater Toronto Area and has a population of over 180,000 as of 2011 census.

In recent years, many Southern Ontario urban centres, have been impacted by extreme storm events, leading to considerable flood and erosion damage (ref. July 26, 2009 Hamilton, July 8, 2013 East Toronto, and August 4, 2014 Burlington). To-date, with the exception of the large storm event of May 2000, the Town of Oakville has fortunately been spared major flood damages. These events (speculated by many to be a result of climate change), along with a need to better manage municipal resources, have led to the Town of Oakville initiating the preparation of a Town-wide Storm Sewer Master Plan.

Town Council and Senior Management have recognized the importance of developing and implementing co-ordinated capital programs to address the town's infrastructure needs, while being fully integrated with other companion initiatives such as the Creek Erosion Management Plan, Flood Management Plan, and the Region's Inflow/Infiltration Plan. With an integrated, balanced, and prioritized plan, town staff can better meet the needs of residents and businesses in an efficient and strategic manner.

The Town of Oakville has also proactively considered the potential for climate change impacts to its community by developing a Climate Change Strategy (ref. Climate Change Adaptation Strategies Technical Report Endorsed by Council September 2014). The Strategy is built upon the vision "to build the town's resiliency to the impacts of a changing climate", and has been structured around three (3) objectives as follows:

Objective 1: to increase the town's capacity to protect against and respond to projected climate changes.

Objective 2: to educate staff and residents through effective and efficient means of communication.

Objective 3: to monitor the implementation of adaptation action and goals in order to make continuous operational improvements.

The Storm Sewer Master Plan represents one component of the town's Stormwater Management Master Plan. The Storm Sewer Master Plan will be completed over multiple phases, integrated with the Stormwater Management Master Plan, and "generally" laid out as:

Phase 1: Data Collection and Preliminary Infrastructure Needs Assessment
Phase 2: Detailed Analytical Assessment
Phase 3: Final Infrastructure Needs Assessment and Implementation Plan
Phase 4: Detailed Design, Permitting, and Construction

The initial Phase (this study) focuses on data collection, data gap filling, and establishing a preliminary "high level" interpretation of storm sewer needs, which will allow town staff to focus on the next phases in terms of budgets and priorities.

The focus of the current phase of the Storm Sewer Master Plan study is on the areas located south of the Queen Elizabeth Way Highway, between Winston Churchill Blvd. on east and Burloak Drive on west. This study area was selected due to the age of the infrastructure in the area, and based upon the knowledge of stormwater management practices employed at the time of development.

The Ontario Environmental Assessment Act provides for "*…the betterment of the people of the whole or any part of Ontario by providing for the protection, conservation and wise management in Ontario of the environment*." An approved Class Environmental Assessment (Class EA) document describes the process that a proponent must follow for a class or group of undertakings in order to satisfy the requirements of the Environmental Assessment Act, and represents a method of obtaining an approval under the Environmental Assessment Act and provides an alternative to carrying out individual environmental assessments for each separate undertaking or project within the class.

Master Plans are one form of Class EA document representing long range plans which integrate infrastructure requirements for existing and future land use with environmental assessment planning principles. The following characteristics distinguish the Master Planning Process from other processes:

a) The scope of Master Plans is broad and usually includes an analysis of the system in order to outline a framework for future works and developments. Master Plans are not typically undertaken to address a site-specific problem.

b) Master Plans typically recommend a set of works which are distributed geographically throughout the study area and which are to be implemented over an extended period of time. Master Plans provide the context for the implementation of the specific projects which make up the plan and satisfy, as a minimum, Phases 1 and 2 of the Class EA process (ref. Figure 1.1). Notwithstanding that these works may be implemented as separate projects, collectively these works are part of a larger management system. Master Plan studies in essence conclude with a set of preferred alternatives and, therefore, by their nature, Master Plans will limit the scope of alternatives which can be considered at the implementation stage.

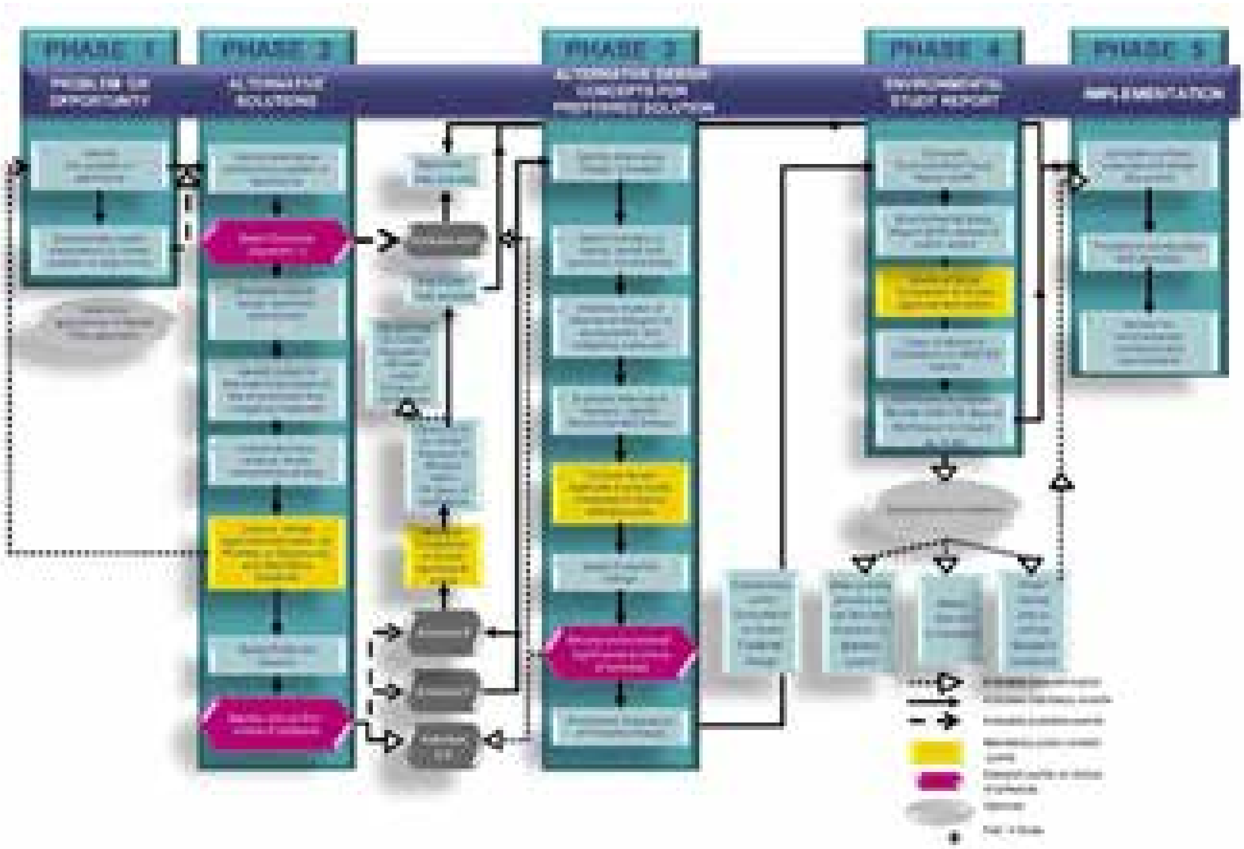


Figure 1.1: Municipal Class EA Process

The Town of Oakville Storm Sewer Master Plan has been prepared in accordance with the Municipal Engineers Association (MEA) Class Environmental (Class EA) procedures. The Master Plan has adopted *Approach #1* in the 2013 MEA Documentation for all Schedule B projects. *Approach # 1* involves the preparation of a Master Plan document at the conclusion of Phases 1 and 2 of the Municipal Class EA process. *Approach # 1* addresses Phases 1 and 2 of the Class EA process (ref. Figure 1.1). Under *Approach #1*, Schedule B projects which are implemented in accordance with the recommendations provided in this Master Plan would require filing of a Project File for public review before the detailed design and implementation stages.

2.0 BACKGROUND INFORMATION REVIEW AND CONSULTATION

The following background information and related consultation has been used for this assessment:

- Town of Oakville 2011 GIS database shape files for maintenance holes, storm sewers, municipal parcels, catch basins, storm outfalls, and stormwater management facilities
- Satellite imagery for the Town of Oakville corresponding to 2010 Conditions
- Microsoft Excel™ spread sheet data including the 2013 geodetic survey results prepared by AquaData for maintenance holes and storm sewers
- Sewer Diagnosis and Assessment, ZOOM™ Camera Inspection Report, AquaData, October 2013.
- CAD drawing depicting the location of areas with historic maintenance issues ("Hot Spot" Areas)
- The Town's Official Plan
- Drawing for Schedule A1 to the Liveable Oakville Plan depicting future development areas in Town of Oakville.
- Town of Oakville Development Engineering Procedures & Guidelines Manual (2011)
- Field reconnaissance by town staff to confirm presence of downspout connections
- Consultation with Halton Region to confirm presence of connection between storm and sanitary sewers
- HEC-RAS hydraulic models for McCraney Creek and Sixteen Mile Creek and their tributaries provided by Conservation Halton
- Local flow monitoring conducted by AMEC within the town's storm sewer network (ref. Appendix E)
- Town of Oakville Climate Change Primer and Technical Document, 2014
- Environmental Strategic Plan, 2011

2.1 Climate Change

As noted in the Introduction, the town has proactively approached the matter of climate change. The Town of Oakville joined ICLEI Canada's Changing Climates, Changing Communities municipal climate change adaptation program in 2011 as one of 12 initial signatory municipalities. This decision was based on the involvement that the town's Environmental Policy department had with the creation of this municipal climate change adaptation toolkit.

Council endorsed the participation and formation of the town's Climate Change Adaptation Team at its meeting in May 2011. Since then town staff have been working to identify what impact changing weather patterns and extreme weather will have on the town, both as a corporation and as a community.

The town's Climate Change Adaptation Strategy and Climate Change Primer, endorsed by Council, identifies town activities and programs, along with their vulnerability to the potential impacts of climate change. The Town of Oakville has successfully completed Milestones 1 and 2 of the 5 Milestone process. Milestone 3 will be achieved with the endorsement of this Strategy. Milestone 4 and 5 will be awarded for the implementation, tracking, monitoring and continuous improvements made over the life of this strategy.

Through the development of the town's public outreach document, Oakville's Climate change Primer, the town has identified a number of potential local scale impacts affecting the community including:

i) Increased risk of personal safety and property damage
ii) Increased risks and delays associated with transportation
iii) Increased closures and risks to users of parks, trails, and sports fields
iv) Increased instances of power outages and rolling blackouts
v) Increased instances of heat, cold, and poor air quality
vi) Decrease in water quality from overland flow and erosion
vii) Increased risks to recreational users of town harbours and Lake Ontario

Having properly planned, designed and maintained drainage systems (both natural and manmade) are critical to achieving a functional, social, environmental and economic balance to address the risks associated with the impacts from a changing climate. The Storm Sewer Master Plan is one of several town initiatives established to proactively integrate climate change considerations and systematically build resiliency into the town's drainage system, protecting residents and businesses and the natural environment.

2.2 Other Companion Initiatives

The town has participated in the development of the North Oakville Urban Forest Strategic Management Plan (ref. May 2012).

North Oakville, planned to be an urban, compact community, presents many strategic planning challenges to the Town of Oakville, in pursuit of a long-term vision to meet the 40% tree canopy cover target. North Oakville Urban Forest Strategic Management Plan (NOUFSMP) is a document prepared to provide the Town of Oakville with a high-level strategy and planning recommendations for achieving a sustainable, healthy urban forest on the north Oakville lands which are roughly bounded by Dundas Street to the south, Ninth Line to the east, Highway 407 and Lower Base Line to the north and Tremaine Road to the west.

The Plan complements and builds upon the recommendations presented in the town's Urban Forest Strategic Management Plan, 2008, which provided direction regarding the effective management and stewardship of the town's 'green infrastructure' within the build context, south of Dundas Street.

The plan ensures a sustainable and healthy urban forest for the lands located north of Dundas Street. It recommends a multi-faceted strategy that connects urban forestry best practices to existing environmental features in Oakville's Natural Heritage System. It is noteworthy that under the plan, trees are identified a green infrastructure and their location and suitability is to be addressed at the onset of the planning process. Development proponents, as part of the plan, are required to provide detailed locations and soil volumes of all trees in composite utility plans. The intents is to ensure that the placement of trees will receive equal consideration as the location for the placement of other services such as water or gas utilities.

3.0 BASELINE CHARACTERIZATION

The area under study is located south of the Queen Elizabeth Way in Town of Oakville, extended to Lake Ontario to the south. The current land use conditions of the study area, as presented in the Town of Oakville Official Plan (ref. Appendix B) are primarily employment for the lands located north of the study area, south of the QEW and urban residential areas with some commercial and parkland areas for the remainder of the lands. Future redevelopment has been planned and is expected for some of the lands within the study area, as presented in Appendix C on the Schedule A1 to the Liveable Oakville Plan. The growth areas have previously been proposed to include lands with existing land use type of employment and commercial with some areas of mixed land use, residential and parklands, however the nature of the redevelopments has not yet been defined within the Liveable Oakville Plan.

The existing storm sewer network for the study area includes over 4800 storm sewer pipes, over 4300 maintenance holes and over 200 outfalls, providing service for the majority of the lands located within the study area. The existing storm sewer network currently has a good structural condition for most of the sewer pipes. Maintenance practices are currently more reactive in terms of maintaining or addressing the physical conditions of the storm sewer pipes. Areas with historic maintenance issues have been identified as “hot spots” which require proactive/preventative maintenance at the onset of storm events to address obstructions at the inlets of the storm sewer system. Downspouts are mostly disconnected within the study area. Based on consultation with the Town of Oakville and Halton Region staff, it is suspected that some cross connections exist between the sanitary and storm sewer networks; however no specific information is available regarding the extent or location of possible cross connections.

Physical condition of the storm sewer has been characterized based upon the results of the ZOOM Camera inspections of the storm sewer pipe network performed by Aquadata. ZOOM ™ Technology can sight upstream and downstream from a maintenance hole some 60 m (+/-), which while not as comprehensive as a CCTV inspection, provides good representative data at a reduced investment. The results of this inventory have been provided in an EXCEL™ spreadsheet. The evaluation of the structural conditions and maintenance requirements for storm sewers within the study area has been completed by Aquadata using the Pipeline Assessment and Certification Program Version 3.0.2 (PACP) Code Matrix, developed by National Association of Sewer Service Companies (NASSCO) which assigns a numerical score of 1 to 5 to each storm sewer pipe, with 1 representing “Excellent” condition and 5 representing a condition requiring “Immediate Attention”. The description of each grade is presented below:

Grade	Description
1- Excellent	Minor Defects
2- Good	Defects that have not begun to deteriorate
3- Fair	Moderate defects that will continue to deteriorate
4- Poor	Severe defects that will become Grade 5 defects within foreseeable future
5- Immediate Attention	Defects requiring immediate attention

The specific description and details regarding the structural and maintenance condition for each storm sewer pipe encompass a wide range of characteristics, which include fractures, pipe failure, collapse, deformation, chemical and mechanical surface damage, lining failure, and weld failure, for structural condition and deposit attachment, deposit settlement, deposit ingression, root infiltration, and obstacles for operational and maintenance condition. A detailed Breakdown of the structural issues and Operations and Maintenance practices, as per the PACP Code Matrix, has been presented in Appendix A.

Recognizing that the deterioration process for each pipe is highly variable and dependant on local conditions, the estimated time before which the defect can cause complete line failure, as per the NASSCO, is provided in general terms as follows:

Grade 1- Failure unlikely in the foreseeable future
Grade 2- Pipe unlikely to fail for at least 20 years
Grade 3- Pipe may fail in 10 to 20 years
Grade 4- Pipe will probably fail in 5 to 10 years
Grade 5- Pipe has failed or will likely fail within the next five years.

A summary of the results of the video inspection (zoom camera) of the storm sewer pipes conducted in 2013 by Aquadata for the study area is presented in Table 3.1 for both structural and operations and maintenance ratings.

Table 3.1: Total Percentage (%) of Storm Sewer Pipes for Structural and O&M Rating (1 to 5)

Grade Class	1	2	3	4	5	Not Rated
Structural	68	16	9	2	1	4
Operation and Maintenance	21	58	12	3	2	4

Based on the results presented in Table 3.1, the majority of the storm sewers (~84%) in the study area are considered to be in a good to excellent structural condition (i.e. scores between 1 and 3) and a very small percentage (~3%) are anticipated to have failed or would be expected to fail within the next 5 to 10 years. The same observation holds true for the operations and maintenance condition of the storm sewers with a high majority (~79%) having a good to excellent condition and only a small percentage (~5%) requiring maintenance immediately or within the next 5 to 10 years. As the above also indicates, the ratings have been applied to ~97% of the storm sewers within the town; a small percentage (~4%) were not rated for the structural condition.

4.0 PROBLEM STATEMENT

The Town of Oakville has initiated the first phase of the town's Storm Sewer Master Plan as part of a multi-phase undertaking. The objectives of the overall Master Plan are to provide the town with clear direction regarding:

i) The existing issues with respect to the structural condition, flow capacity and maintenance requirements of the Municipal storm sewers (minor system),
ii) The location and extent of these issues,
iii) Opportunities and recommendations to address and mitigate,
iv) Timeline for implementation of the recommendations
v) Costs for the implementation and long term maintenance of the system, and
vi) Preferred financial and funding mechanisms

The first phase of this Storm Sewer Master Plan has been initiated to specifically identify and address any data gaps, and to provide a preliminary assessment of the infrastructure needs to set a framework for subsequent more detailed and integrated assessment as part of Phase 2.

As such, the problem statement for this first phase of the overall Storm Sewer Master Plan can be summarized as providing the town with clear direction regarding:

i) What issues or deficiencies currently exist within the town's storm sewers with respect to the structural condition, capacity, and maintenance requirements of the networks,
ii) Where these deficiencies and issues exist within the town,
iii) How the town should proceed to address these deficiencies
iv) When these works should to be completed.

5.0 ASSESSMENT

Various criteria have been applied for the storm sewer infrastructure needs assessment, which are considered indicative of the functional performance and physical conditions of the town's storm sewers. The analyses have been conducted primarily based upon the information provided by Aquadata Inc. (ref. Aquadata, 2013) and additional complementary tools by AMEC.

The following section outlines the process for storm sewer database development, as well as the specific criteria and associated evaluation approach which has been applied for this preliminary assessment of deficiencies for the town's storm sewers.

5.1 Storm Sewer Database Development

5.1.1 Survey Database

A geodatabase has been developed using the geodetic survey results provided by Aquadata Inc. in a spreadsheet format. The survey dataset compiled by Aquadata has been reviewed in order to determine the coverage of the geodetic survey (i.e. maintenance hole rim elevations and storm sewer invert elevations), as well as to identify any gaps in the dataset compared to the 2011 database developed by the Town of Oakville. The data gaps include the maintenance holes which were not inspected by Aquadata due to technical difficulties, as well as inspected maintenance holes where accurate readings were not possible due to location difficulties. The results of this gap analysis are presented in Tables 5.1 and 5.2.

Table 5.1: Summary of Obstacles Observed During the Surveying Process, as per Aquadata, 2013	
Reason for Not Inspecting Maintenance Holes	**Number**
Backyard of industry.	9
Backyard of industry. Tripod	2
Blocking intersection. Flag man	2
Catch basin not attached to main line	5
Confine space entry	1
Construction	5
Flag man	6
Major changes in the configuration of the sewer. town's update required.	13
New maintenance hole found located on a private property with a fence.	1
New maintenance hole found. Private property	13
Night shift	109
Night shift or flag man	1
No Parking	1
Non visible. Not invoiced.	1
Off-road	39
Parking lot train station - access difficult	4
Private property	90
Private property closed	5
Private property with lock	1
Queen Elizabeth Park - parking	6
Stuck cover. Not invoiced	1
Too dangerous to inspect - cliff	1
Tripod - 3 men	1
Tripod. Need to cut some bushes	1
Tripod/off-road – private property.	2
Zone in construction	10
Grand Total	**330**

Table 5.2: Summary of Reasons for Having No Survey Reading for Inspected Maintenance Holes as per Aquadata, 2013	
Reason Why No GPS Coordinates Available	**Number**
Buried maintenance hole	77
Construction zone	17
Maintenance hole not visible	179
No access to maintenance hole via truck	15
No GPS Signal	60
Too dangerous to access	1
Grand Total	**349**

In addition to the above, another 21 maintenance holes were included within the database for which no data was provided with respect to the inverts and/or rim elevations, and no corresponding explanation was provided. The complete dataset provided by Aquadata Inc. has been compared to the previous database for the storm sewers (developed in 2011) in order to identify the extent of these data gaps. The results of this assessment indicate that no data was provided for 700 of the total 4680 +/- maintenance holes within the Town of Oakville (i.e. 15.0% +/-). The locations of the missing data are depicted graphically on Drawing 5.1. As the drawing indicates, the locations of the missing data are generally distributed throughout the town rather than concentrated to any specific sewer network or development area. Nevertheless, as the information in Drawing 5.1 indicates, the missing elevations at the maintenance holes have resulted in incomplete datasets for the storm sewers connecting to the corresponding maintenance holes. While it is recommended that additional survey be completed to address this information gap, the missing data are not considered to significantly affect the reliability of the preliminary analyses as per the Terms of Reference for this current Phase of the overall Master Plan.

5.1.2 Gap Filling and Quality Check

In order to facilitate the capacity assessment, the missing invert elevations have been estimated based upon a linear interpolation of the surveyed inverts within the upstream and downstream maintenance holes. The lengths and diameters of the storm sewers have been retained as per the information provided in the 2013 geodetic survey and 2011 storm sewer database provided by the Town of Oakville, and the invert elevations for the missing datasets have been estimated based upon the overall slope, as determined from the surveyed upstream and downstream inverts, and the lengths of the storm sewers as provided in the town's 2011 database.

In order to determine the accuracy of the geodetic survey of the rim and invert elevations for storm sewer pipes, the surveyed elevations from the GPS survey have been compared with the elevations attained using Total Station Survey. The results of this comparison are presented in Table 5.3.

Table 5.3: Results for Geodetic Survey Accuracy Verification Analysis

Maintenance Hole Number	Coordinates (UTM, Zone 17)			Surveyed Elevations (m)	Difference (m)
	X	Y	Z		
O_0160_6254	602983.2	4803235.7	85.79	85.77	-0.02
O_0160_6255	603033.7	4803186.8	85.1	85.07	-0.03
O_0160_3672	607499.1	4810932.3	76.37	76.31	-0.06
O_0160_4141	605624.2	4808468.5	85.86	85.87	0.01
O_0160_3283	606186.0	4811472.8	101.67	101.68	0.01
O_0160_3284	606228.7	4811530.5	101.38	101.38	0.00
O_0160_5871	606655.0	4810996.1	94.02	94.01	-0.01
O_0160_3977	606435.1	4809847.2	90.58	90.59	0.01
O_0160_3980	606383.2	4809804.1	90.29	90.31	0.02
O_0160_3069	607244.7	4810511.4	84.87	84.88	0.01
O_0160_3070	607259.0	4810499.9	84.67	84.67	0.00
O_0160_2948	607696.8	4811076.9	86.72	86.75	0.03
O_0160_2950	607714.1	4811101.9	86.28	86.31	0.03
O_0160_3662	609190.8	4813064.7	81.43	81.40	-0.03
O_0160_5791	609143.5	4813110.9	81.81	81.82	0.01
O_0160_400075	604737.5	4807201.4	89.87	89.98	0.11
O_0160_400206	605983.6	4808876.3	85.57	85.57	0.00
O_0160_6656	603344.2	4805499.6	89.86	89.95	0.09
O_0160_6674	604061.9	4804982.5	80.89	80.91	0.02

The results presented in Table 5.3 indicate that the difference between the geodetic survey results and GPS elevations vary between -0.06 to 0.11 m with an average of 0.01 m for the selected maintenance holes. Based on this analysis/check, the geodetic survey results are considered to be adequately accurate for the rim and invert elevations of the storm sewer pipes within a 80% confidence interval of +/- 0.03 m and the extent and coverage of the data is considered adequate for use in this Phase of the Storm Sewer Master Plan.

A separate surveying exercise has also been conducted by AMEC at the storm sewer outfalls within the study area to determine the outlet invert and diameter for each individual outfall. The location of the surveyed outfalls is presented on Drawing 5.2. Based on the results, 14 of the outfalls discharge to Lake Ontario directly and 15 of the outfalls discharge to open watercourses for which hydraulic models have been provided.

As part of the database development, the study area has been subdivided into network areas, which represent logical groups of sewersheds which discharge to common receivers at approximately common locations. The size of each network area has been established in an effort to maintain comparable and consistent sizes across the town. The network areas are presented in Drawing 5.1.

5.2 Structural Condition

The geodatabase developed from the information provided by Aquadata Inc. has been queried to determine the structural rankings and corresponding conditions and requirements for remediation based upon location by network areas. The results of the structural condition assessment for each pipe are presented on Drawing 5.3.

The information in the town's database has been reviewed in order to identify the total length of storm pipe corresponding to each rating based upon the structural condition. The results of this assessment are presented in Table 5.4.

Table 5.4: Length of Storm Sewer Pipe with Structural Rating (1 to 5) By Network

Network Area	Total Length of Pipes in Network (m)	Total Length of Pipes with Structural Rating (m)				
		1 (Excellent)	2	3	4	5 (poor)
1	3564	2110	485	873	84	12
2	2370	1677	478	111	104	0
3	3804	2802	622	380	0	0
4	7266	5409	1043	719	95	0
5	2467	2335	66	0	0	0
6	671	394	44	193	40	0
7	1097	240	334	523	0	0
8	4967	2573	1070	1025	108	39
9	3498	2477	385	636	0	0
10	95	95	0	0	0	0
11	1428	862	178	251	0	0
12	459	160	14	216	0	0
13	8278	4818	1769	1668	23	0
14	16312	12085	2855	809	93	31

Table 5.4: Length of Storm Sewer Pipe with Structural Rating (1 to 5) By Network						
Network Area	**Total Length of Pipes in Network (m)**	**Total Length of Pipes with Structural Rating (m)**				
		1 (Excellent)	**2**	**3**	**4**	**5 (poor)**
15	9379	4609	2197	2071	197	202
16	349	301	48	0	0	0
17	1395	568	487	217	123	0
18	4902	3143	748	641	116	55
19	2230	1364	306	260	160	0
20	6414	5158	470	391	238	32
21	1723	468	521	495	74	0
22	580	451	54	0	0	0
23	1883	1443	371	69	0	0
24	3226	1757	921	269	139	0
25	3224	2339	407	303	0	0
26	1615	1225	116	80	0	0
27	9401	5020	1899	1082	938	265
28	1980	1676	135	0	0	0
29	1974	1444	381	31	88	30
30	6584	4907	988	374	194	121
31	1389	948	300	0	86	0
32	1730	819	383	262	87	0
33	4039	2943	147	474	71	0
34	5546	3701	1310	413	89	0
35	5131	3221	1109	548	22	10
36	5807	4217	998	256	95	0
37	4580	3590	466	83	74	0
38	2191	1893	204	58	36	0
39	3726	3139	554	0	29	0
40	1642	1261	185	0	0	0
41	1727	1525	70	54	78	0
42	2563	1790	103	222	0	0
43	2404	1114	406	41	0	0
44	4157	3386	457	201	42	0
45	4014	2641	1098	171	0	104
46	8692	6248	739	743	349	213
47	7932	4953	1992	830	113	0
48	3245	1705	687	829	0	0
49	6916	5590	211	575	0	0
50	4199	3093	684	80	89	0
51	2232	2016	216	0	0	0
52	23575	20711	1761	733	287	0
53	8626	4664	2231	957	430	45
54	13391	10633	1103	895	114	0
55	6306	1455	2017	1119	1139	259
56	13936	8811	3019	1459	355	0
Total	**262831**	**179977**	**41842**	**24690**	**6399**	**1418**

The information in Table 5.4 has been used to calculate the percent of the total sewer length within each network, corresponding to the structural scores from 1 to 5 in order to quantify the proportion of pipe within the study area requiring remediation. The results of this assessment are presented in Table 5.5.

Table 5.5: Percentage of Storm Sewer Pipes with Structural Rating (1 to 5) By Network

Network Area	Total Length of Pipes in Network (m)	Total Percentage of Pipes with Structural Rating (%)				
		1 (Excellent)	2	3	4	5 (poor)
1	3564	59.2	13.6	24.5	2.4	0.3
2	2370	70.8	20.2	4.7	4.4	0.0
3	3804	73.7	16.4	10.0	0.0	0.0
4	7266	74.4	14.4	9.9	1.3	0.0
5	2467	94.6	2.7	0.0	0.0	0.0
6	671	58.7	6.6	28.8	6.0	0.0
7	1097	21.9	30.4	47.7	0.0	0.0
8	4967	51.8	21.5	20.6	2.2	0.8
9	3498	70.8	11.0	18.2	0.0	0.0
10	95	100.0	0.0	0.0	0.0	0.0
11	1428	60.4	12.5	17.6	0.0	0.0
12	459	34.9	3.1	47.1	0.0	0.0
13	8278	58.2	21.4	20.1	0.3	0.0
14	16312	74.1	17.5	5.0	0.6	0.2
15	9379	49.1	23.4	22.1	2.1	2.2
16	349	86.2	13.8	0.0	0.0	0.0
17	1395	40.7	34.9	15.6	8.8	0.0
18	4902	64.1	15.3	13.1	2.4	1.1
19	2230	61.2	13.7	11.7	7.2	0.0
20	6414	80.4	7.3	6.1	3.7	0.5
21	1723	27.2	30.2	28.7	4.3	0.0
22	580	77.8	9.3	0.0	0.0	0.0
23	1883	76.6	19.7	3.7	0.0	0.0
24	3226	54.5	28.5	8.3	4.3	0.0
25	3224	72.5	12.6	9.4	0.0	0.0
26	1615	75.9	7.2	5.0	0.0	0.0
27	9401	53.4	20.2	11.5	10.0	2.8
28	1980	84.6	6.8	0.0	0.0	0.0
29	1974	73.2	19.3	1.6	4.5	1.5
30	6584	74.5	15.0	5.7	2.9	1.8
31	1389	68.3	21.6	0.0	6.2	0.0
32	1730	47.3	22.1	15.1	5.0	0.0
33	4039	72.9	3.6	11.7	1.8	0.0
34	5546	66.7	23.6	7.4	1.6	0.0
35	5131	62.8	21.6	10.7	0.4	0.2
36	5807	72.6	17.2	4.4	1.6	0.0
37	4580	78.4	10.2	1.8	1.6	0.0
38	2191	86.4	9.3	2.6	1.6	0.0
39	3726	84.2	14.9	0.0	0.8	0.0

Table 5.5: Percentage of Storm Sewer Pipes with Structural Rating (1 to 5) By Network						
Network Area	**Total Length of Pipes in Network (m)**	**Total Percentage of Pipes with Structural Rating (%)**				
		1 (Excellent)	**2**	**3**	**4**	**5 (poor)**
40	1642	76.8	11.3	0.0	0.0	0.0
41	1727	88.3	4.1	3.1	4.5	0.0
42	2563	69.8	4.0	8.7	0.0	0.0
43	2404	46.3	16.9	1.7	0.0	0.0
44	4157	81.5	11.0	4.8	1.0	0.0
45	4014	65.8	27.4	4.3	0.0	2.6
46	8692	71.9	8.5	8.5	4.0	2.5
47	7932	62.4	25.1	10.5	1.4	0.0
48	3245	52.5	21.2	25.5	0.0	0.0
49	6916	80.8	3.1	8.3	0.0	0.0
50	4199	73.7	16.3	1.9	2.1	0.0
51	2232	90.3	9.7	0.0	0.0	0.0
52	23575	87.9	7.5	3.1	1.2	0.0
53	8626	54.1	25.9	11.1	5.0	0.5
54	13391	79.4	8.2	6.7	0.9	0.0
55	6306	23.1	32.0	17.7	18.1	4.1
56	13936	63.2	21.7	10.5	2.5	0.0
Total	**262831**	**68**	**16**	**9**	**2**	**1**

The information in Tables 5.4 and 5.5, as well as the information provided in Drawing 5.3, indicate that in general the sewer networks within the study area are in relatively good condition with respect to the structural condition of the storm sewers (i.e. 84% of the pipes have structural score of 1 or 2). The information also indicates that, in general, relatively few pipes are in poor structural condition (i.e. 2% with scores of 4 and 1% with score of 5), hence areas of poor structural condition are considered to be relatively isolated and are generally not localized or concentrated to specific sewershed areas. Network areas 27 and 55 contain the highest number of pipes with poor structural condition (i.e. 1203 m and 1398 m of the storm sewers having a score of 4 or 5 respectively). The total length of pipes with a structural ranking score of 4 or 5 for all other individual network area is less than half of the total length of pipes with score of 4 or 5 in network areas 27 and 55.

5.3 Capacity / Hydraulic Performance

For the purpose of this Phase of the Storm Sewer Master Plan, a simplified analytical approach has been developed and applied for the preliminary assessment to identify those segments of the storm sewers which have a potentially lower conveyance capacity compared to the current design standard required by the Town of Oakville.

The Rational Method has been used in order to determine the design flows for the storm sewers under assessment. The contributing drainage area along key links within the storm sewer network storm sewer pipes have been established based upon the storm sewer layout and lot boundaries as provided in the GIS database supplied by the town. The “links” represent storm sewer segments to, or between, junctions and confluences within the networks, as opposed to individual pipes.

The Town of Oakville Official Plan (September 2006) has been used as a basis for land use, as presented in Appendix 'B', to determine runoff coefficients for the respective storm sewer catchment areas. The runoff coefficients correspond to the following recommended values provided in the Town of Oakville Development Engineering Procedures and Guidelines Manual (October 2009):

– Runoff Coefficient of 0.9 for Commercial and Employment areas.
– Runoff Coefficient of 0.6 for residential areas.
– Runoff Coefficient of 0.2 for parkland.

The rainfall intensity has been calculated using the Town of Oakville's 5 year IDF equation as follows: $i_{5year}=1170/(tc+5.8)^{0.843}$

The Time of Concentration (TOC) for each storm sewer link has been estimated based upon the total contributing drainage area to each link. A minimum TOC of 10 minutes has been applied, in accordance with the Town of Oakville's design standards. This value has been assumed to be applicable for contributing drainage areas of 0.5 ha or less.

For drainage areas greater than 0.5 ha, the TOC has been estimated by areal weighting. The areal weighting relationship has been developed based upon the Bransby Williams Formula:

$$t_c=0.057 \times L/(S_w^{0.2} \times A^{0.1}).$$

The TOC corresponding to an area greater than 0.5 ha is represented by t_{ci}, and the initial time of concentration of 10 min is represented by t_{c1}. Hence, the ratio of t_{ci} and t_{c1} can be calculated as follows:

$$(t_{ci}/t_{c1}) = [(0.057 \times L_i/(S_w^{0.2} \times A_i^{0.1})]/[(0.057 \times L_1/(S_w^{0.2} \times A_1^{0.1})]$$

Assuming that the ratio of the lengths of the contributing drainage areas are equal to the ratio of the subcatchment areas (i.e. $(L_i/L_1) = (A_i/A_1)$), and assuming comparable subcatchment slopes, the foregoing equation simplifies to a function of area only as follows:

$$t_{ci} = (A_i/A_1)^{0.9} \times t_{c1}$$

Applying the assumption that a 10 minute TOC corresponds to drainage areas of 0.5 ha, the equation becomes:

$$t_{ci} = (A_i/0.5)^{0.9} \times (10 \text{ min})$$

The foregoing equation has thus been applied in order to calculate the TOC for drainage areas greater than 0.5 ha for the average intensity factor in the Rational Method equation. While it is recognized that more locally specific data on slope and shape (length) can be derived, for the purpose of this capacity screening assessment, it has been considered appropriate, Phase 2 will apply more detailed analytical assessment to more accurately assess capacity.

The Rational Method has been used to estimate the peak flow for each sewer pipe and the estimated flow values have been compared with full pipe flow peak values calculated using the Manning's equation based on existing pipe size and geometry. A roughness coefficient of 0.013 has been used for the concrete pipe, and the slopes and diameters of the storm sewers have been calculated based upon the pipe lengths, surveyed inverts and diameters provided in the town's storm sewer survey database.

A numerical score has been assigned to each pipe in order to reflect the capacity provided compared to the capacity required. To maintain consistency with the structural and maintenance scoring system, the capacity scores range from 1 to 5 and have been based upon the following criteria to assign a numerical score to each storm sewer pipe based on the flow capacity assessment results.

Flow Comparison Result	Storm Sewer Score
$\frac{\text{QRequired}}{\text{Q Provided}} \leq 1.05$	1
$1.05 < \frac{\text{QRequired}}{\text{Q Provided}} \leq 1.25$	2
$1.25 < \frac{\text{QRequired}}{\text{Q Provided}} \leq 1.50$	3
$1.50 < \frac{\text{QRequired}}{\text{Q Provided}} \leq 1.75$	4
$1.75 < \frac{\text{QRequired}}{\text{Q Provided}}$	5

The Total length of storm sewer pipes with flow capacity rating of 1 to 5 has been presented in Table 5.6 for each network. The results of the flow capacity rating have also been depicted on Drawing 5.4.

Table 5.6: Length of Storm Sewer Pipe with Flow Capacity Rating (1 to 5) By Network

Network Area	Total Length of Pipes in Network (m)	Total Length of Pipes with Flow Capacity Rating (m)				
		1 (Adequate)	2	3	4	5 (Inadequate)
1	3344.1	2776.3	339.2	44.3	110.9	73.3
2	2252.7	2240.1	0.0	12.6	0.0	0.0
3	3567.5	3177.1	147.5	42.8	100.5	99.6
4	6375.5	6044.0	308.3	23.3	0.0	0.0
5	1714.2	1428.0	151.8	91.8	42.5	0.0
6	551.7	202.2	0.0	0.0	21.6	328.0
7	848.9	535.0	153.0	120.8	40.1	0.0
8	3942.8	3312.3	403.1	95.0	0.0	132.4
9	3141.7	2401.7	209.4	203.6	58.2	268.9
10	27.4	27.4	0.0	0.0	0.0	0.0
11	976.4	372.6	93.3	82.2	142.7	285.7
12	121.9	61.3	0.0	0.0	0.0	60.5
13	6726.8	5603.5	343.4	332.5	51.5	396.0
14	12589.4	8493.0	1045.0	780.7	479.2	1791.5
15	8378.3	6334.1	628.9	506.3	302.9	606.3
16	344.2	253.4	54.4	0.0	36.4	0.0
17	1361.7	1065.8	62.9	187.2	0.0	45.9

Table 5.6: Length of Storm Sewer Pipe with Flow Capacity Rating (1 to 5) By Network						
Network Area	**Total Length of Pipes in Network (m)**	**Total Length of Pipes with Flow Capacity Rating (m)**				
		1 (Adequate)	**2**	**3**	**4**	**5 (Inadequate)**
18	3639.6	2689.9	139.3	174.6	319.2	316.7
19	1720.5	1362.7	136.4	126.6	0.0	94.7
20	5070.6	4839.9	0.0	155.4	0.0	75.3
21	1422.4	1357.6	0.0	64.8	0.0	0.0
22	377.2	270.0	55.1	52.1	0.0	0.0
23	1617.6	1255.8	89.1	49.2	168.9	54.7
24	2871.8	2587.5	0.0	284.3	0.0	0.0
25	1654.7	970.6	289.3	160.1	106.6	128.1
26	1107.1	753.8	169.7	79.2	60.8	43.6
27	8440.4	6965.0	226.2	309.1	344.1	596.0
28	1001.5	745.8	67.9	40.4	0.0	147.4
29	1449.1	1038.3	47.0	190.6	84.5	88.7
30	5799.7	4885.7	382.7	80.3	0.0	451.0
31	1072.0	870.6	85.0	76.4	0.0	39.9
32	884.8	444.0	43.2	149.4	35.5	212.7
33	2592.3	1902.1	200.3	42.9	62.3	384.6
34	5150.6	4303.1	56.4	126.9	90.2	574.1
35	4121.7	3277.6	610.0	204.9	0.0	29.3
36	3676.9	3141.7	145.9	263.9	0.0	125.4
37	3121.9	2232.0	23.7	207.5	253.0	405.7
38	1066.7	119.5	158.1	213.6	69.2	506.4
39	2966.2	1926.9	340.7	0.0	301.0	397.6
40	897.4	523.7	66.5	148.6	0.0	158.6
41	1081.5	702.2	80.1	161.1	0.0	138.1
42	1523.7	992.1	274.5	0.0	0.0	257.1
43	848.5	763.9	24.9	0.0	59.7	0.0
44	3241.3	2706.2	188.4	176.9	28.5	141.3
45	2998.0	2397.4	111.2	183.7	98.6	207.0
46	5547.1	4896.7	85.7	279.9	94.8	190.0
47	6314.5	5471.6	193.6	339.8	146.6	162.9
48	2696.0	1767.1	563.7	85.4	137.9	141.9
49	4646.6	3299.8	594.0	522.3	153.4	77.1
50	3856.2	2738.8	303.0	576.2	0.0	238.1
51	1793.3	890.7	439.1	127.7	253.6	82.2
52	19213.0	16582.7	832.2	953.9	424.2	420.1
53	6225.8	5832.6	0.0	77.3	52.3	263.6
54	9280.6	6913.1	358.5	787.5	199.7	1021.8
55	4341.8	3691.9	400.1	249.9	0.0	0.0
56	8865.2	7256.5	270.5	641.7	250.8	445.7
Total	**200461.0**	**159694.6**	**11992.2**	**10887.4**	**5181.6**	**12705.3**

The results presented in Table 5.6 have been used to determine the percentage of the total length of storm sewers with ranking 1 to 5 for each network area. The assessment results are presented in Table 5.7.

Table 5.7: Percentage of Storm Sewer Pipe with Flow Capacity Rating (1 to 5) By Network						
Network Area	Total Length of Pipes in Network (m)	Total Percentage of Pipes with flow capacity Rating (%)				
		1 (Adequate)	2	3	4	5 (Inadequate)
1	3344.1	83.0	10.1	1.3	3.3	2.2
2	2252.7	99.4	0.0	0.6	0.0	0.0
3	3567.5	89.1	4.1	1.2	2.8	2.8
4	6375.5	94.8	4.8	0.4	0.0	0.0
5	1714.2	83.3	8.9	5.4	2.5	0.0
6	551.7	36.6	0.0	0.0	3.9	59.4
7	848.9	63.0	18.0	14.2	4.7	0.0
8	3942.8	84.0	10.2	2.4	0.0	3.4
9	3141.7	76.4	6.7	6.5	1.9	8.6
10	27.4	100.0	0.0	0.0	0.0	0.0
11	976.4	38.2	9.6	8.4	14.6	29.3
12	121.9	50.3	0.0	0.0	0.0	49.7
13	6726.8	83.3	5.1	4.9	0.8	5.9
14	12589.4	67.5	8.3	6.2	3.8	14.2
15	8378.3	75.6	7.5	6.0	3.6	7.2
16	344.2	73.6	15.8	0.0	10.6	0.0
17	1361.7	78.3	4.6	13.7	0.0	3.4
18	3639.6	73.9	3.8	4.8	8.8	8.7
19	1720.5	79.2	7.9	7.4	0.0	5.5
20	5070.6	95.5	0.0	3.1	0.0	1.5
21	1422.4	95.4	0.0	4.6	0.0	0.0
22	377.2	71.6	14.6	13.8	0.0	0.0
23	1617.6	77.6	5.5	3.0	10.4	3.4
24	2871.8	90.1	0.0	9.9	0.0	0.0
25	1654.7	58.7	17.5	9.7	6.4	7.7
26	1107.1	68.1	15.3	7.2	5.5	3.9
27	8440.4	82.5	2.7	3.7	4.1	7.1
28	1001.5	74.5	6.8	4.0	0.0	14.7
29	1449.1	71.7	3.2	13.2	5.8	6.1
30	5799.7	84.2	6.6	1.4	0.0	7.8
31	1072.0	81.2	7.9	7.1	0.0	3.7
32	884.8	50.2	4.9	16.9	4.0	24.0
33	2592.3	73.4	7.7	1.7	2.4	14.8
34	5150.6	83.5	1.1	2.5	1.8	11.1
35	4121.7	79.5	14.8	5.0	0.0	0.7
36	3676.9	85.4	4.0	7.2	0.0	3.4
37	3121.9	71.5	0.8	6.6	8.1	13.0
38	1066.7	11.2	14.8	20.0	6.5	47.5
39	2966.2	65.0	11.5	0.0	10.1	13.4
40	897.4	58.4	7.4	16.6	0.0	17.7
41	1081.5	64.9	7.4	14.9	0.0	12.8
42	1523.7	65.1	18.0	0.0	0.0	16.9
43	848.5	90.0	2.9	0.0	7.0	0.0

Table 5.7: Percentage of Storm Sewer Pipe with Flow Capacity Rating (1 to 5) By Network						
Network Area	**Total Length of Pipes in Network (m)**	**Total Percentage of Pipes with flow capacity Rating (%)**				
		1 (Adequate)	**2**	**3**	**4**	**5 (Inadequate)**
44	3241.3	83.5	5.8	5.5	0.9	4.4
45	2998.0	80.0	3.7	6.1	3.3	6.9
46	5547.1	88.3	1.5	5.0	1.7	3.4
47	6314.5	86.7	3.1	5.4	2.3	2.6
48	2696.0	65.5	20.9	3.2	5.1	5.3
49	4646.6	71.0	12.8	11.2	3.3	1.7
50	3856.2	71.0	7.9	14.9	0.0	6.2
51	1793.3	49.7	24.5	7.1	14.1	4.6
52	19213.0	86.3	4.3	5.0	2.2	2.2
53	6225.8	93.7	0.0	1.2	0.8	4.2
54	9280.6	74.5	3.9	8.5	2.2	11.0
55	4341.8	85.0	9.2	5.8	0.0	0.0
56	8865.2	81.9	3.1	7.2	2.8	5.0
Total	**200461.0**	**79.7**	**6.0**	**5.4**	**2.6**	**6.3**

Results presented in Tables 5.6 and 5.7, as well as the information in Drawing 5.4 indicate that nearly 80% of the storm sewer pipes in the study area are not anticipated to have potential flow capacity deficiencies based upon the findings of this preliminary capacity assessment (i.e. capacity scores of 1). As indicated by the information presented on Drawing 5.4, the occurrence of potential deficient capacities (i.e. pipes with a score greater than 1) tend to correspond to isolated sewer segments, rather than consecutive sewer segments, and hence are considered to represent a relatively localized condition. There are three networks where nearly half of the storm sewer pipes have a score of 5 (i.e. Areas 6, 12 and 38), all of which have relatively smaller lengths of storm sewer pipes compared to other networks within the study area.

The methodology applied for the capacity assessment is recognized as being widely applied throughout the industry, however the assessment has not accounted for the influence of tailwater conditions, inlet restrictions and losses associated with decreasing pipe diameters, and dynamic flow conditions during intense storm events which produce a sudden pulse in the network. These conditions would similarly influence the functional capacity of the network and, in the case of dynamic flow conditions, could result in lifted maintenance holes and surcharging during these more severe storm events. The methodology has also focused on the minor system capacity, and has not evaluated the conveyance capacity of the major (overland) system. The major system capacity is of particular importance to determining whether runoff for larger events up to the 100 year would be contained within the Municipal right-of-way, or whether flooding of private properties may occur.

5.3.1 Correlation with Historic Maintenance Issues

The results of the capacity analysis have been integrated with the locations of historic maintenance issues (i.e. 'hot spots') in order to determine whether or not a potential correlation and causality exists between the pipe capacity and the historic maintenance requirements. This information is depicted graphically on Drawing 5.5. Based upon the information provided in Drawing 5.5, there is no apparent correlation between the number of identified 'hot spots' and the incidences of potentially lower conveyance capacity for the town's storm sewers. Consequently, the requirements to address and maintain the inlet and outlet conditions of the hot spots are considered to be independent of the capacity within the storm sewer. Nevertheless, it is recognized that improvements to the storm sewer outlet would serve to enhance the conveyance capacity of the upstream sewer network, and improvements to the inlet similarly reduce the occurrence and frequency of nuisance flooding during runoff conditions.

5.4 Maintenance Requirements

The operations and maintenance conditions for each storm sewer pipe have been established based upon the results of the ZOOM™ Camera inspections of the storm sewer pipe network performed by Aquadata. The geodatabase developed by AMEC has been queried to determine the maintenance scores and corresponding requirements for remediation based upon location by network areas.

The results of the operations and maintenance assessment have been presented on Drawing 5.6. The information in the developed database has been reviewed in order to identify the total length of storm pipe corresponding to each rating from 1 to 5 based upon the operations and maintenance (O&M) requirements. The results of this assessment are presented in Table 5.8.

Table 5.8: Length of Storm Sewer Pipe with O & M Rating (1 to 5) By Network

Network Area	Total Length of Pipes in Network (m)	Total Length of Pipes with O & M Rating (m)				
		1 (Excellent)	2	3	4	5 (Poor)
1	3564	629	2008	927	0	0
2	2370	1108	1089	173	0	0
3	3804	939	2208	538	38	81
4	7266	2775	4133	358	0	0
5	2467	1167	1076	21	137	0
6	671	378	218	41	34	0
7	1097	377	278	272	129	41
8	4967	1071	2457	896	244	147
9	3498	431	2087	838	74	68
10	95	0	0	51	0	44
11	1428	618	519	132	0	22
12	459	100	227	63	0	0
13	8278	2113	3445	1870	525	325
14	16312	4456	9838	1120	214	245

Table 5.8: Length of Storm Sewer Pipe with O & M Rating (1 to 5) By Network						
Network Area	**Total Length of Pipes in Network (m)**	**Total Length of Pipes with O & M Rating (m)**				
		1 (Excellent)	**2**	**3**	**4**	**5 (Poor)**
15	9379	1727	5697	1493	145	214
16	349	169	124	56	0	0
17	1395	121	1074	200	0	0
18	4902	932	3080	387	143	161
19	2230	214	1208	538	61	69
20	6414	747	4802	342	334	64
21	1723	148	1328	82	0	0
22	580	0	478	27	0	0
23	1883	308	1363	212	0	0
24	3226	673	2025	214	80	94
25	3224	332	1999	436	140	142
26	1615	161	827	218	154	61
27	9401	1582	6309	896	143	274
28	1980	855	485	204	267	0
29	1974	457	1005	314	152	46
30	6584	745	5201	541	97	0
31	1389	57	958	285	34	0
32	1730	66	1092	326	67	0
33	4039	563	2294	478	204	96
34	5546	726	3955	619	0	213
35	5131	473	3109	1031	166	131
36	5807	736	3138	1189	426	77
37	4580	677	2709	560	140	127
38	2191	581	1099	419	59	33
39	3726	1235	1408	421	448	210
40	1642	450	502	445	49	0
41	1727	287	1002	360	46	32
42	2563	60	1757	249	0	49
43	2404	321	935	305	0	0
44	4157	490	2060	1262	168	106
45	4014	593	2265	998	0	158
46	8692	673	5749	1375	495	0
47	7932	653	4300	2039	802	94
48	3245	446	2430	254	56	35
49	6916	1697	2567	1098	378	636
50	4199	854	2341	563	188	0
51	2232	369	933	420	116	394
52	23575	6906	14936	966	330	354
53	8626	1528	5718	729	151	201
54	13391	3865	7624	903	277	76
55	6306	1685	3480	670	64	90
56	13936	3895	8190	698	186	675
Total	**262831**	**55219**	**153139**	**32122**	**7961**	**5885**

The information in Table 5.8 has been used to calculate the percent of the total sewer length within each network, corresponding to the operation and maintenance scores from 1 to 5. The results of this assessment are presented in Table 5.9.

Table 5.9: Percentage (%) of Storm Sewer Pipe with O & M Rating (1 to 5) By Network

Network Area	Total Length of Pipes in Network (m)	Total Percentage of Pipes with O & M Rating (%)				
		1 (Excellent)	2	3	4	5 (Poor)
1	3564	17.6	56.3	26.0	0.0	0.0
2	2370	46.8	45.9	7.3	0.0	0.0
3	3804	24.7	58.0	14.1	1.0	2.1
4	7266	38.2	56.9	4.9	0.0	0.0
5	2467	47.3	43.6	0.9	5.6	0.0
6	671	56.3	32.5	6.1	5.1	0.0
7	1097	34.4	25.3	24.8	11.8	3.7
8	4967	21.6	49.5	18.0	4.9	3.0
9	3498	12.3	59.7	24.0	2.1	1.9
10	95	0.0	0.0	53.7	0.0	46.3
11	1428	43.3	36.3	9.2	0.0	1.5
12	459	21.8	49.5	13.7	0.0	0.0
13	8278	25.5	41.6	22.6	6.3	3.9
14	16312	27.3	60.3	6.9	1.3	1.5
15	9379	18.4	60.7	15.9	1.5	2.3
16	349	48.4	35.5	16.0	0.0	0.0
17	1395	8.7	77.0	14.3	0.0	0.0
18	4902	19.0	62.8	7.9	2.9	3.3
19	2230	9.6	54.2	24.1	2.7	3.1
20	6414	11.6	74.9	5.3	5.2	1.0
21	1723	8.6	77.1	4.8	0.0	0.0
22	580	0.0	82.4	4.7	0.0	0.0
23	1883	16.4	72.4	11.3	0.0	0.0
24	3226	20.9	62.8	6.6	2.5	2.9
25	3224	10.3	62.0	13.5	4.3	4.4
26	1615	10.0	51.2	13.5	9.5	3.8
27	9401	16.8	67.1	9.5	1.5	2.9
28	1980	43.2	24.5	10.3	13.5	0.0
29	1974	23.2	50.9	15.9	7.7	2.3
30	6584	11.3	79.0	8.2	1.5	0.0
31	1389	4.1	69.0	20.5	2.4	0.0
32	1730	3.8	63.1	18.8	3.9	0.0
33	4039	13.9	56.8	11.8	5.1	2.4
34	5546	13.1	71.3	11.2	0.0	3.8
35	5131	9.2	60.6	20.1	3.2	2.6
36	5807	12.7	54.0	20.5	7.3	1.3
37	4580	14.8	59.1	12.2	3.1	2.8
38	2191	26.5	50.2	19.1	2.7	1.5
39	3726	33.1	37.8	11.3	12.0	5.6
40	1642	27.4	30.6	27.1	3.0	0.0

Table 5.9: Percentage (%) of Storm Sewer Pipe with O & M Rating (1 to 5) By Network						
Network Area	**Total Length of Pipes in Network (m)**	**Total Percentage of Pipes with O & M Rating (%)**				
		1 (Excellent)	**2**	**3**	**4**	**5 (Poor)**
41	1727	16.6	58.0	20.8	2.7	1.9
42	2563	2.3	68.6	9.7	0.0	1.9
43	2404	13.4	38.9	12.7	0.0	0.0
44	4157	11.8	49.6	30.4	4.0	2.5
45	4014	14.8	56.4	24.9	0.0	3.9
46	8692	7.7	66.1	15.8	5.7	0.0
47	7932	8.2	54.2	25.7	10.1	1.2
48	3245	13.7	74.9	7.8	1.7	1.1
49	6916	24.5	37.1	15.9	5.5	9.2
50	4199	20.3	55.8	13.4	4.5	0.0
51	2232	16.5	41.8	18.8	5.2	17.7
52	23575	29.3	63.4	4.1	1.4	1.5
53	8626	17.7	66.3	8.5	1.8	2.3
54	13391	28.9	56.9	6.7	2.1	0.6
55	6306	26.7	55.2	10.6	1.0	1.4
56	13936	27.9	58.8	5.0	1.3	4.8
Total	**262831**	**21**	**58**	**12**	**3**	**2**

As the information on Drawing 5.6 indicates, most of the pipes within the study area have a rating of 2 and may require some operations and maintenance work, although this would consist of relatively routine activities. In a few locations, the operations and maintenance grades reach 4 and 5 which would likely require more immediate attention and potentially more significant maintenance work.

The results presented in Tables 5.8 and 5.9 and Drawing 5.6 indicate that, in general, the sewer network areas within the study area are in relatively good or moderate condition with respect to the operations and maintenance requirements of the storm sewers (i.e. score of 1, 2 or 3). The information also indicates that, in general, relatively few pipes are in poor operational condition. Network area 10 has the greatest percentage of pipes requiring immediate attention (i.e. maintenance score of 5); however the total length of pipes within this network area is 95 m which is far less than the rest of the network areas. Similarly, Network area 51 has the highest percentage of storm sewer pipes with an O&M score of 4 or 5 (22.9%) but the actual length of the storm sewer pipes with a score of 4 or 5 is equal to 510 m. Network areas 49 and 47 have the greatest total length of storm sewer pipes requiring immediate attention (i.e. 1014 m and 896 m respectively).

5.5 Other Considerations

5.5.1 Areas with Decreasing Pipe Diameter

The information collected by Aquadata Inc. has been further reviewed to identify locations where the storm sewer diameter decreases from upstream to downstream, thus representing a potential capacity constraint. The storm sewer and maintenance hole data have been imported into Excel™, and the *Lookup* functions have been used to correlate the diameter of the upstream and downstream storm sewers with each maintenance hole. The upstream and downstream diameters have been compared, and a tabular summary has been prepared in Excel™ to denote the specific pipes within the town's storm sewer network which have a diameter smaller than that of the upstream pipe. The results of this assessment are depicted on Drawing 5.7 to present the locations of those pipes which represent a reduction in the diameter from upstream to downstream. The dataset has been reviewed in order to determine the total length of sewers within each network area which represent a reduction to the pipe diameter compared to the upstream segment, as well as the corresponding proportion (i.e. percentage) of the total storm sewer length which comprises a reduced diameter. The results are presented in Table 5.10.

Table 5.10: Length of Storm Sewer Pipe Decreasing in Diameter by Sub-Network

Network Area	Total Length of Pipes in Network (m)	Total Length of Pipes Representative of Decreasing Diameter (m)	Percent of Sewers Representative of Decreasing Diameter (%)
1	3394.6	12.2	0.4
2	2302.4	92.3	4
3	3641.2	0	0
4	6430.5	21.3	0.3
5	1714.2	0	0
6	576.5	0	0
7	923.3	0	0
8	4398.7	8.3	0.2
9	3301.6	223.5	6.8
10	27.4	0	0
11	1286.6	11.4	0.9
12	232.3	0	0
13	6935.1	67.3	1
14	13365.2	386.8	2.9
15	8663.5	117.5	1.4
16	317.1	0	0
17	1308.4	23.9	1.8
18	3673.2	170.8	4.6
19	1574.1	16.6	1.1
20	5363.0	298.4	5.6
21	1521.4	0	0
22	445.6	34.2	7.7
23	1632.8	60.6	3.7
24	2742.8	0	0
25	1924.8	0	0
26	1130.8	0	0
27	8850.4	352.9	4
28	1223.3	116.8	9.5
29	1490.7	32	2.1
30	6266.2	0	0
31	1156.7	0	0
32	1189.2	0	0
33	2847.7	155.7	5.5
34	5183.9	218	4.2

Table 5.10: Length of Storm Sewer Pipe Decreasing in Diameter by Sub-Network			
Network Area	**Total Length of Pipes in Network (m)**	**Total Length of Pipes Representative of Decreasing Diameter (m)**	**Percent of Sewers Representative of Decreasing Diameter (%)**
35	4519.9	423.6	9.4
36	3890.6	24.6	0.6
37	3321.2	0	0
38	1182.3	0	0
39	3134.4	0	0
40	965.6	20.1	2.1
41	1220.2	105.3	8.6
42	1700.6	0	0
43	951.8	45.5	4.8
44	3677.2	28.7	0.8
45	3479.4	153.9	4.4
46	6550.0	156.6	2.4
47	7457.8	215.8	2.9
48	2876.4	139.5	4.9
49	5454.6	0	0
50	5047.0	172.4	3.4
51	1793.3	0	0
52	19434.0	370.7	1.9
53	6355.9	0	0
54	9038.5	126.6	1.4
55	4324.1	51.8	1.2
56	8977.7	257.6	2.9

The information in Table 5.10 and Drawing 5.7 indicates that reductions to the pipe diameter from upstream to downstream affect a relatively low proportion of the storm sewer network areas within the study area (i.e. of 2.1% on average on a total of over 212000 m). As such, reductions to pipe diameter are considered to represent a relatively isolated or localized condition within the network.

5.5.2 Areas with Potential Adverse Slopes

The database developed by AMEC, using the Aquadata Inc. survey information, has been reviewed to identify locations where storm sewers have a reverse (i.e. negative/adverse) slope, which may indicate a potential capacity constraint. Similar to the approach applied for the decreasing diameter assessment, the upstream and downstream inverts for the pipes have been compared using Excel™, and a tabular summary has been prepared to denote the specific pipes within the town's storm sewer network which have a reverse slope. These results have been incorporated into the GIS database, and a plan has been prepared to depict the locations of those pipes which have a negative slope based upon the surveyed inverts; the results are presented on Drawing 5.8. The dataset has been reviewed in order to determine the total length of sewers within each network in the study area which have a reverse slope condition, as well as the corresponding proportion (i.e. percentage) of the total storm sewer length which comprises of a reduced diameter. The results are presented in Table 5.11.

Table 5.11: Length of Storm Sewer Pipe with Reverse Slope by Sub-Network

Network Area	Total Length of Pipes in Network (m)	Total Length of Pipes Representative of Reverse Slope (m)	Percentage of Sewer Pipes Representative of Reverse Slope (%)
1	3395.5	36.9	1.1
2	2347.2	81.7	3.5
3	3642.2	0	0
4	6667.8	139.8	2.1
5	1714.7	0	0
6	576.7	24.8	4.3
7	923.5	74.4	8.1
8	4063.4	119.6	2.9
9	3198.5	5.2	0.2
10	27.4	0	0
11	976.7	0	0
12	232.4	110.5	47.5
13	6717.6	176.1	2.6
14	12668.1	332.3	2.6
15	8808.6	238.3	2.7
16	344.3	0	0
17	1362.1	0	0
18	3534.9	113.4	3.2
19	1269.0	49.9	3.9
20	5161.4	292.1	5.7
21	1481.1	58.3	3.9
22	381.6	0	0
23	1732.5	114.4	6.6
24	2595.0	0	0
25	1976.7	308.2	15.6
26	1131.1	23.6	2.1
27	8443.3	32.5	0.4
28	1133.3	147	13
29	1451.2	0	0
30	6107.3	258.4	4.2
31	1072.3	0	0
32	905.9	45.3	5
33	2684.6	82.8	3.1
34	5240.1	66.8	1.3
35	4418.8	279.5	6.3
36	3834.5	156.7	4.1
37	3212.1	89.4	2.8
38	1182.7	115.6	9.8
39	3222.9	251.3	7.8
40	951.5	53.9	5.7
41	1251.9	67.5	5.4
42	1700.9	177	10.4
43	877.1	28.4	3.2
44	3268.0	93.2	2.9
45	3065.0	66.3	2.2

Table 5.11: Length of Storm Sewer Pipe with Reverse Slope by Sub-Network			
Network Area	**Total Length of Pipes in Network (m)**	**Total Length of Pipes Representative of Reverse Slope (m)**	**Percentage of Sewer Pipes Representative of Reverse Slope (%)**
46	5354.6	10.6	0.2
47	6505.4	189.4	2.9
48	2786.0	89.3	3.2
49	4576.9	17.1	0.4
50	3799.5	132.8	3.5
51	1793.7	0	0
52	20442.9	86.7	0.4
53	6607.8	374.3	5.7
54	10958.9	63	0.6
55	4645.1	138.4	3
56	9814.1	265.9	2.7

The information in Table 5.11 indicates that, in general, reverse slopes affect a relatively small proportion of the networks within the study area (i.e. average 4 %). The one exception is within network 12, whereby reverse slopes have been identified within 47.5 % of the storm sewer pipes. While the proportion of storm sewer pipes within network 12 which contain reverse slope pipes is noted to be higher, the total length of pipe (i.e. 110.5 m) which exhibits the reverse slope is noted to be within the range observed for the rest of the networks. The absolute difference in the upstream and downstream invert elevation for pipes with negative slope is also considered to be generally within the acceptable margin of error of the geodetic survey in most cases. Consequently, the instances of reverse slope pipes are considered to represent a relatively isolated or localized condition within the study area.

5.5.3 Submerged Outfalls

The grades and water surface elevations for the storm outfalls and receivers within the study area have been reviewed in order to determine whether the sewer networks would be anticipated to be submerged during the design event, thereby potentially decreasing the conveyance capacity of the sewer network (i.e. due to backwater). Total Station and GPS survey of the culverts at the storm outfalls has been obtained by AMEC, and invert elevations have been calculated based upon the surveyed culvert elevations and the pipe diameter. The invert elevation at the storm sewer outfalls are provided in Appendix ‘D’. The water surface elevation of the open watercourses within the study area during a 5 year event, have been obtained from the HEC-RAS models provided by Conservation Halton. The simulated 5 year surface elevations have been compared with the invert elevation at the outfall in order to determine the potential for submerged conditions at the outlet during the 5 year design event. The location of the assessed outfalls has been depicted on Drawing 5.9 and results of the assessment have been presented in Table 5.12.

Table 5.12: Submerged Outfalls Assessment Results						
Outfall	Invert	Diameter	Obvert	5 Year WSE		Condition
				UP	DOWN	
	(m)	(m)	(m)	(m)	(m)	
O_0130_299	101.2	0.3	101.5	102.93	102.8	Submerged
O_0130_400043	101.05	1.5	102.55	102.21	101.96	Partially Submerged
O_0130_303	94.79	1.4	96.19	96.63	95.84	Partially Submerged
O_0130_306	90.5	0.6	91.1	91.86	91.57	Submerged
O_0130_307	90.26	0.9	91.16	91.86	91.57	Submerged
O_0130_309	88.21	0.7	88.91	89.68	89.37	Submerged
O_0130_310	86.02	0.45	86.47	87.96	88	Submerged
O_0130_400021	82.61	1.2	83.81	84.69	84.16	Submerged
O_0130_327	81.85	0.45	82.3	83.82	83.13	Submerged
O_0130_324	78.11	0.45	78.56	79.07	78.76	Submerged
O_0130_400033	105.7	0.45	106.15	106.89	106.89	Submerged
O_0130_400023	0	0	0	85.19	84.86	Submerged
O_0130_331	81.56	1.8	83.36	83.17	82.86	Partially Submerged
O_0130_328	80.7	0.9	81.6	82.86	82.89	Submerged
O_0130_329	81.59	0.55	82.14	82.9	82.84	Submerged

The results presented in Table 5.12 indicate that out of all the outfalls discharging to open watercourses where the hydraulic modelling is available, 80% are estimated to be submerged during the 5 year storm event, with the balance partially submerged.

As the information in Table 5.12 indicates, water surface elevations are currently established for only fifteen (15) of the one hundred and seventy-five (175 +/-) outfalls which discharge to open watercourses. As such, additional information would be required in order to fully assess the potential for submerged conditions at all of the storm sewer outfalls within the study area.

5.5.4 Potential Influence of Future Land Use

Current land use conditions within the study area are reflected on Figure B of the Town of Oakville Official Plan. The land use conditions are primarily urban residential, interspersed with some parkland and commercial lands, and employment lands along the north limit adjacent to the QEW. There are currently no locations for Greenfield or infill development within the study area, hence all future development within the study area would be anticipated to consist of redevelopment and/or intensification of the current urban form.

Areas of future redevelopment and growth have been identified within the study area, and provided on Schedule A1 of the Liveable Oakville Plan. The locations, presented on Figure 5.2, encompass existing areas of employment land use, mixed land use, residential land use, and parkland.

The nature of the redevelopment/intensification within the growth areas and the corresponding land use conditions have not been defined within the Liveable Oakville Plan. Although a detailed analysis of the impacts of the future land use conditions cannot be completed, in the absence of this information, a preliminary characterization of the potential impacts of the future land use condition, with respect to the conveyance capacity of the minor system, has been completed by comparing the location of the growth areas with the results of the preliminary capacity assessment and thereby determining whether or not any of the identified growth areas could contribute to storm sewers with potential capacity constraints, as determined from the preliminary assessment.

The results of the preliminary capacity assessment have indicated some potential capacity constraints within the receiving minor system under the existing land use conditions (i.e. capacity scores of 3, 4, or 5), hence any increase in the impervious cover within the contributing drainage areas, as a result of the intensification and redevelopment, would be anticipated to further exacerbate any current surcharge conditions within the storm sewers. As the details of the redevelopment become established, detailed hydrologic and hydraulic analyses will be required in order to determine any impacts of the proposed redevelopment/intensification to the receiving Municipal major and minor system, and to establish a mitigation strategy accordingly. These analyses would most appropriately be completed in support of the planning for the redevelopment/intensification of these areas.

It is recognized that future development and redevelopment within the study area may also consist of redevelopment of individual lots to increase the size of building structures (i.e. houses, stores, etc.). These types of redevelopment could increase the impervious coverage of the lands draining to the minor system, and further exacerbate any surcharge condition within the minor system. While the location and form of these redevelopment areas is unknown at the present time, more detailed analyses will be required at the time of redevelopment to verify any impacts of the proposed redevelopment to the receiving Municipal major and minor system, and to establish a mitigation strategy accordingly.

5.5.5 Potential Influence of Climate Change

In recent years, municipalities across the Province have recognized climate change as an emerging issue related to the design of municipal infrastructure to manage flood risk to public and private properties. These impacts have been demonstrated by formative storm events within recent years (i.e. Peterborough 2004, Mississauga 2009, Hamilton 2009, Binbrook 2012, Toronto 2013, Burlington 2014), as well as the more frequent occurrence of more formative and intense storm events in various Municipalities across the Province which have exceeded the capacity of receiving major and minor systems, particularly those systems within older areas of the Municipality.

While various initiatives have been undertaken at all levels of government to better define the impacts of climate change and provide municipalities and practitioners with clear direction regarding the approaches to manage these impacts, no definitive conclusions have been forthcoming regarding the magnitude of the impacts related to flood risk and mitigation. Notwithstanding, various studies have suggested a general shift to the IDF relationships which are used for the analysis and design of conveyance and stormwater management infrastructure, whereby the frequency of more formative and intense storm events would be anticipated to increase compared to the previous historic trends used to establish the IDF relationships. Studies completed in Cambridge (ref. AMEC 2011) regarding climate change have indicated that storm sewers designed under the historic IDF relationships would, potentially, need to be designed to a 10 year design standard in order to provide capacity for a 5 year storm event under a climate change perspective for the longer duration storm events.

In order to assess the potential influence of Climate Change on the town's storm sewer capacity, the preliminary capacity assessment discussed in Section 5.3 has been modified to apply the current IDF relationship for the 10 year event, as provided in the Town of Oakville Engineering Standards. The impacts to the storm sewer capacity have been assessed using the criteria provided in Section 5.3, in order to determine the areas of potentially deficient capacity under a theoretical Climate Change scenario. The results of this assessment are summarized in Tables 5.13 and 5.14, and are presented graphically on Drawing 5.10.

Table 5.13: Length of Storm Sewer Pipe with Flow Capacity Rating (1 to 5) By Network for Climate Change Assessment

Network Area	Total Length of Pipes in Network (m)	Total Length of Pipes with Flow Capacity Rating (m)				
		1 (Adequate)	2	3	4	5 (Inadequate)
1	3344.1	2776.3	0.0	383.6	0.0	184.2
2	2252.7	2240.1	0.0	12.6	0.0	0.0
3	3567.5	3177.1	115.4	74.9	0.0	200.1
4	6375.5	6044.0	107.5	224.1	0.0	0.0
5	1714.2	1428.0	0.0	151.8	91.8	42.5
6	551.7	198.3	3.9	0.0	0.0	349.6
7	848.9	535.0	30.0	204.8	39.0	40.1
8	3942.8	3298.7	329.3	117.0	65.3	132.4
9	3141.7	2182.6	233.0	304.1	94.9	327.1
10	27.4	27.4	0.0	0.0	0.0	0.0
11	976.4	372.6	0.0	175.5	0.0	428.4
12	121.9	61.3	0.0	0.0	0.0	60.5
13	6726.8	5415.0	188.5	561.7	99.1	462.6
14	12589.4	8232.2	260.8	1598.9	138.0	2359.5
15	8378.3	6292.2	41.9	828.6	306.5	909.2
16	344.2	253.4	0.0	54.4	0.0	36.4
17	1361.7	1065.8	0.0	62.9	187.2	45.9
18	3639.6	2410.2	279.6	139.3	174.6	635.8
19	1720.5	917.5	445.2	136.4	70.1	151.3
20	5070.6	4596.3	243.6	0.0	155.4	75.3
21	1422.4	1269.3	88.3	0.0	64.8	0.0
22	377.2	270.0	0.0	55.1	52.1	0.0
23	1617.6	1255.8	0.0	89.1	49.2	223.5
24	2871.8	2310.0	277.5	0.0	284.3	0.0
25	1654.7	962.8	7.8	289.3	160.1	234.7
26	1107.1	605.9	147.9	169.7	79.2	104.4
27	8440.4	6965.0	0.0	226.2	309.1	940.0
28	1001.5	745.8	0.0	67.9	40.4	147.4
29	1449.1	1038.3	0.0	47.0	190.6	173.2
30	5799.7	4885.7	0.0	382.7	80.3	451.0
31	1072.0	870.6	0.0	85.0	76.4	39.9
32	884.8	376.1	67.9	43.2	149.4	248.2
33	2592.3	1877.3	24.8	200.3	42.9	446.9
34	5150.6	4222.9	80.2	56.4	126.9	664.2

Table 5.13: Length of Storm Sewer Pipe with Flow Capacity Rating (1 to 5) By Network for Climate Change Assessment						
Network Area	**Total Length of Pipes in Network (m)**	**Total Length of Pipes with Flow Capacity Rating (m)**				
		1 (Adequate)	**2**	**3**	**4**	**5 (Inadequate)**
35	4121.7	3098.2	179.4	610.0	204.9	29.3
36	3676.9	3141.7	0.0	145.9	263.9	125.4
37	3121.9	2232.0	0.0	23.7	207.5	658.7
38	1066.7	119.5	0.0	158.1	213.6	575.6
39	2966.2	1827.4	99.5	340.7	0.0	698.6
40	897.4	523.7	0.0	66.5	148.6	158.6
41	1081.5	702.2	0.0	80.1	161.1	138.1
42	1523.7	992.1	0.0	274.5	0.0	257.1
43	848.5	763.9	0.0	24.9	0.0	59.7
44	3241.3	2636.9	69.3	188.4	176.9	169.8
45	2998.0	2397.4	0.0	111.2	183.7	305.6
46	5547.1	4780.4	116.3	85.7	279.9	284.7
47	6314.5	5451.8	19.9	193.6	339.8	309.4
48	2696.0	1767.1	0.0	563.7	85.4	279.8
49	4646.6	3069.6	230.2	594.0	522.3	230.5
50	3856.2	2539.3	199.5	303.0	576.2	238.1
51	1793.3	885.3	5.4	439.1	127.7	335.8
52	19213.0	16447.8	134.9	832.2	811.2	987.0
53	6225.8	5832.6	0.0	0.0	77.3	315.9
54	9280.6	6872.5	40.6	358.5	718.3	1290.7
55	4341.8	0.0	3691.9	400.1	249.9	0.0
56	8865.2	0.0	7256.5	270.5	282.3	1055.9
Total	**200461.0**	**145260.9**	**15016.3**	**12807.0**	**8758.3**	**18618.5**

Table 5.14: Percentage of Storm Sewer Pipe with Flow Capacity Rating (1 to 5) By Network for Climate Change Assessment						
Network Area	**Total Length of Pipes in Network (m)**	**Total Percentage of Pipes with Structural Rating (%)**				
		1 (Adequate)	**2**	**3**	**4**	**5 (Inadequate)**
1	3344.1	83.0	0.0	11.5	0.0	5.5
2	2252.7	99.4	0.0	0.6	0.0	0.0
3	3567.5	89.1	3.2	2.1	0.0	5.6
4	6375.5	94.8	1.7	3.5	0.0	0.0
5	1714.2	83.3	0.0	8.9	5.4	2.5
6	551.7	35.9	0.7	0.0	0.0	63.4
7	848.9	63.0	3.5	24.1	4.6	4.7
8	3942.8	83.7	8.4	3.0	1.7	3.4
9	3141.7	69.5	7.4	9.7	3.0	10.4
10	27.4	100.0	0.0	0.0	0.0	0.0
11	976.4	38.2	0.0	18.0	0.0	43.9
12	121.9	50.3	0.0	0.0	0.0	49.7
13	6726.8	80.5	2.8	8.3	1.5	6.9
14	12589.4	65.4	2.1	12.7	1.1	18.7

Table 5.14: Percentage of Storm Sewer Pipe with Flow Capacity Rating (1 to 5) By Network for Climate Change Assessment						
Network Area	**Total Length of Pipes in Network (m)**	**Total Percentage of Pipes with Structural Rating (%)**				
		1 (Adequate)	**2**	**3**	**4**	**5 (Inadequate)**
15	8378.3	75.1	0.5	9.9	3.7	10.9
16	344.2	73.6	0.0	15.8	0.0	10.6
17	1361.7	78.3	0.0	4.6	13.7	3.4
18	3639.6	66.2	7.7	3.8	4.8	17.5
19	1720.5	53.3	25.9	7.9	4.1	8.8
20	5070.6	90.6	4.8	0.0	3.1	1.5
21	1422.4	89.2	6.2	0.0	4.6	0.0
22	377.2	71.6	0.0	14.6	13.8	0.0
23	1617.6	77.6	0.0	5.5	3.0	13.8
24	2871.8	80.4	9.7	0.0	9.9	0.0
25	1654.7	58.2	0.5	17.5	9.7	14.2
26	1107.1	54.7	13.4	15.3	7.2	9.4
27	8440.4	82.5	0.0	2.7	3.7	11.1
28	1001.5	74.5	0.0	6.8	4.0	14.7
29	1449.1	71.7	0.0	3.2	13.2	12.0
30	5799.7	84.2	0.0	6.6	1.4	7.8
31	1072.0	81.2	0.0	7.9	7.1	3.7
32	884.8	42.5	7.7	4.9	16.9	28.1
33	2592.3	72.4	1.0	7.7	1.7	17.2
34	5150.6	82.0	1.6	1.1	2.5	12.9
35	4121.7	75.2	4.4	14.8	5.0	0.7
36	3676.9	85.4	0.0	4.0	7.2	3.4
37	3121.9	71.5	0.0	0.8	6.6	21.1
38	1066.7	11.2	0.0	14.8	20.0	54.0
39	2966.2	61.6	3.4	11.5	0.0	23.6
40	897.4	58.4	0.0	7.4	16.6	17.7
41	1081.5	64.9	0.0	7.4	14.9	12.8
42	1523.7	65.1	0.0	18.0	0.0	16.9
43	848.5	90.0	0.0	2.9	0.0	7.0
44	3241.3	81.4	2.1	5.8	5.5	5.2
45	2998.0	80.0	0.0	3.7	6.1	10.2
46	5547.1	86.2	2.1	1.5	5.0	5.1
47	6314.5	86.3	0.3	3.1	5.4	4.9
48	2696.0	65.5	0.0	20.9	3.2	10.4
49	4646.6	66.1	5.0	12.8	11.2	5.0
50	3856.2	65.9	5.2	7.9	14.9	6.2
51	1793.3	49.4	0.3	24.5	7.1	18.7
52	19213.0	85.6	0.7	4.3	4.2	5.1
53	6225.8	93.7	0.0	0.0	1.2	5.1
54	9280.6	74.1	0.4	3.9	7.7	13.9
55	4341.8	0.0	85.0	9.2	5.8	0.0
56	8865.2	0.0	81.9	3.1	3.2	11.9
Total	**200461.0**	**72.5**	**7.5**	**6.4**	**4.4**	**9.3**

The results in Table 5.13 have been compared with the results previously presented in Table 5.6 for the capacity assessment under existing conditions, in order to determine the percent change in length of sewer under each capacity score under a Climate Change scenario and thereby characterize the impacts to conveyance capacity under a Climate Change scenario compared to existing conditions. The results of this assessment are summarized in Table 5.15.

Table 5.15: Change in Capacity Rating for Storm Sewers Under a Theoretical Climate Change Scenario Compared to Existing Conditions

Assessment	Total Length (m)	Flow Capacity Rank				
		1	2	3	4	5
Flow Capacity	200461	159695	11992	10887	5182	12705
Climate Change	200461	145261	15016	12807	8758	18619
% Change		**-9**	**25**	**18**	**69**	**47**

As expected, the results in Table 5.15 indicate that, under a Climate Change scenario, the number of pipes with potentially deficient conveyance capacity (i.e. scores of 3, 4, or 5) would be anticipated to increase. This is considered to be consistent with trends and observations from other studies regarding the potential influence of Climate Change on Municipal infrastructure.

As previously noted, the exact or precise influence of Climate Change is not fully understood, and the science of studying and evaluating these impacts, as well as the practice of defining the requirements to manage these impacts, remain in their infancy. Notwithstanding, it is recognized that the current meteorological trends suggest a potential need to further evaluate the potential influence of Climate Change as related to the design of Municipal infrastructure, and to establish feasible and functional management strategies accordingly.

5.5.6 Opportunities to Service Currently Non-Storm Sewered Areas

The minor system within the study area also includes roadways with rural drainage systems (i.e. ditches, swales, and driveway culverts) within areas of existing residential development.

During the course of this Phase of the Storm Sewer Master Plan, town staff has inquired as to opportunities to mitigate drainage issues in these areas. In particular, it was questioned as to whether or not opportunities exist to extend the existing minor system of storm sewers into these areas and to thereby upgrade the existing rural drainage systems with urban minor systems. To this end, the results of the preliminary capacity analysis have been reviewed in combination with the location of these areas with rural drainage systems in order to identify, at a high level, potential capacity constraints which may preclude the possibility of extending the existing minor system into these areas. The locations of these areas with rural drainage systems, are presented on Drawing 5.11, along with the results of the preliminary capacity assessment for the urban minor system. Drainage issues have been identified by town staff in various rurally-serviced areas of the municipality (i.e. West Street, Belvedere, Coronation Park, Maplehurst). The specific drainage issues vary by location, according to the specific conditions of the area. Some previously identified drainage issues within the rurally-serviced areas include the following:

- reduced conveyance capacity and/or standing water within ditches as a result of unapproved alterations to the ditches by members of the public or by utilities companies
- deficient inlet capacity where ditches discharge to storm areas
- collapsed driveway culverts
- frequent or prolonged sump pump discharge to ditches, sometimes resulting from groundwater interception by utilities connection
- alterations to private lot grading
- undersized ditches (i.e. inadequate conveyance capacity)
- ditches on private property, not owned by town, which are altered but not subject to approval
- backwater created by fluctuating water levels as Lake Ontario where ditches outlet to the lake

The information on Drawing 5.11 indicates that multiple urban sewer networks surround the areas with rural drainage systems, hence various locations are available for connecting an urban drainage system within these areas to the existing storm sewer network within the town (subject to detailed grading analyses). The results also indicate various locations and degrees of potential capacity constraints within the potential receiving minor system under current land use conditions, hence the addition of runoff from the currently rurally-serviced areas would be anticipated to further exacerbate any current surcharge conditions within the minor system.

Recognizing that each area with a rural drainage system presents its own unique set of opportunities and constraints, associated with connecting a new urban minor system into the existing minor system, detailed analyses would be required for each area, in order to evaluate each alternative and develop a preferred approach toward extending the limits of the urban drainage system into each area. The opportunities to be considered include “do nothing”, “re-ditching”, connecting to the existing storm sewers, and/or urbanizing the existing rural system. These analyses would necessarily also need to consider requirements to provide a major (overland flow) drainage system within these areas (as possible), requirements for easements and access for maintenance and implementation, as well as any local constraints associated the size and drainage pattern of the existing development area and potential for redevelopment and intensification within the contributing drainage area.

Another consideration relates to the potential impact on water quality as rurally-serviced areas provide informal treatment and urbanizing those drainage systems has the impact of reducing this measure of treatment. As such, each area needs to include a fulsome assessment of all possible opportunities to improve runoff water quality as well, including potential strategic retention of open ditches where appropriate.

A fulsome assessment of each alternative is beyond the scope of this Phase 1 study, and would more appropriately be conducted. As part of Phase 2 of the town’s Stormwater Management Master Plan, at that time a fourth assessment of these impacts and opportunities should be completed in order to establish a preferred solution to mitigate the existing known and identified drainage issues within the rurally-serviced areas. A prioritization for implementation shall likewise be established as part of the Phase 2 study using a scoring system which would apply a weighting to each alternative, according to the benefits gained by each alternative according to the following criteria:

Social

- number of people benefitting from proposed works
- improvements to public safety (i.e. reduced flooding of roadways versus reduced nuisance flooding)

Functional

- reduction in extent of flooding
- reduction in depth of flooding
- feasibility for implementation/requirement for further study/design
- permitting requirement for implementation/need for further consultation
- timelines for implementation

Economic

- study costs
- capital costs
- long-term operations and maintenance

Environmental

- enhancement to water quality
- impact to erosion
- aquatic habitat within receiving system

5.6 Summary of Infrastructure Needs Assessment

The storm sewers within the study area in the Town of Oakville are generally in good condition with respect to physical condition, conveyance capacity, and functionality. Nevertheless, as indicated by the information presented in the preceding sections, it will be necessary for the town to undertake additional investigations and projects in order to comprehensively and accurately address identified deficiencies related to the structural condition and maintenance requirements of the storm sewers, as well as to further evaluate the current and anticipated future requirements (i.e. "as-of-right") of the storm sewers to convey runoff from adjacent properties.

The infrastructure needs related to the structural condition of the minor system and the maintenance requirements are attributable to each individual pipe rather than segments or networks of storm sewers. The locations of the storm sewers requiring immediate attention with respect to the structural condition of the sewer or maintenance requirements to restore functionality have been identified in the preceding sections.

The preliminary analyses of the conveyance capacity for the minor system is similarly of generally good condition, particularly given the vintage of much of the system, with approximately 80 % of the storm sewers complying with current town design standards. Nevertheless, additional more detailed and accurate analyses are considered required in order to verify the conveyance capacity of the minor system, as well as to further evaluate alternatives and opportunities to address any deficiencies which may be identified through the detailed analysis. The conveyance requirements should also consider anticipated future requirements to address changes in land use as well as statistical shifts in the current IDF relationships.

The Town of Oakville has identified various locations requiring frequent maintenance in order to maintain the capacity of the inlets and outlets of the minor system. More permanent solutions to optimize and/or enhance the capture and conveyance capacity of the minor system through enhancements to the inlet and outlet structures are required in order to better ensure the function of the minor system.

6.0 ALTERNATIVE ASSESSMENT

The preceding section has identified various needs related to the structural and functional condition of the existing storm sewers within the study area. A list of alternatives to mitigate these conditions has been developed, based upon industry standard practices, with consideration for the site-specific conditions within the study area as appropriate and to the extent possible. While a fulsome screening of these alternatives for certain needs is beyond the scope of the current Phase of the Storm Sewer Master Plan, the list of alternatives provided herein is intended to be advanced for further consideration as part of the Second Phase of the Storm Sewer Master Plan, integrated with a broader consideration of both the minor and major system, as well as for other complementary considerations of water quality management.

6.1 Structural Condition

The following alternatives are available to address the structural deficiencies within the town's storm sewers, as identified by the survey completed by Aquadata Inc.:

Alternative #1: "Do Nothing"

Alternative #2: Replace damaged storm sewers

Alternative #3: Repair in-situ

Alternative #4: Combinations

The following describes considerations related to each alternative:

- Alternative 1 would result in the continued deterioration of sewers which have been currently identified as requiring immediate or near-term attention. On this basis, this alternative has been screened from further consideration.
- Alternative 2 would address the requirements to mitigate the structurally deficient condition of some of the storm sewers within the study area and has been advanced for further consideration.
- Alternative 3 may address the requirements to mitigate the structurally deficient condition of some of the storm sewers within the study area, however it is possible that the condition of the pipes is such that they have deteriorated to the point that repairs are no longer viable. Nevertheless, this alternative has been advanced for further consideration.
- Alternative 4 would consist of strategic combinations of the above alternatives, whereby repairs would be completed where feasible appropriate and replacement completed for the balance of the pipes. This alternative has been advanced for further consideration.

6.2 Capacity / Hydraulic Performance

The following alternatives have been advanced to address the potentially deficient capacity of the storm sewers within the Town of Oakville:

Alternative #1: "Do Nothing"

Alternative #2: Replace pipes with deficient capacity

Alternative #3: Implement offline storage within existing lands

Alternative #4: Incorporate quantity controls into future development areas

Alternative #5: Implement local diversions to redirect runoff from networks with identified capacity constraints

Alternative #6: Implement source controls and Low Impact Development (LID) Best Management Practices (BMPs)

Alternative #7: Combinations

As noted previously, the capacity assessment completed as part of this Phase of the Storm Sewer Master Plan has applied a simplified approach to identify potential capacity constraints, hence the results of the assessment are considered to be preliminary in nature and insufficient for the purposes of providing clear and integrated direction regarding the preferred approach to address capacity constraints. In this regard, the next study phase will be required to more comprehensively evaluate the areas with deficient capacity and to establish the preferred approach to mitigate with due consideration of the major and minor system in a fully integrated manner. It is anticipated that the preferred solution would consist of combinations of Alternatives 2 through 6 (i.e. Alternative #7 Combinations), with the preferred alternative being established with consideration of the local conditions and constraints specific to each network as well as the opportunities available given the local conditions. In addition, it is recognized by the town that for source controls and LID BMPs to be effective, there needs to be a comprehensive outreach program to the town's residents in order to appropriately engage the public. Without an education plan, the level of short-term uptake is expected to be low, compromising the potential for long term success.

7.0 COST ESTIMATES

Costs for storm sewer system management have been estimated in order to provide a scale of investment for capital works, Operations and Maintenance practices and monitoring of the storm sewer pipes for each storm sewer network area. The replacement cost has been estimated premised on a three times multiplier of the supply cost for concrete storm sewer pipes (as per 2013 pricing list provided by Con Cast Pipe). Maintenance costs have been estimated to be 20% of the total replacement cost, as a one time cost, based on industry rates and monitoring costs for storm sewer pipes have been estimated to be 3$/m length of the storm sewer pipes based on industry standards. The results of the cost estimation assessment have been presented in Appendix H.

Based on the results presented in Appendix H, the total replacement cost for the storm sewer pipes projected/predicted to require replacement due to deteriorated structural condition is estimated to be $3,272,415 for the 5 year and 10 year programs. A previous study conducted by Philips Engineering Ltd. In 2003 estimated the total replacement cost for all existing storm sewers based on the new sewer being the same size and length as existing conditions to be $190,555,542. In addition, the total maintenance cost for storm sewer pipes requiring operation and maintenance is estimated to be $1,016,216 for the 5 year and 10 year programs.

8.0 IMPLEMENTATION AND NEXT STEPS

8.1 Prioritization

The respective storm sewer network areas under this study have been prioritized for storm sewer system management based on the physical condition of the storm sewer pipes which include structural conditions and Operations and Maintenance requirements. Based on the structural scores of the storm sewer pipes, it has been recommended to replace all the storm sewer pipes with a structural score of 5 within the next five years. For storm sewer pipes with a structural score of 4 it has been notionally recommended that a quarter (25%) of these pipes will need to be replaced within the next 5 to 10 years.. The remaining storm sewer pipes have been recommended to be monitored on regular basis (i.e. as per current service standard of 5 to 7 years, or to coincide with planned road works by the town or Region. A similar approach has been recommended to address the operations and maintenance requirements of the storm sewers with all pipes with an O&M score of 5 have been recommended to undergo maintenance within the next 5 years. As noted, 25% of the sewer pipes with an O&M score of 4 have been recommended to undergo maintenance within the next 5 to 10 years and the balance of the storm sewer pipes to be monitored regularly.

8.2 Phasing

Based on the available information for structural and operations and maintenance conditions of the storm sewer pipes, a 3 level phasing plan has been provided which includes requirements within the next 5 years; requirements within the next 5 to 10 years are requirements for the next 10 to 15 years.

8.2.1 5 Year Program

The recommended 5 year plan for each storm sewer network has been presented in Table 8.1. Drawing 8.1 depicts the location of the recommended actions for the next 5 years. 162 storm sewer pipes with a total length of 8505 m have been identified to lack video inspection results and have no structural and O&M score assigned to them and therefore are recommended to be examined/assessed within the next 1 to 2 years. Based upon the current results, 22 storm sewer pipes with a total length of 1418 m have been identified for replacement due to deteriorated structural conditions. 112 storm sewer pipes with a total length of 5885 m have been identified to require maintenance. The remaining storm sewer pipes have been recommended to be monitored on annual regular basis. It should be noted that in cases where a storm sewer pipe has been identified to require immediate replacement due to structural condition and immediate maintenance, priority has been given to replacement. However, it is recommended that the 5 year program be finalized based upon the results of the additional CCTV inspection.

The preliminary flow capacity constraints identified as part of this phase of the Storm Sewer Master Plan may be indicative of potential capacity limitations which require more detailed assessment; including integrated major/minor system modelling for verification and therefore it is recommended that detailed flow capacity assessment to be conducted as part of Phase 2 of the town's Drainage Master Plan.

Table 8.1: 5 Year program for Capital Works, Operations and Maintenance practices and Monitoring of Storm Sewer Pipes								
Network	Replacement		Maintenance		To be Surveyed		To be Monitored	
	No. of Pipes	Total Length (m)	No. of Pipes	Total Length (m)	No. of Pipes	Total Length (m)	No. of Pipes	Total Length (m)
1	1	12	0	0	0	0	58	3552
2	0	0	0	0	0	0	42	2370
3	0	0	1	81	0	0	69	3723
4	0	0	0	0	0	0	119	7266
5	0	0	0	0	2	66	33	2401
6	0	0	0	0	0	0	17	671
7	0	0	1	41	0	0	16	1056
8	1	39	2	147	2	152	85	4629
9	0	0	1	68	0	0	60	3430
10	0	0	2	44	0	0	1	51
11	0	0	1	22	3	137	29	1269
12	0	0	0	0	3	69	10	390
13	0	0	8	325	0	0	134	7953
14	1	31	5	245	7	439	245	15597
15	2	202	4	214	2	103	151	8860
16	0	0	0	0	0	0	8	349
17	0	0	0	0	0	0	22	1395
18	1	55	4	161	5	199	82	4487
19	0	0	1	69	3	140	35	2021
20	2	32	2	64	3	125	79	6193
21	0	0	0	0	2	165	23	1558
22	0	0	0	0	2	75	10	505
23	0	0	0	0	0	0	36	1883
24	0	0	1	94	2	140	36	2992
25	0	0	3	142	5	175	58	2907
26	0	0	1	61	4	194	21	1360
27	3	265	3	274	2	197	131	8665
28	0	0	0	0	6	169	46	1811
29	1	30	1	46	0	0	38	1898
30	1	121	0	0	0	0	97	6463
31	0	0	0	0	1	55	24	1334
32	0	0	0	0	7	179	25	1551
33	0	0	5	96	9	404	91	3539
34	0	0	3	213	1	33	79	5300
35	1	10	5	131	7	221	93	4769
36	0	0	4	77	4	241	97	5489
37	0	0	3	127	4	367	58	4086
38	0	0	1	33	0	0	42	2158
39	0	0	4	210	1	4	58	3512
40	0	0	0	0	3	196	26	1446
41	0	0	2	32	0	0	37	1695
42	0	0	2	49	7	448	28	2066
43	0	0	0	0	9	843	28	1561
44	0	0	2	106	1	71	69	3980
45	1	104	2	158	0	0	60	3752

Table 8.1: 5 Year program for Capital Works, Operations and Maintenance practices and Monitoring of Storm Sewer Pipes								
Network	Replacement		Maintenance		To be Surveyed		To be Monitored	
	No. of Pipes	Total Length (m)	No. of Pipes	Total Length (m)	No. of Pipes	Total Length (m)	No. of Pipes	Total Length (m)
46	1	213	0	0	5	400	103	8079
47	0	0	3	94	1	44	122	7794
48	0	0	1	35	1	24	55	3186
49	0	0	10	636	10	540	84	5740
50	0	0	0	0	3	253	63	3946
51	0	0	5	394	0	0	32	1838
52	0	0	6	354	2	83	389	23138
53	1	45	3	201	8	299	153	8081
54	0	0	1	76	10	646	197	12669
55	5	259	1	90	6	317	103	5640
56	0	0	8	675	9	292	231	12969
Grand Total	**22**	**1418**	**112**	**5885**	**162**	**8505**	**4138**	**247023**

8.2.2 10 Year Program

The recommended 10 year plan for each storm sewer network area has been presented in Table 8.2. Drawing 8.2 depicts the location of the recommended actions for the next 5 to 10 years. Under the 10 year program, 100 (25) storm sewer pipes with a total length of 6399 (1600) m have been recommended to be replaced due to deteriorating structural conditions. 130 (33) storm sewer pipes with a total length of 7646 (1912) m have been identified to require maintenance. The remaining storm sewer pipes have been recommended to be monitored on an annual basis. It should be noted that in cases where a storm sewer pipe has been identified to require replacement due to structural condition and maintenance, priority has been given to replacement. The 10 year plan should be updated as appropriate based upon the findings of the additional CCTV inspection noted in the previous section.

[Note: Values presented in brackets above represent the values of replacement and repair of only 25% of the storm sewers with a structural or operation and maintenance grade of 4 as opposed to replacement and repair of all storm sewers with similar conditions.]

Table 8.2: 10 Year program for Capital Works, Operation and Maintenance practices and Monitoring on Storm Sewer Pipes

Network	Replacement		Maintenance		To be Monitored	
	No. of Pipes	Total Length (m)	No. of Pipes	Total Length (m)	No. of Pipes	Total Length (m)
1	1 (0.25)	84 (21)	0 (0)	0 (0)	58 (58)	3480 (3480)
2	1 (0.25)	104 (26)	0 (0)	0 (0)	41 (41)	2266 (2266)
3	0 (0)	0 (0)	1 (0.25)	38 (9.5)	69 (69.5)	3766 (3785)
4	1 (0.25)	95 (23.75)	0 (0)	0 (0)	118 (118)	7171 (7171)
5	0 (0)	0 (0)	2 (0.5)	137 (34.25)	31 (32)	2264 (2332.5)
6	1 (0.25)	40 (10)	1 (0.25)	34 (8.5)	15 (15.5)	597 (614)
7	0 (0)	0 (0)	2 (0.5)	129 (32.25)	15 (16)	968 (1032.5)
8	2 (0.5)	108 (27)	4 (1)	205 (51.25)	82 (84)	4502 (4604.5)
9	0 (0)	0 (0)	1 (0.25)	74 (18.5)	60 (60.5)	3424 (3461)
10	0 (0)	0 (0)	0 (0)	0 (0)	3 (3)	95 (95)
11	0 (0)	0 (0)	0 (0)	0 (0)	30 (30)	1291 (1291)
12	0 (0)	0 (0)	0 (0)	0 (0)	10 (10)	390 (390)
13	1 (0.25)	23 (5.75)	7 (1.75)	525 (131.25)	134 (137.5)	7730 (7992.5)
14	2 (0.5)	93 (23.25)	4 (1)	214 (53.5)	245 (247)	15566 (15673)
15	3 (0.75)	197 (49.25)	3 (0.75)	145 (36.25)	151 (152.5)	8934 (9006.5)
16	0 (0)	0 (0)	0 (0)	0 (0)	8 (8)	349 (349)
17	2 (0.5)	123 (30.75)	0 (0)	0 (0)	20 (20)	1272 (1272)
18	2 (0.5)	116 (29)	2 (0.5)	143 (35.75)	83 (84)	4444 (4515.5)
19	2 (0.5)	160 (40)	1 (0.25)	61 (15.25)	33 (33.5)	1869 (1899.5)
20	3 (0.75)	238 (59.5)	4 (1)	323 (80.75)	76 (78)	5728 (5889.5)
21	2 (0.5)	74 (18.5)	0 (0)	0 (0)	21 (21)	1484 (1484)
22	0 (0)	0 (0)	0 (0)	0 (0)	10 (10)	505 (505)
23	0 (0)	0 (0)	0 (0)	0 (0)	36 (36)	1883 (1883)
24	1 (0.25)	139 (34.75)	1 (0.25)	80 (20)	35 (35.5)	2867 (2907)
25	0 (0)	0 (0)	6 (1.5)	140 (35)	55 (58)	2909 (2979)
26	0 (0)	0 (0)	2 (0.5)	154 (38.5)	20 (21)	1267 (1344)
27	12 (3)	938 (234.5)	3 (0.75)	143 (35.75)	122 (123.5)	8123 (8194.5)
28	0 (0)	0 (0)	4 (1)	267 (66.75)	42 (44)	1544 (1677.5)
29	1 (0.25)	88 (22)	1 (0.25)	64 (16)	38 (38.5)	1822 (1854)
30	3 (0.75)	194 (48.5)	3 (0.75)	97 (24.25)	92 (93.5)	6293 (6341.5)
31	1 (0.25)	86 (21.5)	1 (0.25)	34 (8.5)	22 (22.5)	1214 (1231)
32	1 (0.25)	87 (21.75)	1 (0.25)	67 (16.75)	23 (23.5)	1397 (1430.5)
33	3 (0.75)	71 (17.75)	5 (1.25)	190 (47.5)	88 (90.5)	3374 (3469)
34	2 (0.5)	89 (22.25)	0 (0)	0 (0)	80 (80)	5424 (5424)
35	1 (0.25)	22 (5.5)	5 (1.25)	166 (41.5)	93 (95.5)	4722 (4805)
36	1 (0.25)	95 (23.75)	6 (1.5)	426 (106.5)	94 (97)	5045 (5258)
37	1 (0.25)	74 (18.5)	2 (0.5)	66 (16.5)	58 (59)	4073 (4106)
38	1 (0.25)	36 (9)	2 (0.5)	59 (14.75)	40 (41)	2096 (2125.5)
39	2 (0.5)	29 (7.25)	7 (1.75)	448 (112)	53 (56.5)	3245 (3469)
40	0 (0)	0 (0)	1 (0.25)	49 (12.25)	25 (25.5)	1397 (1421.5)
41	1 (0.25)	78 (19.5)	2 (0.5)	46 (11.5)	36 (37)	1603 (1626)
42	0 (0)	0 (0)	0 (0)	0 (0)	30 (30)	2115 (2115)
43	0 (0)	0 (0)	0 (0)	0 (0)	28 (28)	1561 (1561)
44	2 (0.5)	42 (10.5)	2 (0.5)	168 (42)	67 (68)	3876 (3960)

Table 8.2: 10 Year program for Capital Works, Operation and Maintenance practices and Monitoring on Storm Sewer Pipes						
Network	**Replacement**		**Maintenance**		**To be Monitored**	
	No. of Pipes	**Total Length (m)**	**No. of Pipes**	**Total Length (m)**	**No. of Pipes**	**Total Length (m)**
45	0 (0)	0 (0)	0 (0)	0 (0)	63 (63)	4014 (4014)
46	3 (0.75)	349 (87.25)	5 (1.25)	420 (105)	96 (98.5)	7523 (7733)
47	1 (0.25)	113 (28.25)	9 (2.25)	802 (200.5)	115 (119.5)	6973 (7374)
48	0 (0)	0 (0)	1 (0.25)	56 (14)	55 (55.5)	3165 (3193)
49	0 (0)	0 (0)	4 (1)	378 (94.5)	90 (92)	5998 (6187)
50	1 (0.25)	89 (22.25)	3 (0.75)	188 (47)	59 (60.5)	3669 (3763)
51	0 (0)	0 (0)	2 (0.5)	116 (29)	35 (36)	2116 (2174)
52	5 (1.25)	287 (71.75)	7 (1.75)	330 (82.5)	383 (386.5)	22875 (23040)
53	9 (2.25)	430 (107.5)	2 (0.5)	137 (34.25)	146 (147)	7760 (7828.5)
54	2 (0.5)	114 (28.5)	6 (1.5)	277 (69.25)	190 (193)	12354 (12492.5)
55	17 (4.25)	1139 (284.75)	2 (0.5)	64 (16)	90 (91)	4786 (4818)
56	6 (1.5)	355 (88.75)	3 (0.75)	186 (46.5)	230 (231.5)	13103 (13196)
Grand Total	100 (25)	6399 (1599.75)	130 (32.5)	7646 (1911.5)	4042 (4107)	240281 (244104)

*Values in brackets represent replacement and repair of only 25% of the storm sewers with a structural or operation and maintenance grade of 4, as opposed to replacement and repair of all storm sewers with similar conditions.

8.2.3 15 Year Program

For the 15 year program, it is proposed to conduct CCTV review and based on the results of this assessment, replace the remaining storm sewer pipes with a structural grade of 4. Additionally, the remaining storm sewer pipes with an Operation and Maintenance score of 4 are proposed to undergo maintenance based on the CCTV review conclusions.

8.3 Requirements for Future Studies

This report summarizes the findings of Phase 1 of the multi-phase Storm Sewer Master Plan within the Town of Oakville. The information presented in the foregoing sections has summarized the preliminary infrastructure needs as identified based upon the detailed review and analysis of the background information provided, as well as supplemental analyses to identify anticipated capacity constraints within the existing storm sewer network. As part of the overall Storm Sewer Master Plan, additional phases of study and investigation are to be completed, in order to further assess the physical and functional condition of the town's conveyance system, evaluate alternatives for remediation, identify preferred solutions, and develop an approach toward implementation. It is the intent of the overall Storm Sewer Master Plan to build upon the information and findings presented in the preceding Phases, and to further refine the analyses as appropriate.

Phase 2 of the Storm Sewer Master Plan is proposed to involve more detailed analytical assessment of the town's drainage system including the major overland system. As part of this phase of study, it is recommended that a detailed review of the ZOOM™ camera survey and supplemental CCTV survey be completed in order to assess the structural condition of the pipes identified as having a high priority for repair/replacement (i.e. structural scores 4 or 5), and to determine the most appropriate approach to address these conditions (i.e. the use of liners, full replacement, etc.). In addition, additional survey information should be collected at the maintenance hole structures and within the minor system to fill the gaps in the current database and develop a complete inventory of the town's minor system.

As part of Phase 2, it is further recommended that detailed analyses be conducted to verify the locations and extent of the anticipated capacity constraints within the town's minor system. These analyses should consider numerical techniques to account for the influence of tailwater conditions within the receiving watercourses and/or the stormwater management facilities within the town, and should also include analyses for the capacity of the major system to assess the performance under runoff for storm events up to the 100 year as related to impacts within the Municipal right-of-way and off of private property, and propose mitigation strategies accordingly.

The recent major storm events in Toronto (July 8, 2013) and Burlington (August 4, 2014) further highlight the need for the town to proactively consider climate change stresses on its drainage networks and where feasible and practical, build in resiliency and capacity.

These analyses for Phase 2 should consider the influence of Climate Change and shifting meteorological trends related to the design of drainage and stormwater management infrastructure. The analyses should consider the flow data collected as part of the monitoring program conducted under this Phase 1 assessment, in order to calibrate the simulated runoff response to observed conditions (ref. Appendix 'G').

Other emerging stormwater management practices which could be considered through the Phase 2 of the Storm Sewer Master Plan include:

- Foundation drainage management practices
- Water quality retrofits
- Influence of Endangered Species Act
- Influence of Species at Risk Act
- Need for and form of Regional Storm controls
- Intensification (increased lot coverage, severances and infills) in residential neighbourhoods particularly those with rural drainage networks (ref. Appendix 'F')
- Remnant (non-regulated) channels
- Updated floodline mapping
- Development Charges for stormwater systems (erosion management in creeks)

The town may also wish to consider a risk-based vulnerability assessment (similar to the PIEVC protocol ref. Engineers Canada v. VA-10, May 2012) to determine which systems are at greatest risk and where the priorities are as related to future action to address the influence of climate change on the drainage networks across the town.

8.4 Policies, By-laws, Guidelines, Emerging Directions

The town's current Policies, By-Laws, and Guidelines related to stormwater and environmental protection/management have been reviewed. In addition, various emerging directions in the stormwater management field have been identified for consideration as part of the ultimate Stormwater Management Master Plan for the town. Regardless, any revisions brought forward by the town must comply with current Provincial policies and regulations, and should also build upon the current practices within the industry as applicable to the Town of Oakville. The following provides an overview of current regulatory requirements and practices within the industry, for consideration in the future phases of the Stormwater Management Master Plan.

a) Integrated Water Quality Management Programs

Municipalities are evaluating the best approach to manage the impacts from urbanization on receiving streams, rivers, and lakes. By considering both existing and future development impacts holistically, municipalities can more effectively establish integrated solutions which take into account multiple strategies including: new greenfield facilities, retrofits of existing stormwater management facilities, and storm sewer outlets, as well as LID BMPs (for both greenfield and existing development).

- These integrated systems establish strategic locations for constructing end-of-pipe facilities (i.e. wetlands, wet ponds, hybrids) to provide stormwater quality treatment for existing untreated urban areas in lieu of requiring on-site stormwater quality control for each future infill and redevelopment area.
- The preferred locations are typically within existing dry pond facilities, within floodplains adjacent to watercourses (preferably between the storm sewer outfall and the receiving watercourse), or on publicly-owned open spaces with adjacent storm sewers which afford the most efficient and economical locations for implementing end-of-pipe stormwater quality management facilities.
- Size of area treated by retrofits within an existing development area often exceeds total area of future development requiring stormwater quality control.
    - Smaller size of facilities is required in order to achieve equivalent average annual TSS removal as would be achieved through implementation of individual on-site stormwater quality control for future infill and intensification areas.
    - Improves overall stormwater quality for more frequent events.
- Reduces construction, and operations and maintenance costs compared to multiple on-site facilities.
- Forms the basis for establishing a cash-in-lieu of on-site stormwater management program for future development.
- Provides an opportunity to evaluate options to “go beyond”
    - Pilot studies to implement at source (lot-level) retrofits within existing neighbourhoods.
    - Stormwater quality performance of rural drainage systems needs to be inherently considered.

b) Endangered Species Act (ESA)

- Administered and enforced by the Ontario Ministry of Natural Resources and Forestry (MNRF) to protect and provide management guidance for selected terrestrial wildlife and vegetation, and aquatic species.
- The list of endangered species is continually updated (new species added to the list generally every 1 – 2 years); the “need” and form of mitigation thus changes with time.
- Presence of terrestrial species (e.g. butternut, bobolink, barn swallow) influences the planning of stormwater management infrastructure (siting).

- Presence of aquatic species (e.g. redside dace) affects form of stormwater infrastructure and associated design criteria/function.
- Level of guidance and acceptable practices to manage/mitigate impacts varies by species; MNRF staff and practitioners alike are often required to determine acceptable mitigation/management practices in the absence of clear direction from the Province.
- MNRF preference: "Avoidance First", however this is recognized as not always feasible.
- The focus in practice is on protecting "strongholds" with high densities of endangered species.
- Other potentially acceptable mitigation/management practices include:
  - Habitat recreation (applicable to terrestrial fauna)
  - Specialized infrastructure to mitigate specific impacts (i.e. thermal mitigation for stormwater management facilities to protect redside dace)
- Preferably, management strategies would be established as part of holistically-based higher-level studies (i.e. Subwatershed Studies) in consultation with MNRF.
- By way of example, thermal enrichment of stormwater runoff from urbanization areas can negatively impact resident species in cold or cool water environments; thermal impact modelling is complex and rife with uncertainties, hence the trend is towards the broad-based application of numerous mitigation techniques.
- In some jurisdictions, MNRF has been recommending deeper end-of-pipe facilities (i.e. wet ponds with a minimum 3 m permanent pool depth) to provide thermal mitigation for redside dace habitat; MNRF and MOECC currently reviewing the feasibility with respect to current stormwater quality standards for province of Ontario.

c) Water Opportunities Act

- Released by the Ministry of the Environment (now MOECC) in 2010.
- Confers upon the MOECC the authority to require municipalities and other water service providers to prepare Water Sustainability Plans.
- Regulations outlining specific requirements for a Water Sustainability Plan are being developed (none have been issued by the Province to-date); generally required that Municipalities work more closely with Conservation Authorities.
- The Town of Oakville participated in a pilot study in 2011/2012 to determine the best approach to water sustainability planning, along with key opportunities and issues.
- Some of the issues related to development of a Water Sustainability Plan included:
  - Overlap and gaps among water-based Public Services and providers (i.e. Town, Region, Conservation Authority).
  - Lack of funding and prioritization of stewardship/education programs.
  - Lack of coordination among monitoring programs (i.e. information collected, monitoring locations, information exchange, equipment and methods applied).
  - Adequacy of operation and maintenance practices (i.e. funding/financing, coordination and integration of infrastructure maintenance, training, aging infrastructure, frequency).
  - Integration with Land Use Planning
  - Integration with local and Provincial design standards
  - Coordinated Emergency planning
  - Compliance and enforcement of environmental protection practices

d) Source Water Protection

- Source Water Protection Plans are developed by Conservation Authorities and regional municipalities in accordance with the MOECC Clean Water Act to determine the best ways to protect the quality and quantity of Public drinking water sources within watersheds at risk.
- A three-tiered approach is applied to assess the threats to the quality and quantity of drinking water within a system; the level of study applied to a system depends upon the types and form of threat to the drinking water supply as determined by the preceding levels of study.
- The analyses completed for these studies focuses on water budgets with a particular emphasis on impacts to the groundwater.
- Emerging considerations though for source water protection relate to the potential to protect aquifers which are used privately (i.e. rural residential wells); this may in the future affect parts of rural Oakville.

e) Regional Storm Regulatory Controls

- As development areas continue to expand, hydrologic changes affecting the timing and volume of runoff have begun to show potential impacts on regulatory flood flows, having the potential to increase off-site (downstream) flood risk.
- Some Conservation Authorities and Municipalities have thus instituted the requirement for quantity controls for future development, beyond the conventional 100 year standard.
- Providing Regional Storm controls conflicts with current Provincial Standards for defining the Regulatory Limit; Conservation Authorities remain in dialogue with the Province to resolve this conflict.
- Regional Storm flood controls can consist of:
  - Offline storage within end-of-pipe facilities.
  - Online storage within designated watercourse blocks.
  - Diversions.
  - Off-site hydraulic improvements or flood proofing.
  - Combinations.
- Preferred alternatives are generally established as part of Watershed/Subwatershed Studies or Master Drainage Plans.
- Considerations for selecting preferred alternative for Regional Storm Control:
  - Land area required for implementation versus land area available.
  - Flood risk/flood potential to adjacent private properties and public infrastructure (i.e. roads).
  - Impacts to terrestrial and aquatic systems resulting from inundation (i.e. duration and extent of flooding within wetlands, frequency of flooding within floodplain, impacts to geomorphic stability, impacts to vegetation and/or wildlife, fish passage).
  - Type of structure and size of opening required to provide Regional Storm control.
  - Operations and maintenance requirements (potential for obstruction?).
  - Permitting and approval requirements (LRIA? Applicable Inflow Design Flood?).
  - Opportunities to integrate with other infrastructure (i.e. roadway crossings).

f) Other

- Drainage Requirements for Redevelopment and Infill Development (ref. Appendix F):
  - Increases impervious coverage on small areas (i.e. larger home footprint, severances, infills).
  - Individually, the impacts of these developments to the overall system (i.e. sewershed, subwatershed) are nominal, however, when the impacts of these types of development are considered in their entirety, the cumulative impacts can be significant.
  - The location and type of these developments are difficult to predict and can be complex to assess cumulatively or holistically as part of a higher level studies (i.e. Master Plans); planning applications are typically submitted as individual site plans.
  - The impacts relate to local lot grading and drainage, increase in peak, volume, and duration of surface runoff, as well as increased foundation drainage due to larger and deeper home footprint.
  - Holistic or centralized management strategies are best established as part of detailed neighbourhood studies through Class EA's.
  - In the absence of comprehensive investigations it is important to encourage a level of responsibility on the individual landowner through effective source controls.
  - What management strategies are appropriate/acceptable to mitigate impacts?

g) Overland Flow Routes

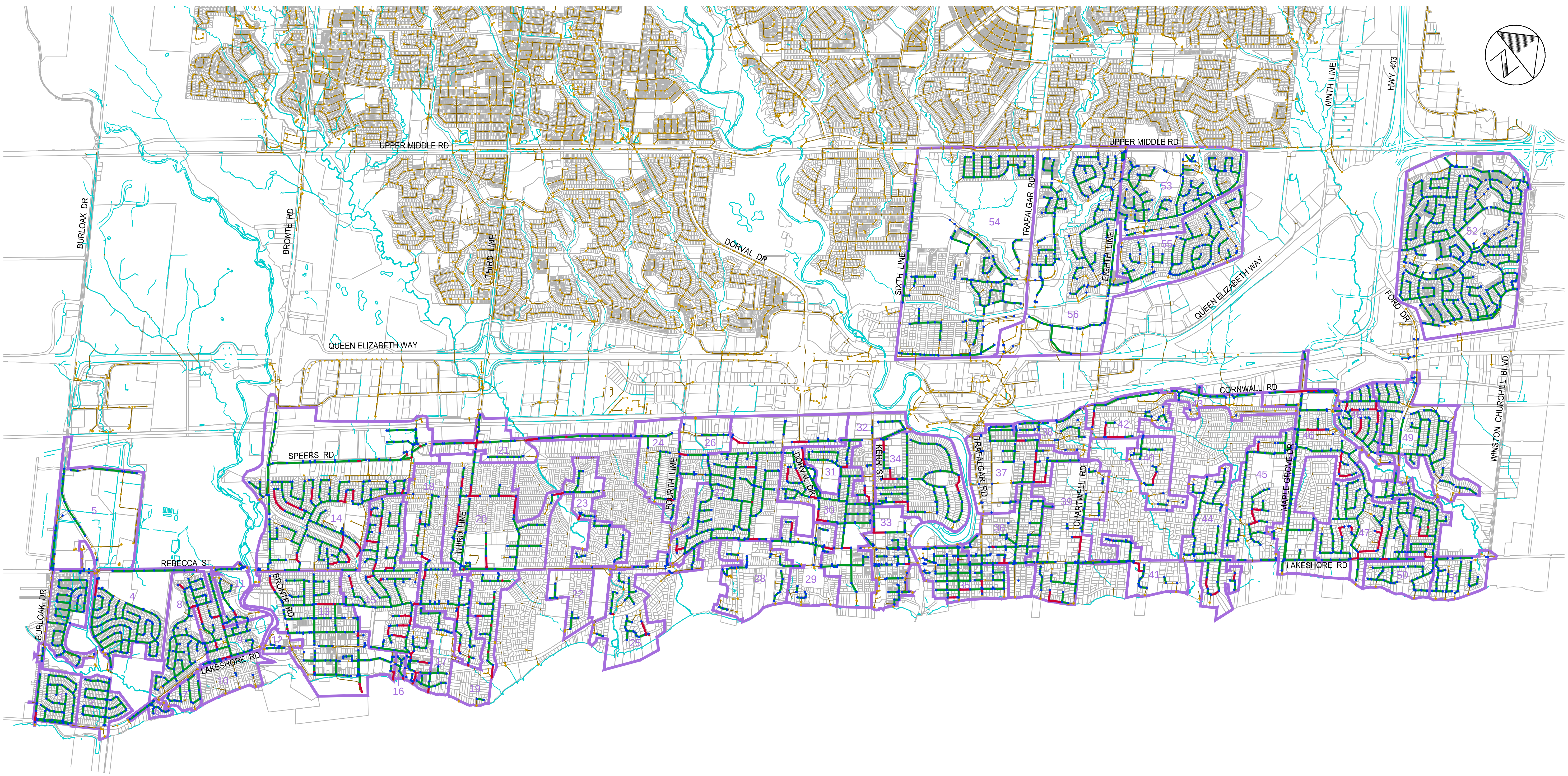
- Recent major storms in close proximity to Oakville [July 2009 (Mississauga/Hamilton), July 2013 (Toronto), August 2014 (Burlington)] demonstrate the need to determine the performance of the overland system (major network) and identify how best to build resiliency and capacity into this important functional component of the town's drainage infrastructure.
- Rights-of-way in older sections of Oakville predate current design standards for providing positively graded overland flow routes to convey runoff during intense storm events; this contributes to flooding on private properties.
- Requires a review of various Municipal Engineering Standards (i.e. road design standards, grading, etc.) and possibly updates to various standards to address general and locally specific problem areas.

h) Private Drainage System

- Issue relates to drainage infrastructure on private properties which needs to function (and be maintained) to properly service an area (i.e. more than the local lot).
- Oakville is considering pursuing a by-law, similar to Burlington whereby if drainage infrastructure is located on private lands it needs to be maintained by the private landowner and kept in good working condition.

i) Remnant (Unregulated) Channels

- The Town of Oakville has a number of open water features which are remnants of former tributaries to area creeks which are not regulated watercourses.
- These features tend to drain/serve several private properties and can also receive runoff from public lands (i.e. roads).
- Issues arise when local landowners modify the ‘natural’ capacity of these features, or develop their lots placing themselves or others at risk of flooding.
- The town is working to address these situations through risk-based studies and directives to being these systems into some level of public control to better manage risk potential.



LEGEND

- WATERCOURSE
- PROPERTY BOUNDARY
- SEWERSHED BOUNDARY
- 13 SEWERSHED IDENTIFICATION NUMBER
- 2011 OUTFALL
- 2011 MANHOLE
- 2011 STORM SEWER
- 2013 MANHOLE DEFINED
- 2013 MANHOLE INTERPOLATED
- 2013 STORM SEWER DEFINED
- 2013 STORM SEWER INTERPOLATED

Path: P:\Work\111018\Water\dwg\Apr2014\Dwg5-1 DataInventory.dwg

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Plotted: 2014-04-14
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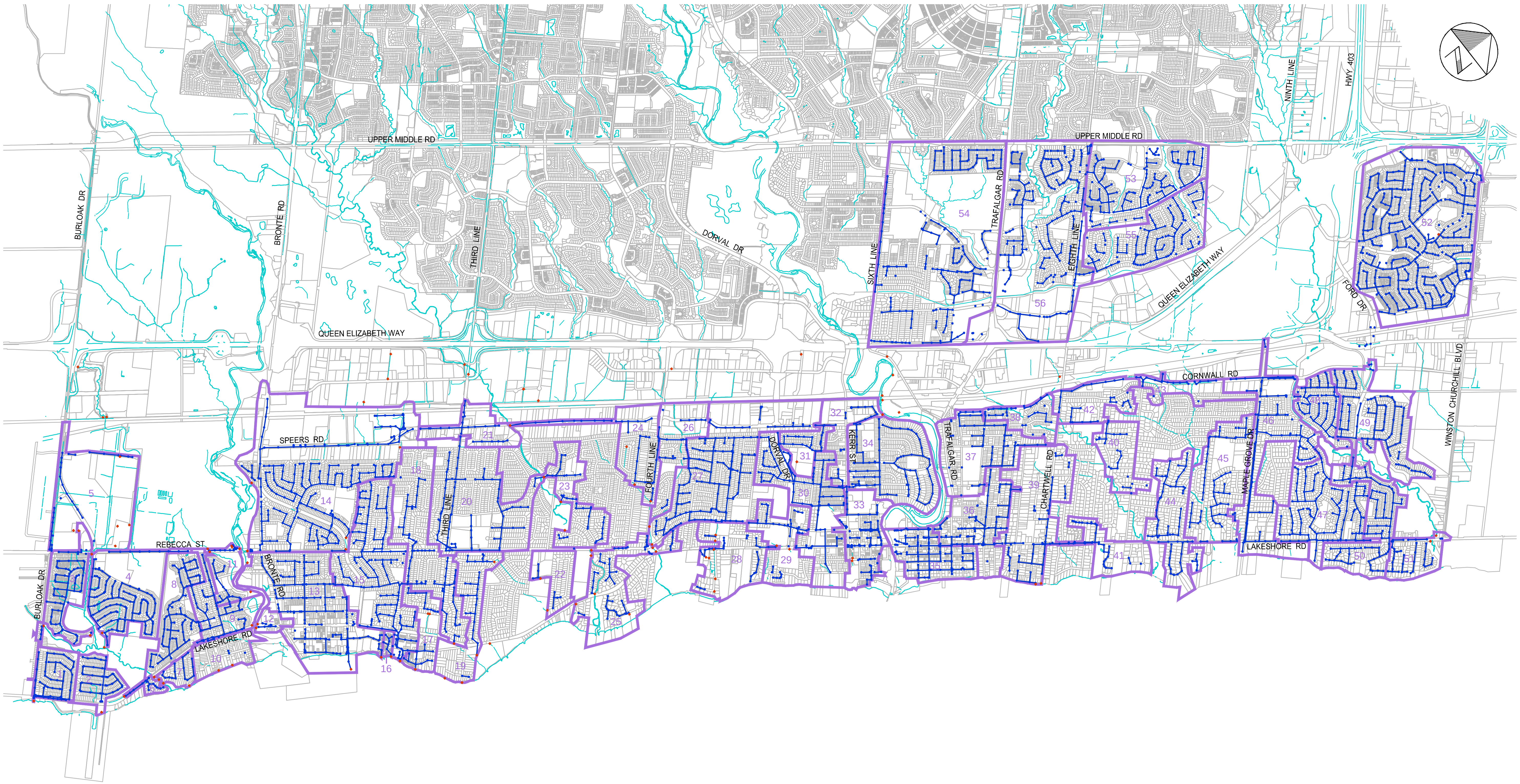
OAKVILLE STORM SEWER MASTER PLAN TOWN OF OAKVILLE	STORM SEWER NETWORK SYSTEM INTERPOLATION 2011 DATA vs 2013 DATA	amec	Scale 1 : 20000 (0 200 400 800) Consultant File No. TP111018 Drawing No. 5.1

SCALE VALID ONLY FOR 24"x36" VERSION



LEGEND

- WATERCOURSE
- PROPERTY BOUNDARY
- SEWERSHED BOUNDARY
- 13 SEWERSHED IDENTIFICATION NUMBER
- STORM SEWER
- MANHOLE
- SURVEYED OUTFALL

SCALE VALID ONLY FOR 24"x36" VERSION

OAKVILLE STORM SEWER MASTER PLAN TOWN OF OAKVILLE	SURVEYED OUTFALLS	amec	Scale 1 : 20000 (0 200 400 800) Consultant File No. TP111018 Drawing No. 5.2

Path: P:\Work\111018\Water\dwg\Apr2014\Dwg5-2 SurveyOutfall.dwg

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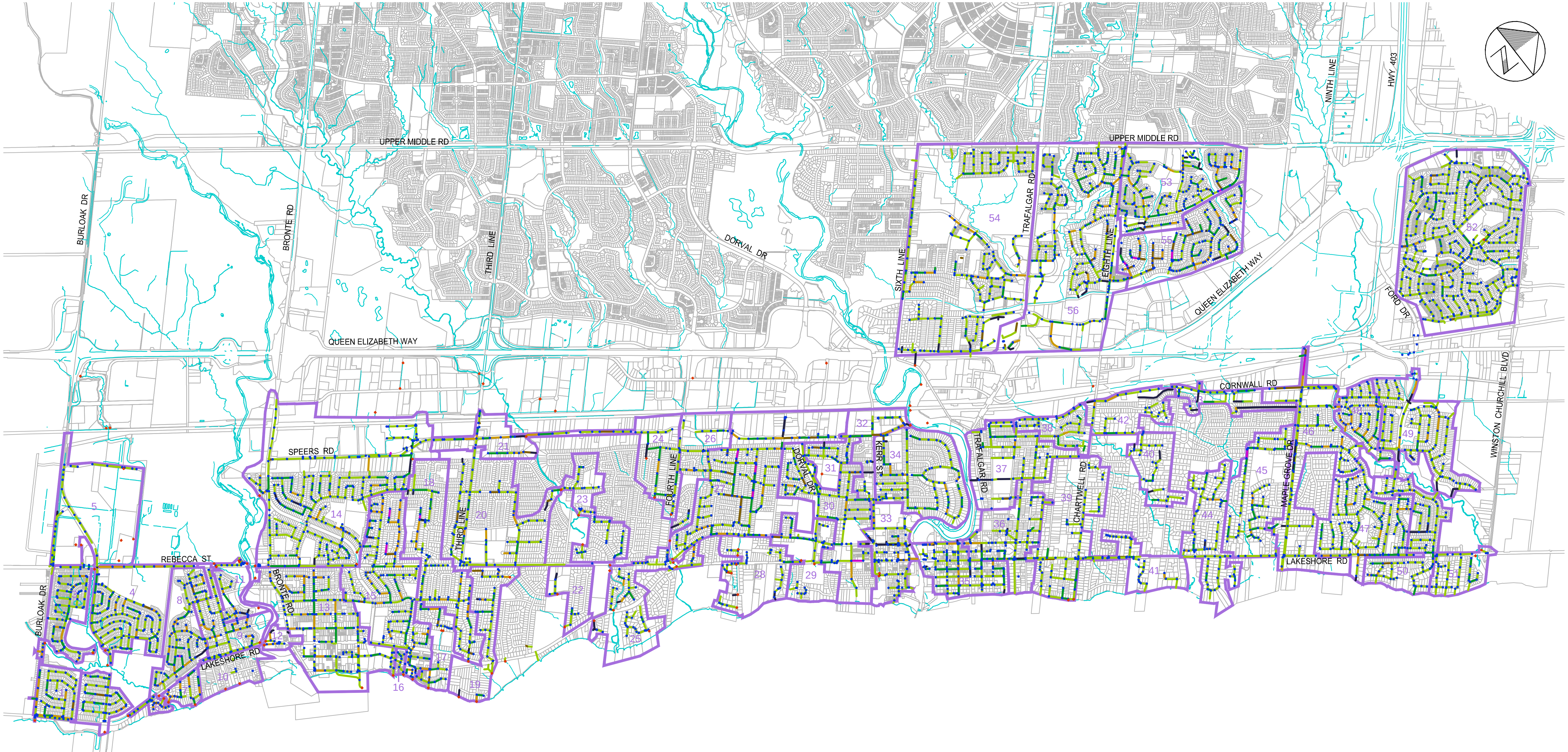

LEGEND

WATERCOURSE
PROPERTY BOUNDARY
SEWERSHED BOUNDARY
13 SEWERSHED IDENTIFICATION NUMBER
MANHOLE
OUTFALL
STRUCTURAL GRADE – 1
STRUCTURAL GRADE – 2
STRUCTURAL GRADE – 3
STRUCTURAL GRADE – 4
STRUCTURAL GRADE – 5
STORM SEWER EXCLUDED

OAKVILLE STORM SEWER MASTER PLAN
TOWN OF OAKVILLE

STRUCTURAL GRADE

amec

SCALE VALID ONLY FOR 24"x36" VERSION

Scale 1 : 20000
0 200 400 800

Consultant File No. TP111018

Drawing No. 5.3

Path: P:\Work\111018\Water\dwg\Apr2014\Dwg5-3 StructuralGrade.dwg

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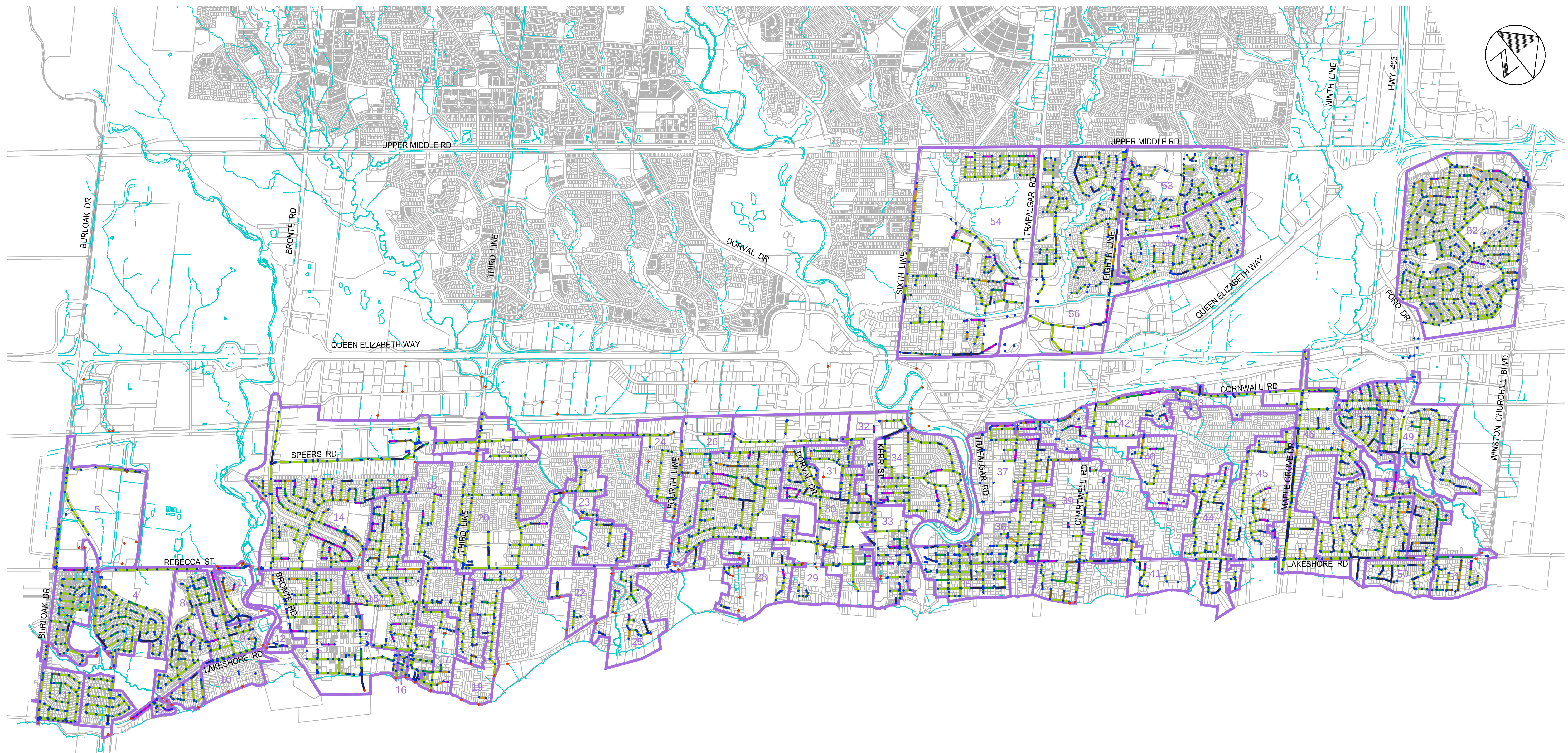

LEGEND

- WATERCOURSE
- PROPERTY BOUNDARY
- SEWERSHED BOUNDARY
- 13 SEWERSHED IDENTIFICATION NUMBER
- MANHOLE
- OUTFALL
- FLOW CAPACITY GRADE – 1
- FLOW CAPACITY GRADE – 2
- FLOW CAPACITY GRADE – 3
- FLOW CAPACITY GRADE – 4
- FLOW CAPACITY GRADE – 5
- STORM SEWER EXCLUDED

SCALE VALID ONLY FOR 24"x36" VERSION

OAKVILLE STORM SEWER MASTER PLAN TOWN OF OAKVILLE	FLOW CAPACITY GRADE	amec	Scale 1 : 20000 (0 200 400 800) Consultant File No. TP111018 Drawing No. 5.4

Path: P:\Work\111018\Water\dwg\Apr2014\Dwg5-4 FlowCapacity.dwg

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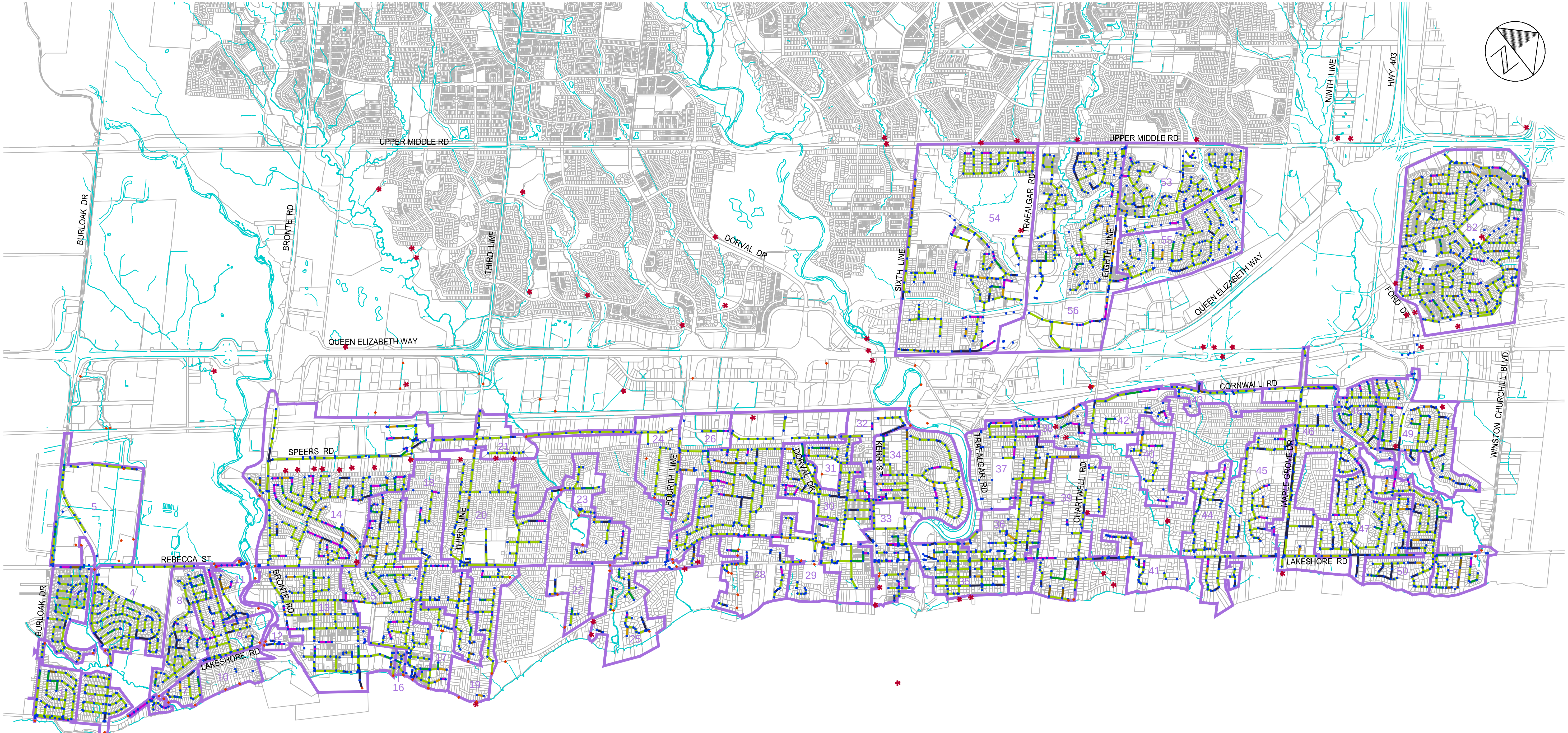

LEGEND

- WATERCOURSE
- PROPERTY BOUNDARY
- SEWERSHED BOUNDARY
- 13 SEWERSHED IDENTIFICATION NUMBER
- MANHOLE
- OUTFALL
- HOTSPOT LOCATION
- FLOW CAPACITY GRADE – 1
- FLOW CAPACITY GRADE – 2
- FLOW CAPACITY GRADE – 3
- FLOW CAPACITY GRADE – 4
- FLOW CAPACITY GRADE – 5
- STORM SEWER EXCLUDED

SCALE VALID ONLY FOR 24"x36" VERSION

OAKVILLE STORM SEWER MASTER PLAN TOWN OF OAKVILLE	HOTSPOT LOCATIONS	amec	Scale 1 : 20000 (0 200 400 800) Consultant File No. TP111018 Drawing No. 5.5

Path: P:\Work\111018\Water\dwg\Apr2014\Dwg5-5 HotSpots.dwg

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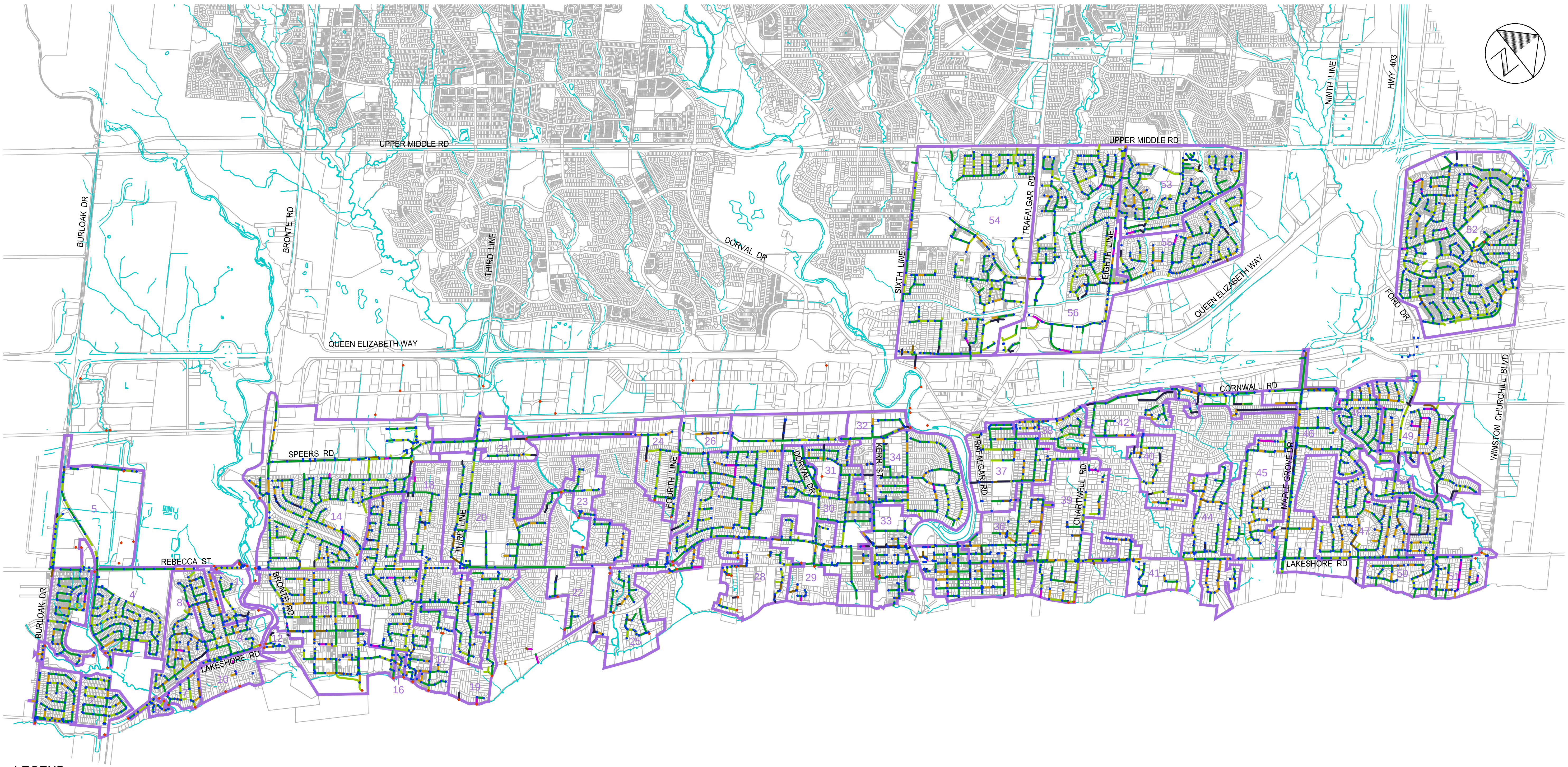
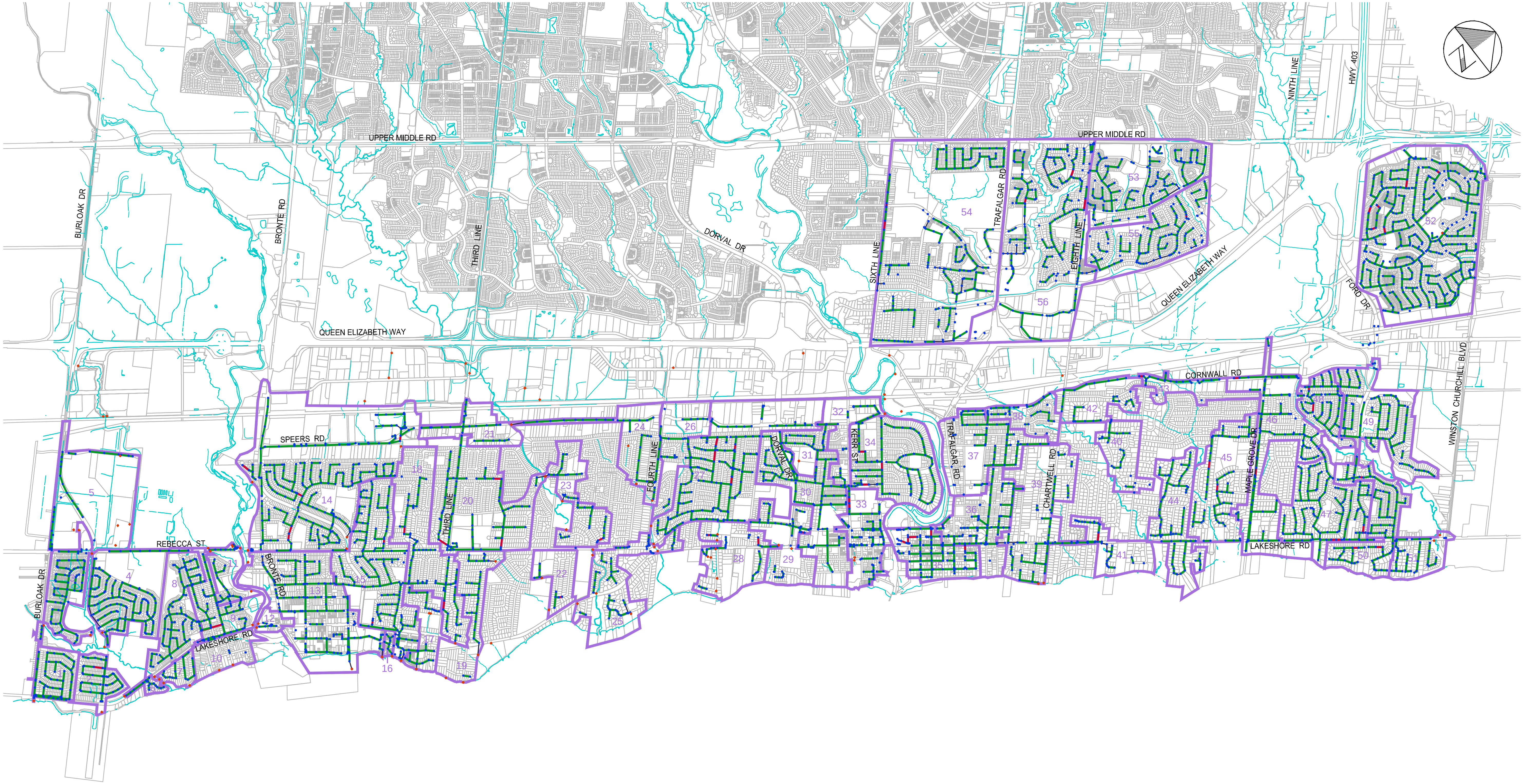


LEGEND

- WATERCOURSE
- PROPERTY BOUNDARY
- SEWERSHED BOUNDARY
- 13 SEWERSHED IDENTIFICATION NUMBER
- MANHOLE
- OUTFALL
- O&M GRADE – 1
- O&M GRADE – 2
- O&M GRADE – 3
- O&M GRADE – 4
- O&M GRADE – 5
- STORM SEWER EXCLUDED

SCALE VALID ONLY FOR 24"x36" VERSION

OAKVILLE STORM SEWER MASTER PLAN TOWN OF OAKVILLE	OPERATION AND MAINTENANCE GRADE	amec	Scale 1 : 20000 (0 200 400 800) Consultant File No. TP111018 Drawing No. 5.6



LEGEND

- WATERCOURSE
- PROPERTY BOUNDARY
- SEWERSHED BOUNDARY
- 13 SEWERSHED IDENTIFICATION NUMBER
- MANHOLE
- OUTFALL
- STORM SEWER DIAMETER ADEQUATE
- STORM SEWER DIAMETER DECREASED
- STORM SEWER DATA INCOMPLETE

SCALE VALID ONLY FOR 24"x36" VERSION

OAKVILLE STORM SEWER MASTER PLAN TOWN OF OAKVILLE	LOCATION OF DECREASED STORM SEWER DIAMETER FROM UPSTREAM TO DOWNSTREAM	amec	Scale 1 : 20000 (0 200 400 800) Consultant File No. TP111018 Figure No. 5.7

Path: P:\Work\111018\Water\dwg\Apr2014\Dwg5-7 DecreasedDia.dwg

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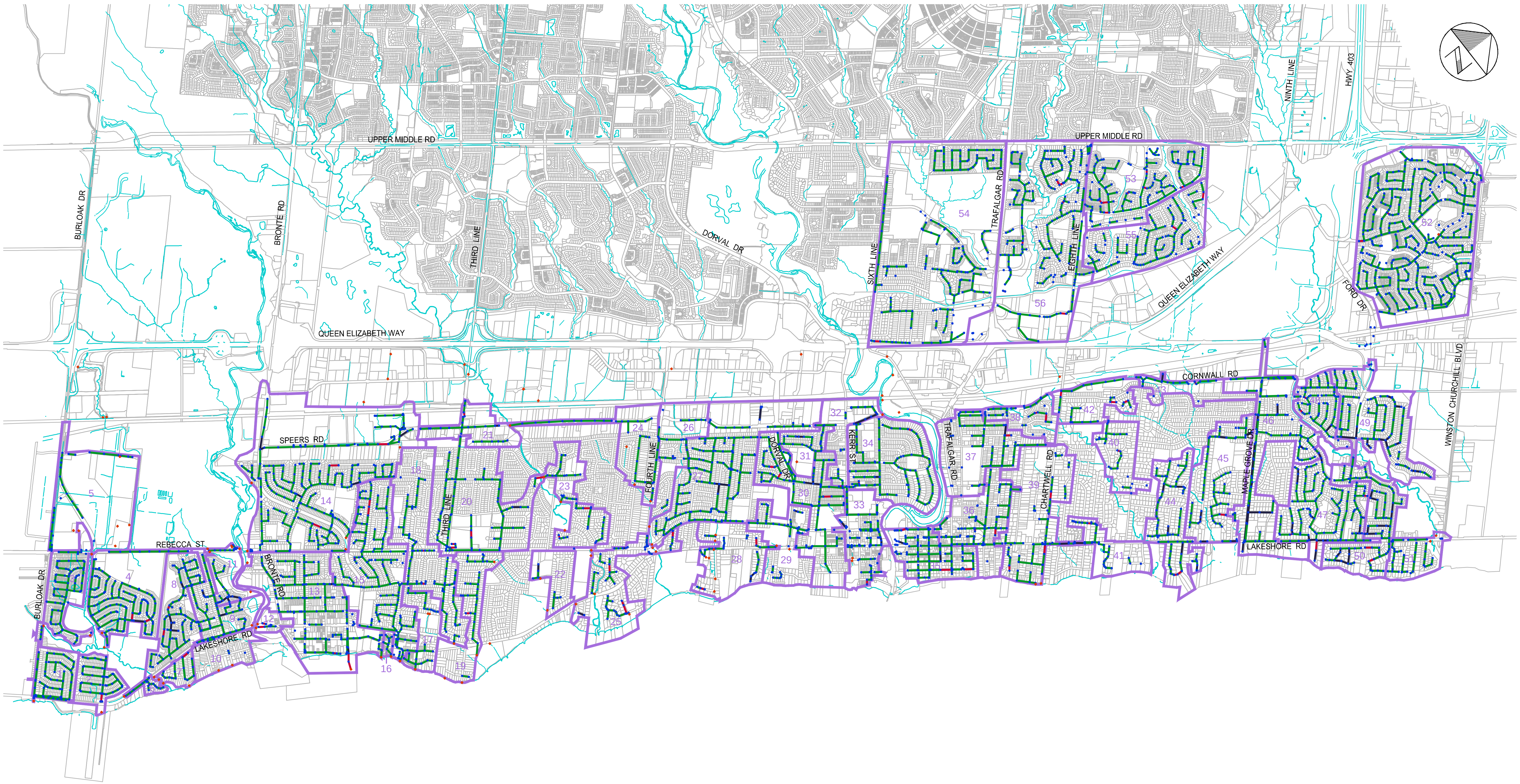

LEGEND

- WATERCOURSE
- PROPERTY BOUNDARY
- SEWERSHED BOUNDARY
- 13 SEWERSHED IDENTIFICATION NUMBER
- MANHOLE
- OUTFALL
- POSITIVE STORM SEWER SLOPE
- NEGATIVE STORM SEWER SLOPE
- STORM SEWER DATA INCOMPLETE

Path: P:\Work\111018\Water\dwg\Apr2014\Dwg5-8 SlopeClass.dwg

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Plotted: 2014-04-14
Last Saved: 2014-04-10

SCALE VALID ONLY FOR 24"x36" VERSION

OAKVILLE STORM SEWER MASTER PLAN

TOWN OF OAKVILLE

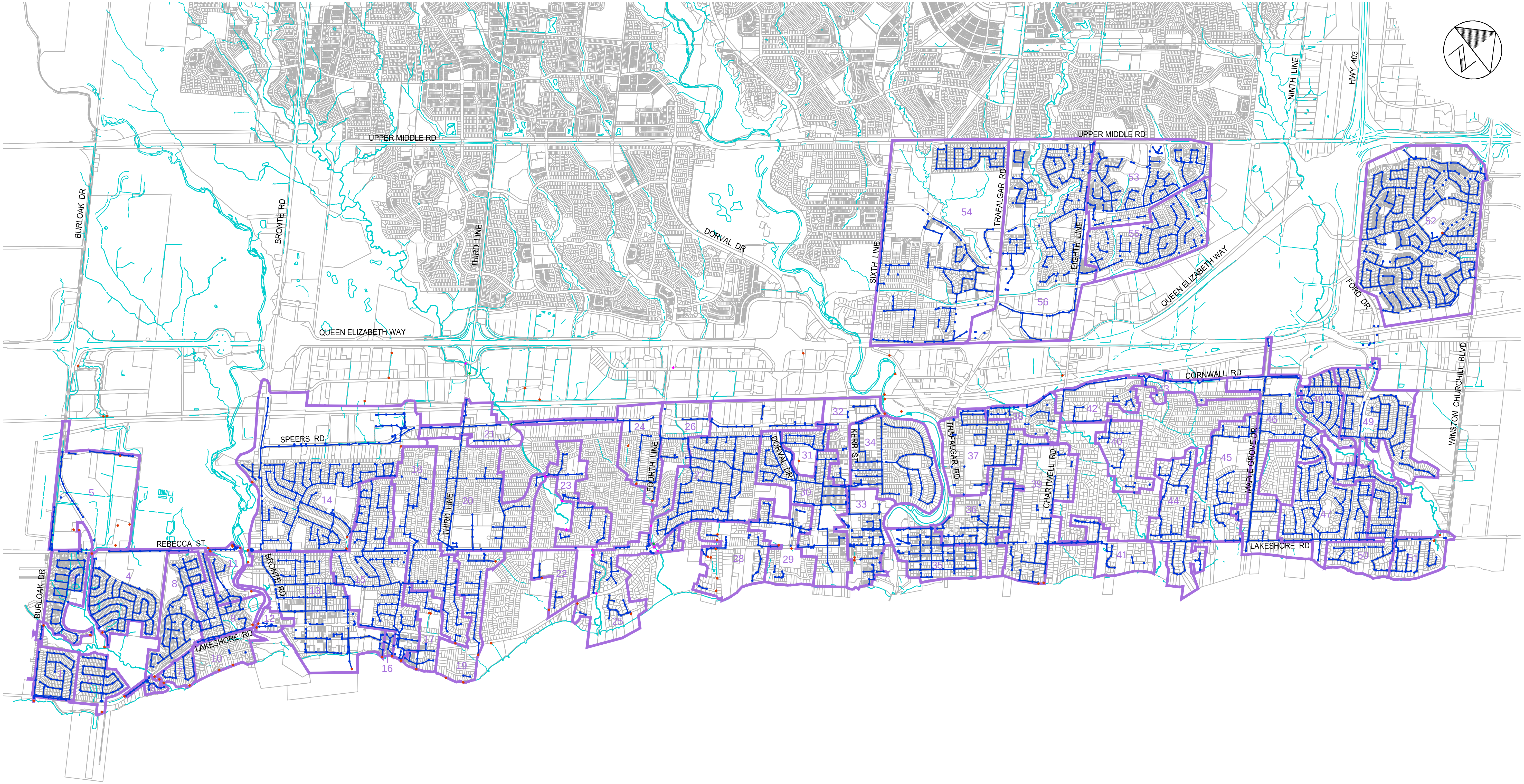
LOCATION OF NEGATIVE SLOPE IN SEWER NETWORK

amec

Scale 1 : 20000
0 200 400 800

Consultant File No. TP111018

Drawing No. 5.8



LEGEND

(watercourse line)	WATERCOURSE
(property line)	PROPERTY BOUNDARY
(sewershed line)	SEWERSHED BOUNDARY
13	SEWERSHED IDENTIFICATION NUMBER
(storm sewer line)	STORM SEWER
•	MANHOLE
•	OUTFALL
•	PARTIALLY SUBMERGED OUTFALL
•	SUBMERGED OUTFALL

Path: P:\Work\111018\Water\dwg\Apr2014\Dwg5-9 SurveyedOutfalls.dwg

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Plotted: 2014-04-14
Last Saved: 2014-04-10

SCALE VALID ONLY FOR 24"x36" VERSION

OAKVILLE STORM SEWER MASTER PLAN

TOWN OF OAKVILLE

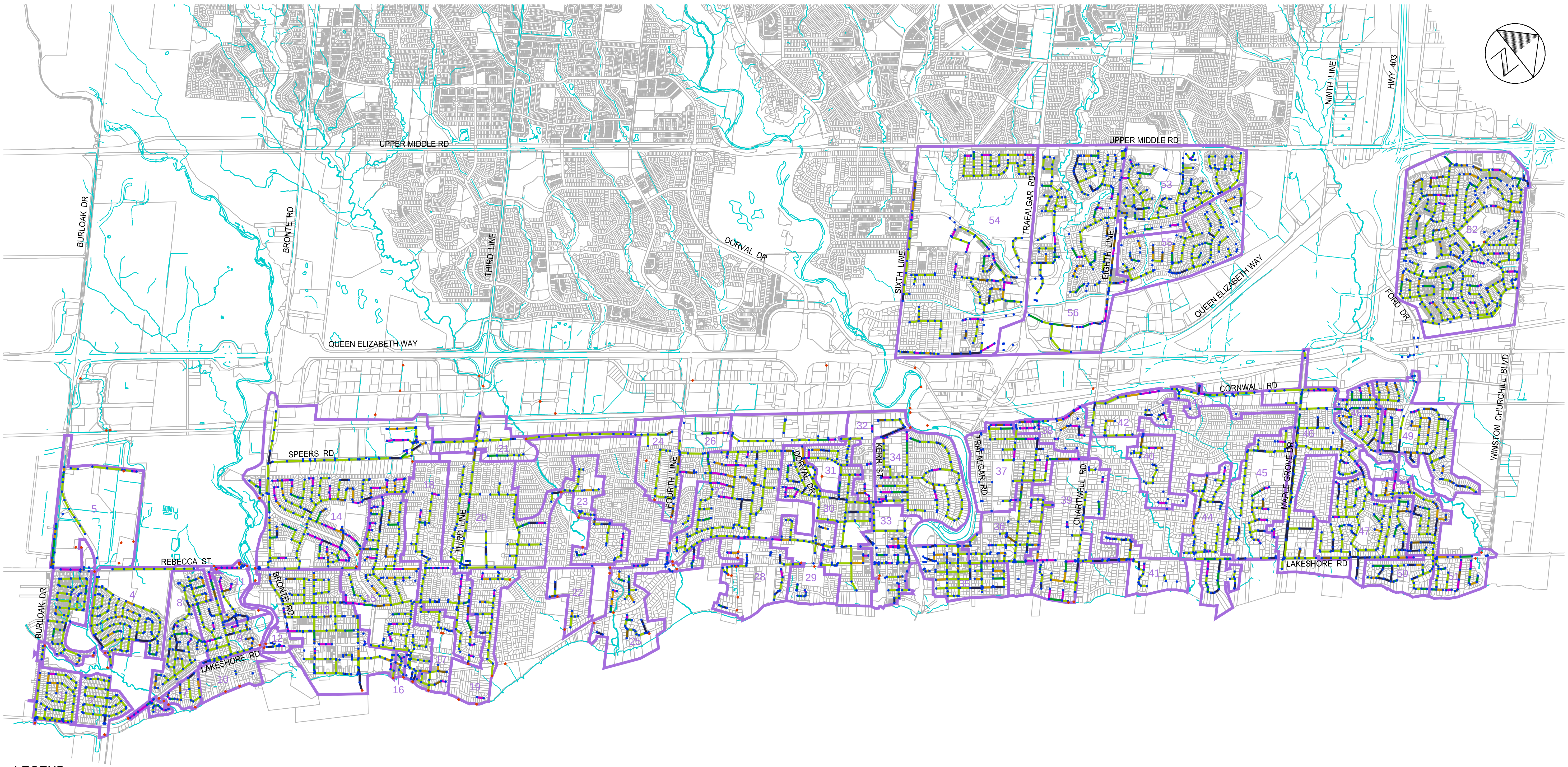
LOCATION OF SUBMERGED AND PARTIALLY SUBMERGED OUTFALLS

amec

Scale 1 : 20000 (0 200 400 800)

Consultant File No. TP111018

Drawing No. 5.9



LEGEND

	WATERCOURSE
	PROPERTY BOUNDARY
	SEWERSHED BOUNDARY
13	SEWERSHED IDENTIFICATION NUMBER
•	MANHOLE
•	OUTFALL
	CLIMATE CHANGE CLASS – 1
	CLIMATE CHANGE CLASS – 2
	CLIMATE CHANGE CLASS – 3
	CLIMATE CHANGE CLASS – 4
	CLIMATE CHANGE CLASS – 5
	STORM SEWER EXCLUDED

Path: P:\Work\111018\Water\dwg\Apr2014\Dwg5-10 ClimateChange.dwg

Plotted By: richard.bartolo
Last Saved By: richard.bartolo

Plotted: 2014-04-14
Last Saved: 2014-04-10

SCALE VALID ONLY FOR 24"x36" VERSION

OAKVILLE STORM SEWER MASTER PLAN

TOWN OF OAKVILLE

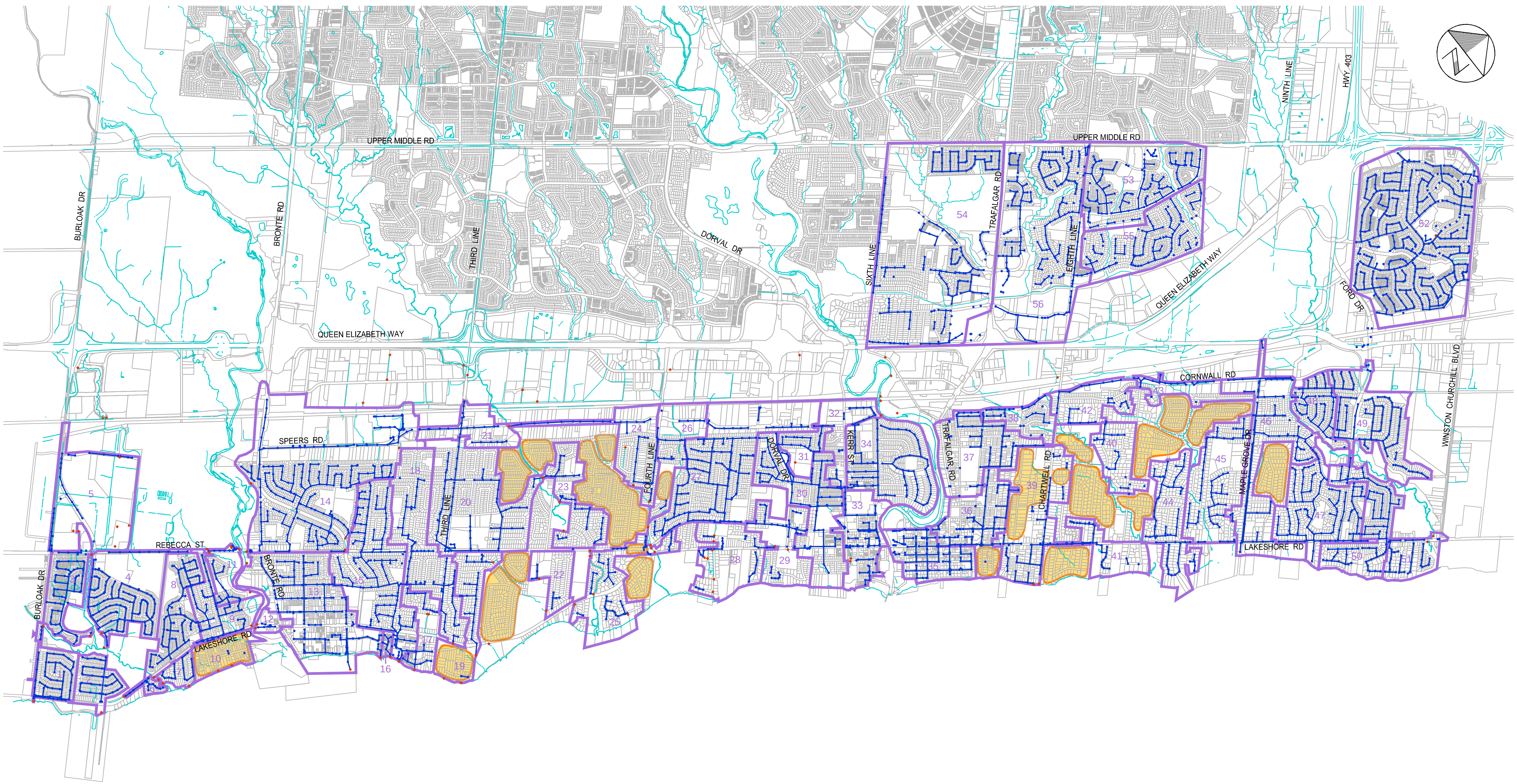
FLOW CAPACITY GRADE UNDER CLIMATE CHANGE CONDITIONS

amec

Scale 1 : 20000
0 200 400 800

Consultant File No.
TP111018

Drawing No.
5.10



LEGEND

- WATERCOURSE
- PROPERTY BOUNDARY
- SEWERSHED BOUNDARY
- 13 SEWERSHED IDENTIFICATION NUMBER
- STORM SEWER
- MANHOLE
- OUTFALL
- UNSERVICED AREA

SCALE VALID ONLY FOR 24"x36" VERSION

OAKVILLE STORM SEWER MASTER PLAN TOWN OF OAKVILLE	LOCATION OF CURRENTLY RURALLY SERVICED AREAS	amec	Scale 1 : 20000 (0 200 400 800) Consultant File No. TP111018 Drawing No. 5.11

Path: P:\Work\111018\Water\dwg\Apr2014\Dwg5-11 UnservicedAreas.dwg

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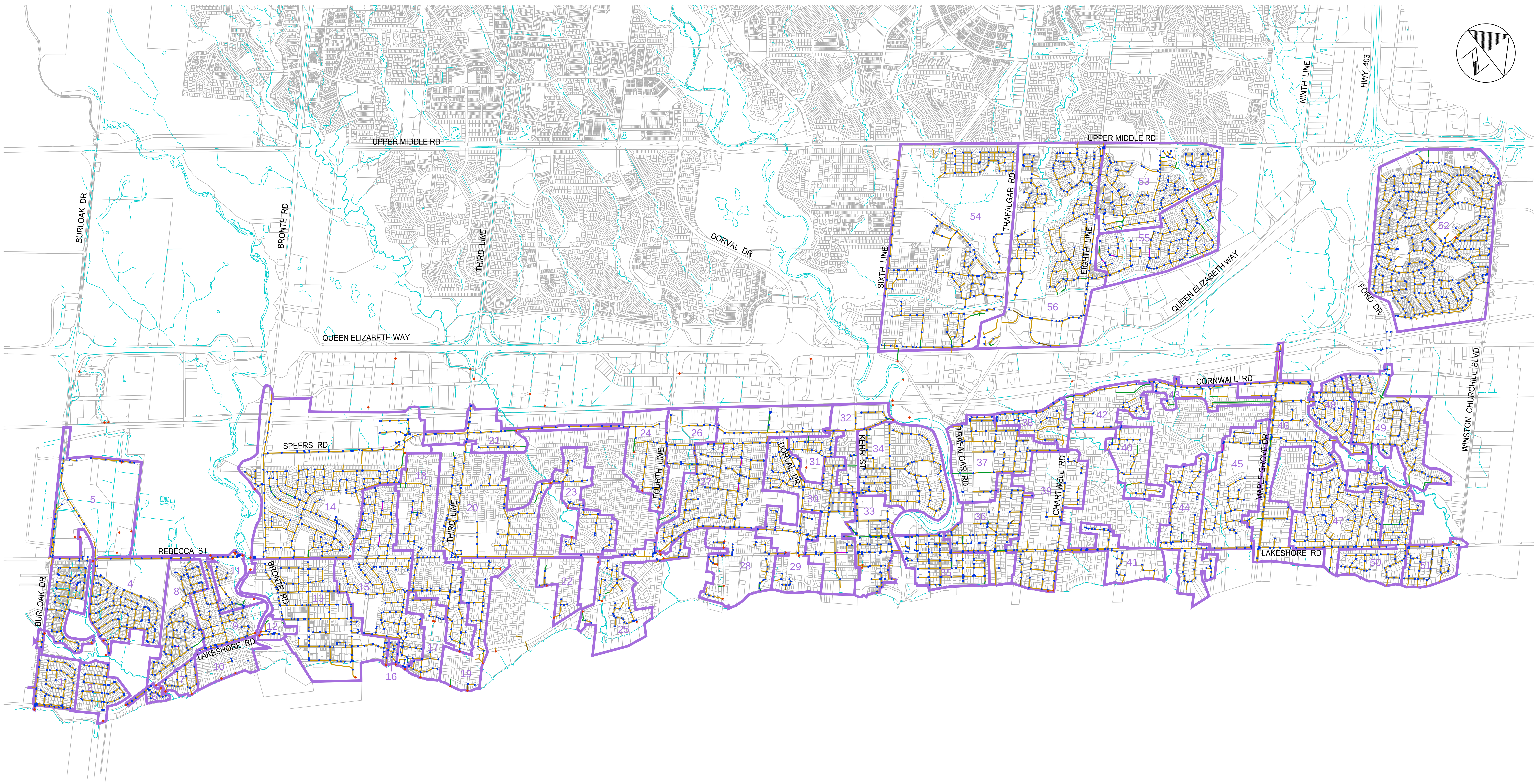
Plotted: 2015-02-20
Last Saved: 2015-02-20



LEGEND

- WATERCOURSE
- PROPERTY BOUNDARY
- SEWERSHED BOUNDARY
- 13 SEWERSHED IDENTIFICATION NUMBER
- MANHOLE
- OUTFALL
- TO BE INSPECTED
- MONITOR
- MAINTENANCE
- REPLACEMENT

SCALE VALID ONLY FOR 24"x36" VERSION

OAKVILLE STORM SEWER MASTER PLAN TOWN OF OAKVILLE	5 YEAR MAINTENANCE AND REPLACEMENT PROGRAM	amec	Scale 1 : 20000 (0 200 400 800) Consultant File No. TP111018 Drawing No. 8.1

Path: P:\Work\111018\Water\dwg\Apr2014\Dwg8-1 5yrProgram.dwg

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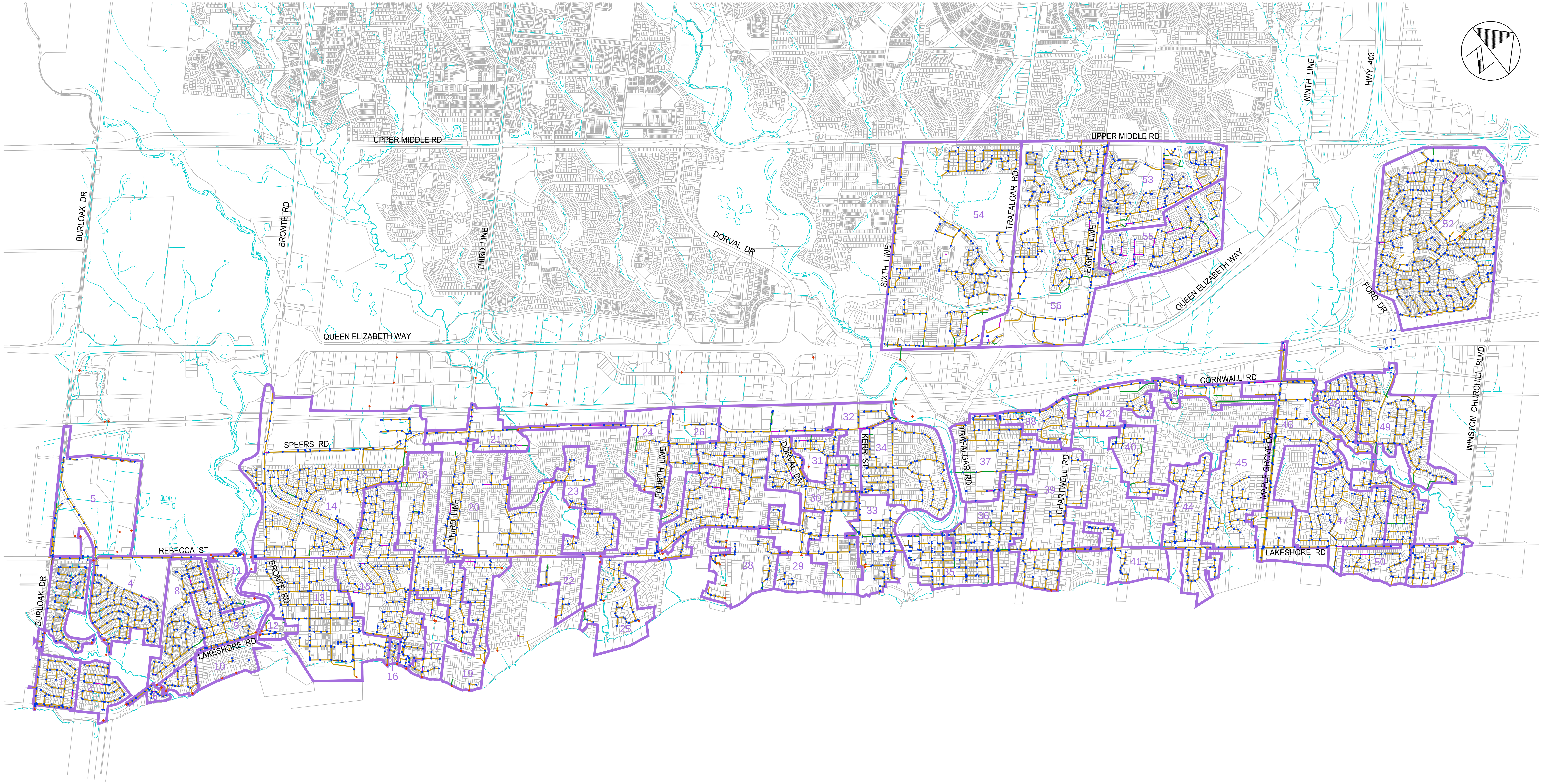
Plotted: 2015-09-14
Last Saved: 2015-09-14



LEGEND

- WATERCOURSE
- PROPERTY BOUNDARY
- SEWERSHED BOUNDARY
- 13 SEWERSHED IDENTIFICATION NUMBER
- MANHOLE
- OUTFALL
- TO BE INSPECTED
- MONITOR
- MAINTENANCE
- REPLACEMENT

Path: P:\Work\111018\Water\dwg\Apr2014\Dwg8-2 10yrProgram.dwg

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Plotted: 2015-09-14
Last Saved: 2015-09-14

SCALE VALID ONLY FOR 24"x36" VERSION

OAKVILLE STORM SEWER MASTER PLAN TOWN OF OAKVILLE	10 YEAR MAINTENANCE AND REPLACEMENT PROGRAM	amec	Scale 1 : 20000 (0 200 400 800) Consultant File No. TP111018 Drawing No. 8.2