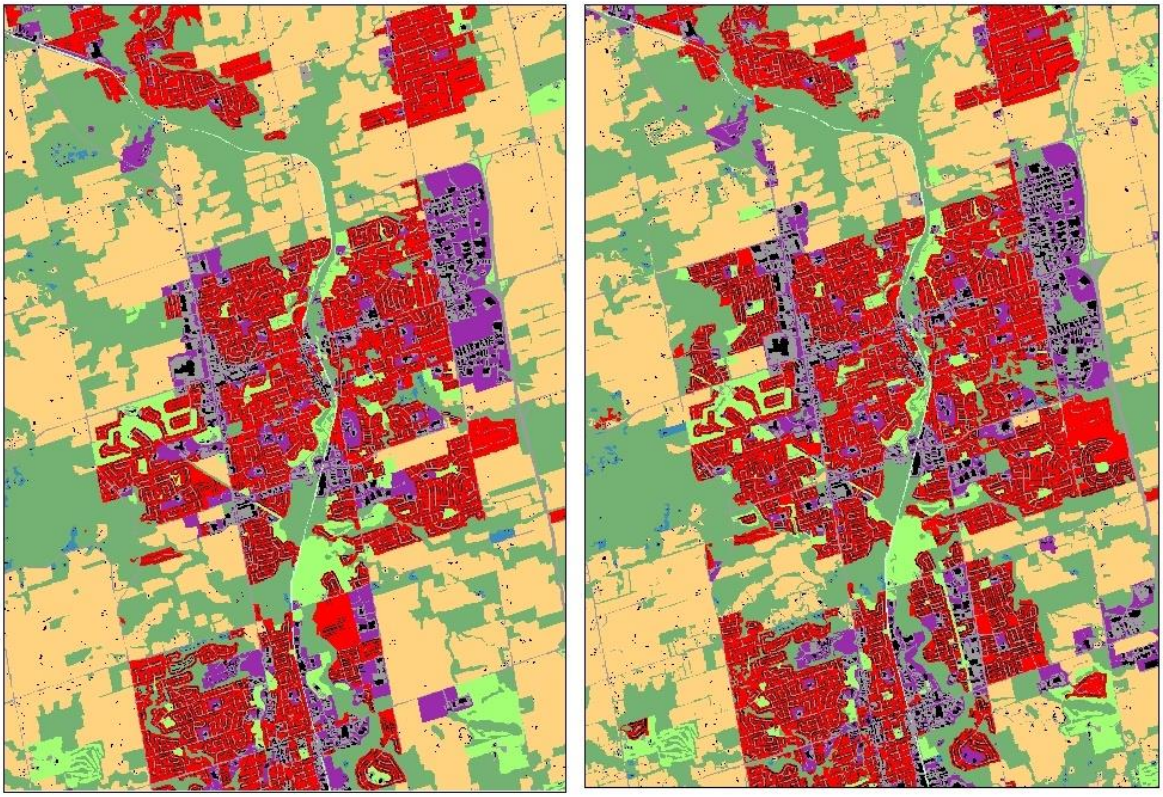
Lake Simcoe Region
conservation authority



2002 2013

Distribution and Change in Impervious Cover in the Lake Simcoe Watershed, 2002 to 2013

Lake Simcoe Region Conservation Authority gratefully acknowledges financial support from the Province of Ontario, without which this report would not have been possible. The views represented in this report do not necessarily reflect those of the Province.

Executive Summary

Comprehensive air photo coverage of the Lake Simcoe watershed in 2002/2003, 2008, and 2013 have permitted the development of a time series of land cover maps, and an analysis of changes in impervious cover. In 2013, impervious cover in the watershed was at 4.3%. This general land cover class, which includes roads, parking lots, and buildings has increased since 2002, as the watershed's population has increased. The rate of that increase has decreased from the 2002-2008 period to the 2008-2013 period however, indicating that land use is becoming more efficient in the watershed. Similarly, variation in per capita rate of land use across the watershed's municipalities suggest that large municipalities are more efficient users of land, and are able to absorb increases in population with smaller increases in those impacts associated with impervious cover, including changes in stream flow, groundwater, and aquatic communities.

Introduction

Located as it is on the northern edge of the Greater Toronto Area, the Lake Simcoe watershed is an area receiving growth and development pressures greater than elsewhere in Ontario (Palmer et al. 2011). The need to manage these pressures has led to the development of the Lake Simcoe Protection Plan, the Lake Simcoe Phosphorus Reduction Strategy, and a series of twelve subwatershed plans.

Impervious features such as roads, buildings, and parking lots are some of the major drivers of changes to watershed health, impacting factors such as fish communities (Stanfield and Kilgour 2006), water quality (Brabec et al. 2002), groundwater recharge (Howard and Gerber 2018) and stream flow (Shuster et al. 2007). Recognizing this, Strategic Directions three and four in the Lake Simcoe Phosphorus Reduction Strategy speak to managing or reducing phosphorous loading from impervious features. Similarly, the LSRCA has developed a phosphorus offsetting policy and a new staff division focused on implementing stormwater retrofit projects in order to manage these challenges.

Lake Simcoe Region Conservation Authority and its partners have also been mapping and monitoring land use and land cover within the Lake Simcoe watershed for many years, although it has been largely under-utilized in environmental reporting.

This project improved resolution of land cover mapping in the Lake Simcoe watershed to permit more accurate tracking of changes in impervious land use and to support more focused delivery of programs related to urban stormwater, including LID implementation, stormwater retrofits, and salt reduction programming.

Methods

Data capture

Complete airphoto coverage is available for the Lake Simcoe watershed for three time periods in approximately 5-year intervals: 2002/2003, 2008, and 2013. For each period, seamless land cover maps were created for the watershed, through visual airphoto interpretation and classification by LSRCA staff. In each of the three periods, land use was classified as being one of 13 categories (Table 1) in ArcMap with the resulting data incorporated into a GIS featureclass.

Table 1. Land use classification in Lake Simcoe landcover map (LSRCA 2018)

Land use class	Definition
Active Aggregate	Identified by pits, extraction machinery, unvegetated landscape, and piles of extracted materials; may also contain open water
Commercial	Properties that contain a building and adjacent parking lot, including shopping malls and strip malls
Estate Residential	Includes a home within a natural heritage feature including the manicured area around the home and driveway, but not the natural heritage feature
Industrial	Larger areas than commercial; includes large factories, etc
Institutional	Includes schools, churches, hospitals and other institutional structure and adjacent fields. Sometimes it includes large stormwater ponds
Intensive agriculture	Cultivated fields producing crops (e.g. corn and wheat). This includes specialty agriculture, which consists of orchards, market gardens, Christmas tree plantations, and nurseries. Interpreted from air photos by plow marks, signs of harvesting and tile drainage.
Manicured open space	Dominated by gardens, parkland, and lawn areas. For example, cemeteries, golf courses, urban parks, ski hills, and residential/industrial open space with a minimum size of 2 hectares. This did not include backyards or school yards.
Natural heritage feature	Woodlands, wetlands, and grasslands which meet the definition of "communities" in the Ecological Land Classification for Southern Ontario, or wetlands in the Ontario Wetland Evaluation System
Non-intensive agriculture	Fields dominated with herbaceous vegetation and grasses, including pasture/grazing areas. Weedy hay and/or pasture cover more than 50% of the area. Associated with extensive or unconfined grazing of livestock and minimal evidence of recent cultivation.
Rail	Rail corridors with tracks, including both track and shoulder
Road	Roads, including both surface and shoulder
Rural development	These are lands between 0.5 and 2.0 ha that contain residential, commercial or other buildings not directly associated with a farming operation, and manicured open space (e.g. estate residential or service station).
Urban residential	Urban related uses including continuous ribbon development. Interpreted from air photos by number of roof tops, and groupings of 5 or more residential units equaling 2 or more hectares (i.e. the presence of pavement, buildings and structures).

This project involved adding an additional attribute to the landcover featureclass, called SurfaceType, composed of four categories (Table 2). As with the land use attribute, features were classified as belonging to one of the defined SurfaceType classes, based on visual interpretation of the air photos by LSRCA staff. Where necessary, land use polygons were split by digitizing boundaries between surface types to ensure each polygon represents a single surface type category.

Table 2. Surface type classification in Lake Simcoe landcover map

Surface Type class	Definition
Building	Building footprints of houses, commercial, industrial, farm, and institutional buildings. Some data provided by York Region and City of Barrie, with additional footprints digitized by LSRCA staff
Paved	Areas covered in asphalt or gravel, including roads and parking lots
Stormwater pond	Open water features, predominantly occurring in urban areas, interpreted as performing a role in stormwater management
Unpaved	All other features

No area narrower than 3 metres or polygon smaller than 10.5 m^2 was digitized. Sticky Move Tolerance was set to 999,999 to ensure no accidental slides occurred.

Quality control was implemented through three approaches: a visual inspection by a second staff person to confirm that polygon boundaries appeared correct, queries to ensure that classification of land use and surface type within polygons made sense (e.g. confirming that paved areas did not occur in natural heritage features), and use of the ArcMap 'dissolve' and 'select' functions to ensure that properties classified as commercial, industrial, and estate residential were associated with paved and building surface types.

For more detail on the data capture methodology, see LSRCA (2018).

Change analysis

Land use was summarized in 2002/2003, 2008, and 2013 using generalized land use classes and surface types, and total area change in the two intervals (i.e. 2002/2003 to 2008 and 2008 to 2013) was calculated as a measure of land use change over time.

More detailed change analysis of impervious features was also conducted over those same two intervals. Change metrics included total area of impervious features, total area of individual feature types (parking lots, roads, buildings), as well as the size and number of each of the above features. Analysis was conducted for the entire watershed, as well on a municipality- and subwatershed-scale to assess how changes in land use were distributed throughout the watershed.

Per capita land use (i.e. hectares of impervious divided by municipal population) was also calculated for those municipalities wholly or substantially within the Lake Simcoe watershed (i.e. Aurora, Barrie, Bradford West Gwillimbury, Brock, East Gwillimbury, Georgina, Innisfil, Newmarket, Orillia, Oro-Medonte, Orillia, and Uxbridge) to assess if there were any evidence of increasing efficiency in land use from 2002/2003 to 2013. Population numbers were provided by Statistics Canada community profiles from census data dating from 2001, 2006, and 2011 which unfortunately introduces a slight mismatch between census dates and date of air photo capture.

The significance of change in median size of paved features between inventory dates was assessed with the use of Mann-Whitney U-tests, and relationships between municipal population and impervious cover was assessed using linear regression of log-transformed data. Differences in the change in impervious land use per capita in watershed municipalities in the period before the Lake Simcoe Protection Plan came into force (i.e. 2002/03 to 2008) and after it came into force (i.e. 2008 to 2013) was assessed with a t-test.

Results and Discussion

Land use change

The greatest changes in land use over the study period was a decrease in area classified as agricultural land use (4359 ha, or 1.5% of the watershed), and natural heritage features (458 ha, or 0.2%), and an increase in urban area including both residential (1479 ha, 0.5%) and the industrial, commercial, institutional sector (1064 ha, or 0.4%) (Figure 1, Appendices 1-4).

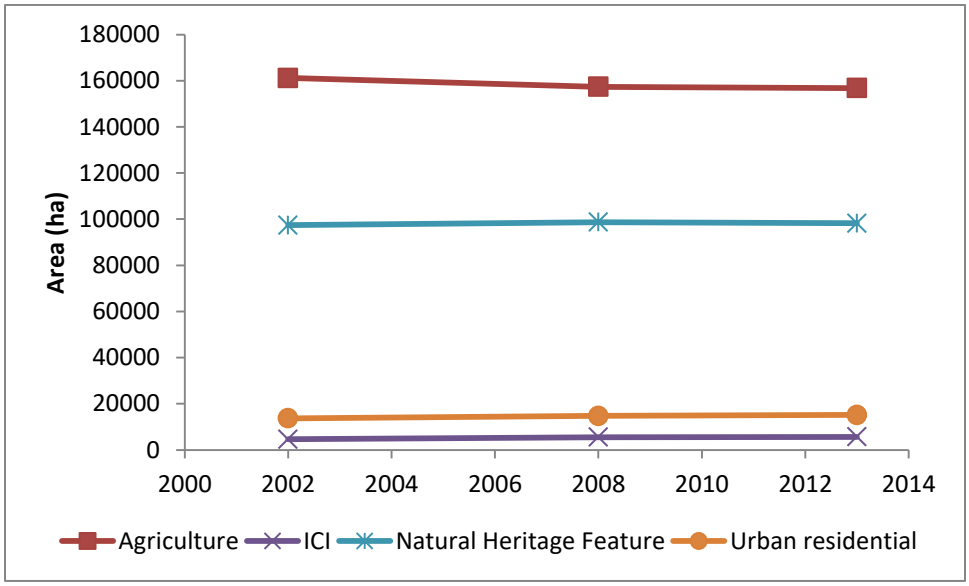


Figure 1. Land cover by land use type in the Lake Simcoe watershed (2003 to 2013)

Shifts in land use were not as simple as a shift from one land use type (such as agriculture) to other types (such as Industrial, Commercial or Institutional [or ICI]) however (Appendices 3 and 4). In many cases, agricultural land use was converted to one of the other categories, however even within the agricultural land use category there was a net shift from pervious land use (e.g. farm fields) to impervious (e.g. barns or other buildings) representing a net shift towards larger operations and more intensive practices (e.g. Figure 2). In addition to this shift was a shift from agriculture land use to natural heritage features (Appendix 3). Part of this shift reflects an increase in forest cover due to afforestation by LSRCA and others, as well as natural forest succession transitioning low intensity or marginal farmland to young forests. Unfortunately, some of this shift also reflects a change in mapping methodology between the two periods. The initial land cover mapping on the 2002/2003 air photos was done by LSRCA solely, and was largely an airphoto interpretation project. In 2008, field-based wetland mapping provided by MNRF was also included in the dataset. The inclusion of this data led to a reclassification of some meadows (previously classified as agriculture) to meadow marshes (re-classified as natural heritage), and shrubby farm fields (previously classified as agriculture) to thicket swamps (re-classified as natural heritage). A project similar to this one, but focused on natural features would be necessary to disentangle those classifications.

Figure 2. Example of increasing intensification of agriculture between 2002/2003 (left) and 2013 (right)

General patterns in land use change from 2008 to 2013 were similar (Appendix 4), with the greatest changes seen in agriculture, natural heritage, ICI, and urban residential categories. Similar to the initial time period, in addition to an overall reduction in farm land, there was also a net shift from pervious to impervious land cover within farms. Unlike the earlier period, mapping of natural heritage feature methodology did not change from 2008 to 2013, resulting in greater confidence in the reported net decrease of natural features in this interval (460 ha, or 0.2% of the watershed).

Change in impervious cover

Unsurprisingly, the extent of impervious features in the Lake Simcoe watershed has increased from 3.4% in 2003 to 4.3% in 2013 (Figure 3). Also unsurprisingly, this increase has been greatest in subwatersheds in municipalities experiencing rapid paces of growth, such as Hewitts and Lovers Creek near Barrie, West Holland near Bradford West Gwillimbury, and the East Holland which includes parts of Newmarket, Aurora, and East Gwillimbury (Figure 4).

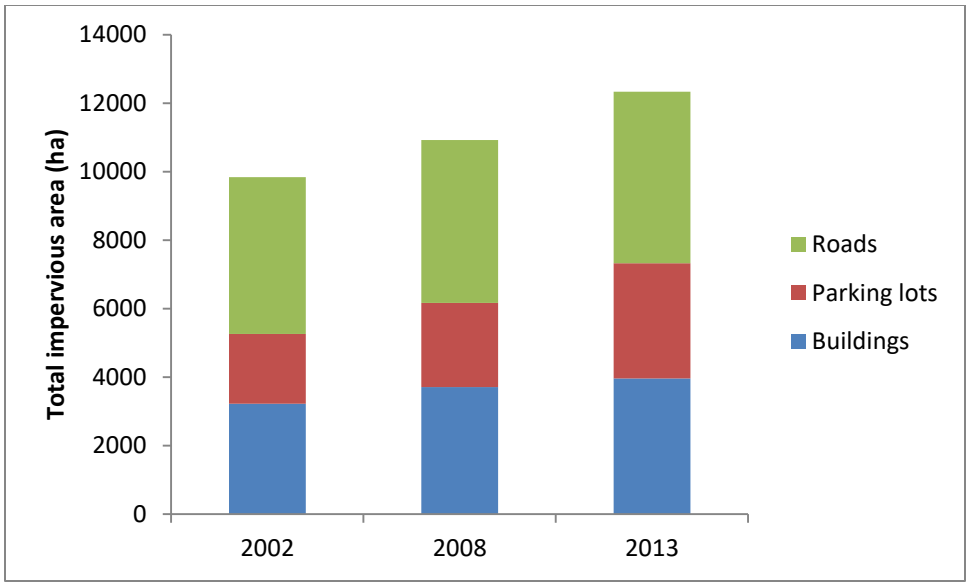


Figure 3. Extent of impervious features in the Lake Simcoe watershed (2002/2003, 2008 and 2013)

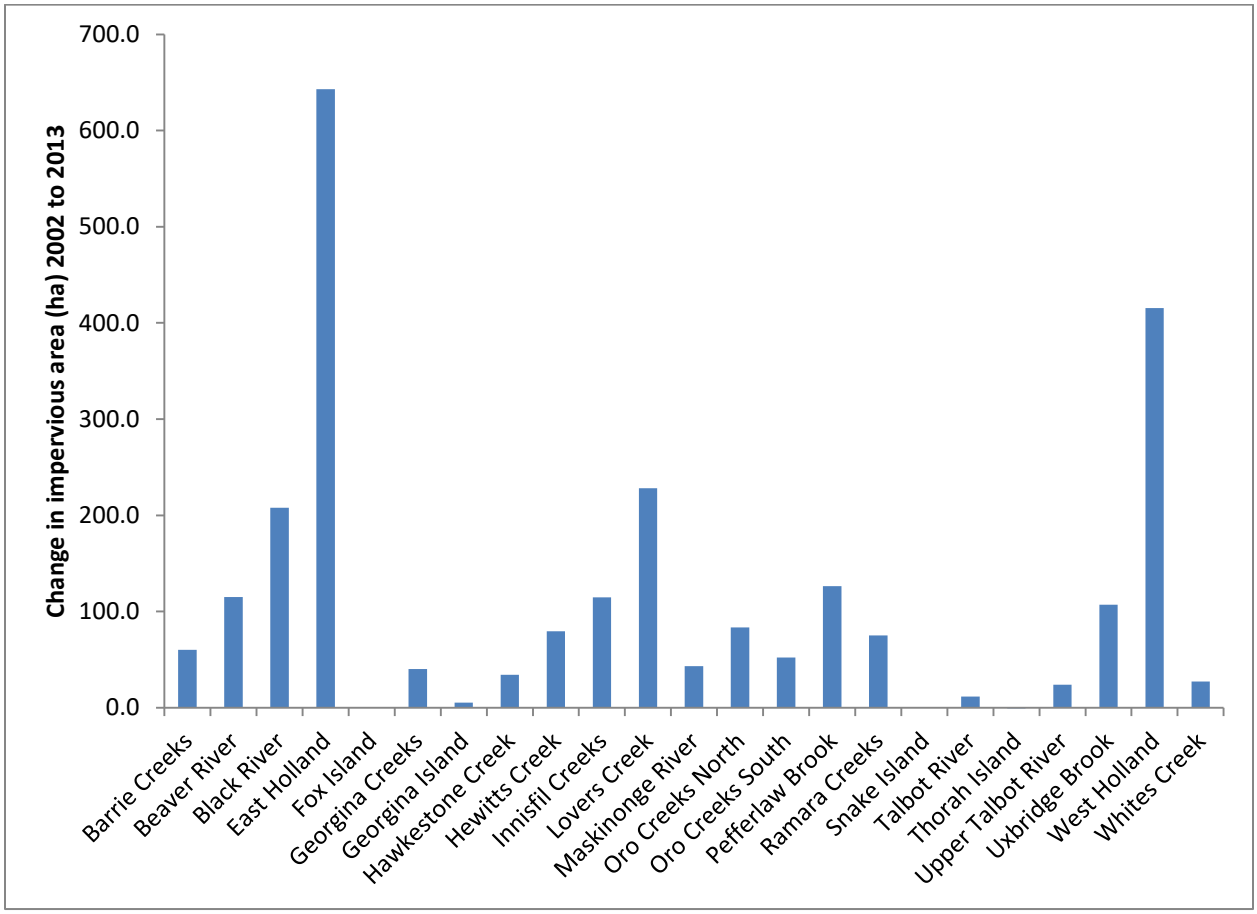


Figure 4. Change in impervious cover in Lake Simcoe's subwatersheds (2002/2003 to 2013)

As can be seen from Figure 3, much of the change in impervious cover is a result of a change in the extent of roads and parking lots in the watershed. In fact, not only has the number of parking lots

increased, median size of parking lots has increased significantly from 2003 to 2008 and from 2008 to 2013 as well ($p<0.0001$ in both cases; Figure 5). This reiterates the importance of programming focused on parking lots, both with respect to LID implementation, as well as outreach and engagement related to winter salt reduction.

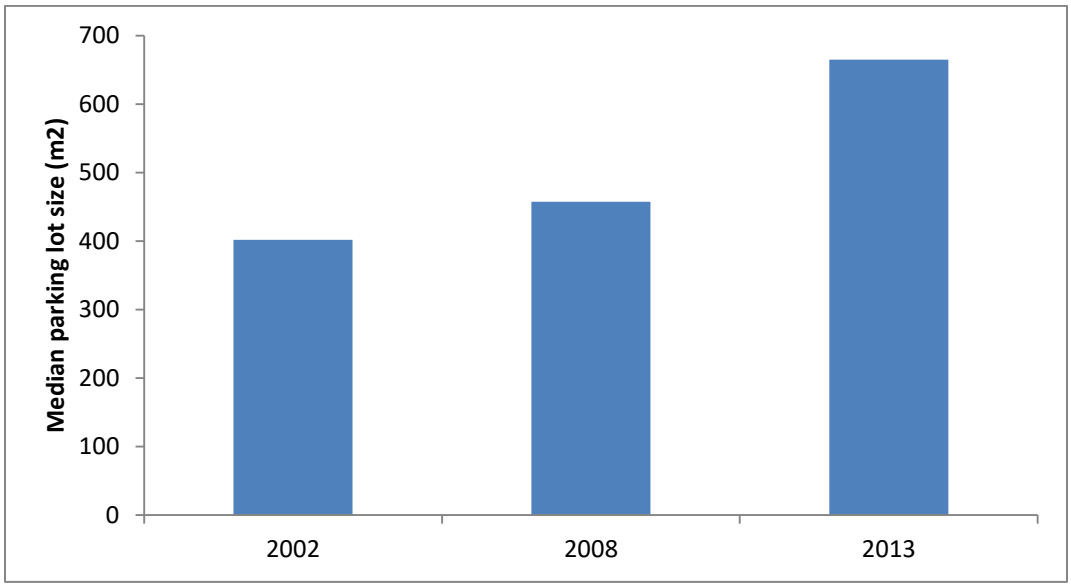


Figure 5. Median size of parking lots in the Lake Simcoe watershed (2002/2003, 2008 and 2013)

Per capita impervious cover

This growth in impervious land use was largely driven by an increase in watershed population; however it is notable that the increase in per capita land use was significantly lower ($t_{13} = -2.50$, $p = 0.026$) between 2008 and 2013 than it was in the earlier mapping interval, timing which is associated with the Lake Simcoe Protection Plan coming into force.

In fact, among municipalities, a statistically significant ($F_{1,10} = 14.98$, $p=0.003$) negative relationship exists between community size and per capita impervious area (Figure 6), which suggests that larger communities are able to meet needs of their populations with greater efficiency in land use. Perhaps more interesting is the negative relationship municipal population and change in total impervious cover between 2002/2003 and 2013 (Figure 7, $F_{1,10} = 20.02$, $p=0.001$), suggesting that larger communities also have lower marginal rate of increase in impervious area as their population grows (in other words, they can accommodate a growing population with reduced increases in impervious cover). While intensification has long been promoted as a tool to reduce loss of natural areas and farm land (e.g. Furberg and Ban 2012), these results suggest that intensification is also an effective tool for reducing impervious cover within the Lake Simcoe watershed, which will reduce the marginal impacts of population growth on water quality and aquatic ecosystems.

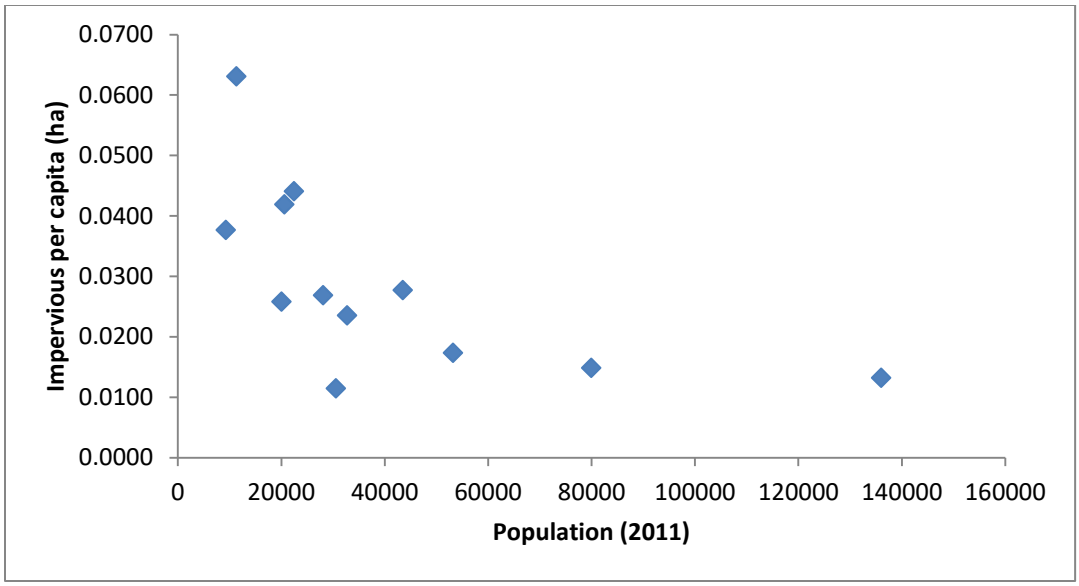


Figure 6. Relationship between population and per capita impervious land cover in Lake Simcoe's municipalities (2013)

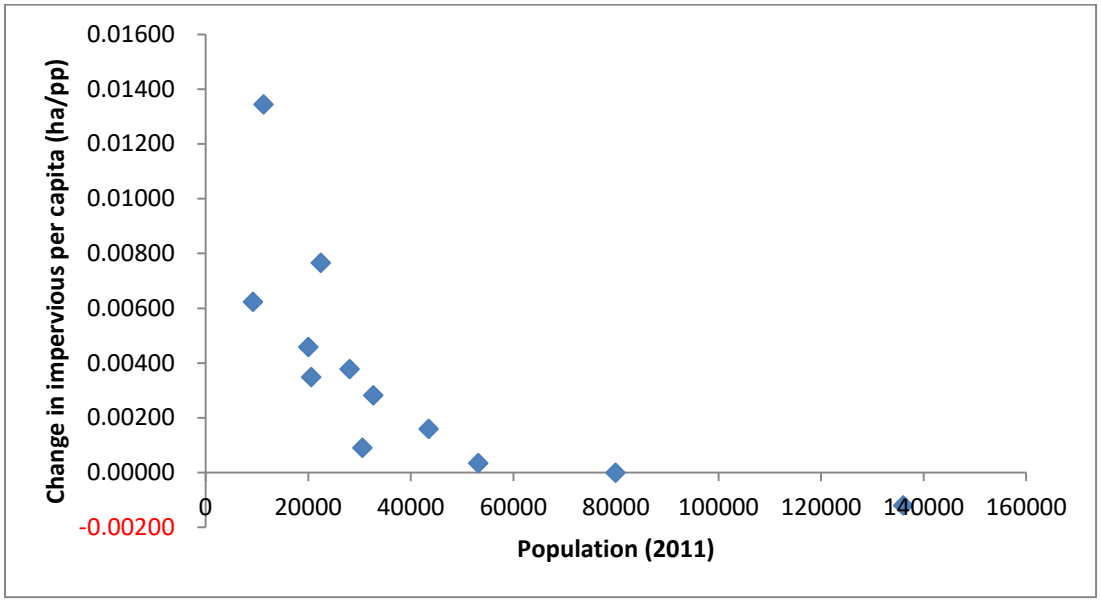


Figure 7. Relationship between population and changes in per capita impervious land cover in Lake Simcoe's municipalities, 2002/2003 to 2013

This improved data on impervious cover will assist municipalities in developing and updating their stormwater management master plans, in implementing proposed stormwater utility rates, and in identifying and prioritizing areas for increases in urban forest cover. Similarly, this data will assist the conservation authority and other partners in identifying and prioritizing areas for urban stormwater retrofits, and in identifying and managing potential sources of atmospheric deposition to the lake. The data on changes in impervious cover between 2002 and 2013 will be of value in modelling changes in phosphorus and chloride loads to Lake Simcoe's tributaries.

Given that the first two time periods (2002 and 2008) predate the Lake Simcoe Act and Plan, and the third (2013) is subsequent to the Plan coming into force, this data will also begin to provide some insight as to whether the Plan is promoting improved land use in the watershed. Repeating this study on forthcoming complete air photo imagery from 2018 would provide two land cover inventories before the LSPP and two after, giving a stronger assessment of the role of the plan in protecting natural features and hydrologic function. Additional effort in clarifying differences between marginal farmland and wetlands in earlier mapping would be of additional value in tracking overall land use change.

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Appendix 1. Area of land use and surface type classes in Lake Simcoe's subwatersheds in 2002/2003 (ha)

	Aggregate			Agriculture			Estate Residential			ICI				Manicured Open Space				Natural Heritage Feature	Rail	Road		Urban Residential		
Subwatershed	Building	Paved	Unpaved	Building	Paved	Unpaved	Building	Paved	Unpaved	Building	Paved	Unpaved	Storm Pond	Building	Paved	Unpaved	Storm Pond	Unpaved	Paved	Paved	Unpaved	Building	Unpaved	Storm Pond
Barrie Creeks	0	0	46	1	0	410	1	2	17	151	324	335	0	0	9	172	0	461	24	349	0	251	1202	0
Beaver River	0	2	378	69	17	22830	3	5	61	7	22	74	0	0	1	146	0	8491	8	292	0	37	284	0
Black River	1	8	276	128	93	18628	15	14	227	13	43	52	6	2	6	282	1	16114	80	457	0	96	993	1
East Holland	0	0	94	58	32	10744	25	19	240	216	481	847	19	5	31	995	3	6130	46	852	0	681	3193	5
Fox Island	0	0	0	1	0	6	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0
Georgina Creeks	0	0	22	13	6	2272	1	1	14	8	23	46	0	1	4	110	0	1599	0	128	0	102	584	0
Georgina Island	0	0	7	4	1	243	0	0	0	0	0	6	0	0	0	2	0	1018	0	10	0	0	0	0
Hawkestone Creek	0	3	77	8	6	2152	1	1	11	1	5	19	0	0	1	35	0	2332	0	49	0	6	75	0
Hewitts Creek	0	0	0	5	1	1186	1	0	8	1	3	7	0	0	0	8	0	298	13	34	0	15	172	1
Innisfil Creeks	0	0	61	21	9	5851	3	2	44	8	28	68	1	1	4	191	0	2926	18	205	0	135	1140	0
Lovers Creek	0	0	16	8	5	2809	3	3	60	63	191	330	1	0	4	130	0	1677	24	193	0	68	407	2
Maskinonge River	0	0	0	21	7	4927	0	0	7	7	23	37	0	0	0	27	0	1033	0	87	0	33	139	0
Oro Creeks North	0	0	95	14	9	3426	1	2	11	47	123	214	0	0	4	34	0	2770	0	153	0	85	539	0
Oro Creeks South	0	0	0	14	17	2812	3	3	29	2	20	125	0	0	5	70	1	2189	0	76	0	26	346	0
Pefferlaw Brook	1	2	863	68	33	15148	10	11	246	4	12	46	0	1	4	254	0	10863	33	303	0	50	537	0
Ramara Creeks	0	0	17	18	6	8113	0	0	2	4	29	51	0	0	6	63	0	4669	22	129	0	47	552	0
Snake Island	0	0	0	3	0	44	0	0	0	0	0	0	0	0	0	0	0	89	0	0	0	0	0	0
Talbot River	0	0	115	8	7	4376	0	0	5	1	3	5	0	0	4	25	0	2272	9	58	0	8	118	0
Thorah Island	0	0	0	1	0	187	0	0	0	0	0	0	0	0	0	0	0	251	0	0	0	0	0	0
Upper Talbot River	0	0	116	14	15	12775	3	4	41	1	2	10	0	0	1	40	0	15944	0	212	0	18	258	0
Uxbridge Brook	0	3	177	46	23	9981	6	8	129	13	36	60	0	1	2	157	0	4751	13	215	0	60	453	0
West Holland	0	0	8	173	64	24209	15	12	188	32	99	172	11	2	8	362	0	8210	22	706	6	103	789	0
Whites Creek	0	0	15	16	3	7005	0	0	6	2	6	14	0	0	0	0	0	3306	12	76	0	9	69	0
Total	**4**	**18**	**2383**	**710**	**353**	**160131**	**91**	**89**	**1346**	**580**	**1474**	**2515**	**38**	**15**	**96**	**3105**	**5**	**97407**	**324**	**4582**	**7**	**1830**	**11849**	**8**

Appendix 2. Area of land use and surface type classes in Lake Simcoe's subwatersheds in 2008 (ha)

	Aggregate			Agriculture				Estate Residential			ICI				Manicured Open Space				Natural Heritage Feature	Rail	Road		Urban Residential		
Subwatershed	Building	Paved	Unpaved	Building	Paved	Unpaved	Storm Pond	Building	Paved	Unpaved	Building	Paved	Unpaved	Storm Pond	Building	Paved	Unpaved	Storm Pond	Unpaved	Paved	Paved	Unpaved	Building	Unpaved	Storm Pond
Barrie Creeks	0	3	60	1	1	440	0	1	2	11	155	343	328	0	0	11	157	0	400	24	350	0	274	1192	0
Beaver River	0	3	436	70	23	22448	0	3	5	55	10	24	64	0	0	2	140	0	8799	8	293	0	36	305	0
Black River	2	9	270	128	108	18353	1	16	16	164	21	60	135	9	2	12	328	0	16440	67	468	1	111	816	0
East Holland	0	1	51	53	32	10010	0	28	26	248	275	626	862	26	4	20	964	3	6200	46	922	0	813	3501	4
Fox Island	0	0	0	1	0	6	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0
Georgina Creeks	0	0	9	8	5	2127	0	1	1	12	10	27	71	0	1	5	131	0	1644	0	130	0	113	635	0
Georgina Island	0	0	12	5	3	251	0	0	0	1	0	0	7	0	0	0	0	0	1000	0	10	0	0	0	0
Hawkestone Creek	0	3	101	8	4	2117	0	1	1	11	1	9	32	0	0	1	34	0	2320	0	48	0	7	85	0
Hewitts Creek	0	0	0	5	2	1087	0	0	0	6	2	7	15	2	0	0	17	0	261	12	54	0	44	239	0
Innisfil Creeks	0	0	23	19	10	5965	0	5	6	36	10	32	76	1	0	4	123	0	2836	18	218	0	157	1177	0
Lovers Creek	0	0	20	7	5	2609	0	4	6	86	85	257	386	4	0	3	125	1	1616	22	212	0	97	451	0
Maskinonge River	0	0	0	20	8	4888	0	0	0	5	8	25	38	0	0	0	4	0	1050	0	90	0	39	171	0
Oro Creeks North	0	1	162	12	11	3263	0	1	2	18	50	134	266	0	0	4	33	0	2806	0	149	0	87	524	0
Oro Creeks South	0	0	0	11	11	2739	0	4	6	50	4	26	131	0	1	9	67	1	2200	0	75	0	32	373	0
Pefferlaw Brook	1	3	780	63	39	14475	0	15	15	209	5	14	74	0	2	8	496	0	11209	51	312	0	58	659	0
Ramara Creeks	0	0	45	17	7	7965	0	0	0	3	5	36	62	0	1	7	80	0	4675	23	137	0	53	614	0
Snake Island	0	0	0	3	0	45	0	0	0	0	0	0	0	0	0	0	0	0	87	0	0	0	0	0	0
Talbot River	0	3	171	8	6	4392	0	0	1	7	1	5	18	0	0	2	19	0	2217	9	58	0	7	92	0
Thorah Island	0	0	0	1	0	170	0	0	0	0	0	0	0	0	0	0	0	0	268	0	0	0	0	0	0
Upper Talbot River	0	4	168	13	16	12771	0	2	4	54	1	2	9	0	0	2	43	0	15860	0	218	0	19	268	0
Uxbridge Brook	0	3	179	46	28	9559	0	7	8	114	19	43	84	0	1	3	177	0	5058	12	227	0	77	490	0
West Holland	0	0	0	187	67	23595	0	16	12	213	46	140	254	11	3	11	414	0	8426	23	705	11	141	919	0
Whites Creek	0	0	15	17	5	6984	0	0	0	6	1	5	46	0	0	0	1	0	3288	6	76	0	10	79	0
Total	**5**	**31**	**2499**	**703**	**388**	**156262**	**2**	**107**	**113**	**1310**	**709**	**1815**	**2958**	**53**	**16**	**105**	**3353**	**5**	**98673**	**321**	**4754**	**12**	**2174**	**12588**	**6**

Appendix 3. Area of land use and surface type classes in Lake Simcoe's subwatersheds in 2013 (ha)

	Aggregate			Agriculture				Estate Residential			ICI				Manicured Open Space				Natural Heritage Feature	Rail	Road	Urban		
Subwatershed	Building	Paved	Unpaved	Building	Paved	Unpaved	Storm Pond	Building	Paved	Unpaved	Building	Paved	Unpaved	Storm Pond	Building	Paved	Unpaved	Storm Pond	Unpaved	Paved	Paved	Building	Unpaved	Storm Pond
Barrie Creeks	0	0	11	1	2	425	0	1	2	10	154	350	390	2	0	13	184	0	366	21	359	265	1195	0
Beaver River	0	2	464	71	106	22369	0	3	6	61	10	31	93	0	0	1	136	0	8732	4	299	39	300	0
Black River	1	7	313	136	204	18303	1	18	21	168	22	60	142	8	2	9	305	1	16352	64	484	118	795	2
East Holland	0	1	74	58	90	9851	0	31	23	270	295	671	821	22	4	27	967	4	6169	44	985	859	3439	8
Fox Island	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	1	6	0
Georgina Creeks	0	0	8	9	10	2116	0	1	1	10	11	31	60	0	2	8	151	1	1631	0	133	121	630	0
Georgina Island	0	0	11	4	2	212	0	0	0	1	0	0	10	0	0	0	0	0	997	0	10	4	38	0
Hawkestone Creek	0	9	100	8	21	2130	0	1	1	7	1	10	9	0	0	3	34	0	2303	0	55	7	85	0
Hewitts Creek	0	0	0	5	9	1050	0	0	0	0	3	12	21	0	0	1	26	1	256	12	58	51	244	1
Innisfil Creeks	0	0	29	22	39	5860	1	5	7	42	12	31	60	1	0	6	157	0	2746	17	236	172	1271	0
Lovers Creek	0	0	19	7	16	2595	1	4	5	67	97	299	347	3	0	4	162	1	1578	23	231	102	432	2
Maskinonge River	0	0	0	21	29	4878	0	0	1	7	10	26	49	0	0	0	5	0	1020	0	94	40	168	0
Oro Creeks North	0	5	129	14	35	3271	0	1	2	14	50	156	233	3	0	5	55	0	2772	0	159	91	526	0
Oro Creeks South	0	0	0	14	38	2792	1	1	2	13	3	30	125	0	0	18	48	1	2169	0	78	33	372	0
Pefferlaw Brook	1	10	845	68	102	14542	0	14	16	207	6	14	65	0	1	9	452	1	11097	30	319	65	627	0
Ramara Creeks	0	0	45	16	34	7923	0	0	1	5	8	36	73	0	0	10	84	0	4672	22	156	55	590	0
Snake Island	0	0	0	2	0	31	0	1	0	8	0	0	0	0	0	0	0	0	93	0	0	0	0	0
Talbot River	0	0	164	7	22	4376	0	0	1	9	0	3	8	0	0	0	27	0	2221	9	62	4	99	0
Thorah Island	0	0	0	0	0	171	0	0	0	1	0	0	0	0	0	0	0	0	268	0	0	0	0	0
Upper Talbot River	0	0	178	15	35	12529	0	3	5	106	1	2	21	0	0	1	39	0	16006	0	215	18	280	0
Uxbridge Brook	0	3	196	49	70	9531	0	6	9	113	20	48	70	0	1	3	168	0	5026	12	228	81	498	0
West Holland	0	0	0	202	219	23084	0	15	10	171	54	159	270	4	2	9	450	3	8420	22	763	197	1137	0
Whites Creek	0	0	15	16	20	6948	0	0	1	12	2	8	20	0	0	0	10	0	3308	1	82	10	87	0
Grand Total	**3**	**38**	**2600**	**744**	**1105**	**154985**	**3**	**106**	**116**	**1302**	**761**	**1978**	**2888**	**44**	**14**	**126**	**3462**	**12**	**98213**	**282**	**5009**	**2332**	**12819**	**13**

Appendix 4. Change in land use and surface type in Lake Simcoe's watersheds, 2002/2003 to 2008 (ha). Negative numbers are shown in red

	Aggregate			Agriculture				Estate Residential			ICI				Manicured Open Space				Natural Heritage Feature	Rail	Road		Urban			
Subwatershed	Building	Paved	Unpaved	Building	Paved	Unpaved	Storm Pond	Building	Paved	Unpaved	Building	Paved	Unpaved	Storm Pond	Building	Paved	Unpaved	Storm Pond	Unpaved	Paved	Paved	Unpaved	Building	Paved	Unpaved	Storm Pond
Barrie Creeks	0	3	14	0	0	31	0	0	0	-6	4	19	-6	0	0	2	-15	0	-61	-1	1	0	23	0	-10	0
Beaver River	0	1	58	2	7	-382	0	0	-0	-6	3	2	-10	0	0	1	-6	0	308	0	2	0	-1	0	20	0
Black River	0	1	-6	-0	15	-275	1	2	2	-63	7	17	83	3	0	6	46	-1	326	-12	12	0	15	-0	-178	-1
East Holland	-0	0	-43	-5	0	-734	0	3	7	7	59	145	15	7	-1	-11	-31	0	71	-0	70	0	132	0	308	-0
Fox Island	0	0	0	-0	0	-0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Georgina Creeks	0	0	-12	-5	-1	-145	0	0	1	-1	3	4	25	0	-0	1	21	0	45	0	2	0	11	0	51	0
Georgina Island	0	0	6	1	2	9	0	0	0	1	0	-0	2	0	0	0	-2	0	-18	0	-0	0	0	0	-0	0
Hawkestone Creek	-0	-0	24	-0	-3	-34	-0	-0	-0	1	0	3	13	0	0	0	-1	0	-12	0	-1	0	1	0	10	0
Hewitts Creek	0	0	0	0	0	-98	0	-1	-0	-2	1	4	8	2	0	0	10	0	-37	-1	20	0	29	0	66	-1
Innisfil Creeks	-0	0	-39	-2	1	115	0	1	3	-8	2	5	8	0	-0	-0	-68	0	-90	-0	14	0	22	0	37	0
Lovers Creek	-0	0	3	-1	0	-200	0	1	2	26	22	66	56	3	-0	-1	-6	0	-61	-2	20	0	30	0	44	-2
Maskinonge River	0	0	0	-0	1	-39	0	-0	0	-2	1	3	1	0	-0	0	-23	0	16	0	4	0	7	-0	32	0
Oro Creeks North	0	1	67	-1	2	-163	-0	0	0	6	4	12	52	0	-0	1	-0	0	36	0	-3	0	1	0	-15	0
Oro Creeks South	0	0	0	-3	-6	-73	-0	1	4	20	1	6	6	0	0	3	-3	0	10	0	-1	0	5	-0	28	0
Pefferlaw Brook	0	1	-83	-5	6	-673	0	5	5	-36	1	2	28	0	1	3	242	0	346	18	9	0	8	0	122	0
Ramara Creeks	-0	0	28	-0	0	-148	0	-0	-0	1	1	7	11	0	0	1	17	0	6	1	8	-0	6	0	62	0
Snake Island	0	0	0	0	0	1	0	-0	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0
Talbot River	0	3	56	0	-1	16	0	0	0	2	0	1	13	0	-0	-2	-7	0	-55	0	1	0	-1	0	-26	0
Thorah Island	0	0	0	-0	0	-17	0	0	0	0	0	0	0	0	0	0	0	0	17	0	0	0	0	0	0	0
Upper Talbot River	0	3	51	-0	0	-4	0	-0	-0	14	0	-0	-0	0	0	1	3	0	-84	0	6	0	1	0	10	0
Uxbridge Brook	0	0	1	-0	5	-421	0	2	1	-15	6	7	23	0	0	1	20	0	307	-1	11	0	17	0	37	0
West Holland	-0	0	-8	13	3	-614	0	1	1	25	13	40	82	0	1	3	52	0	216	0	-0	5	38	-0	130	0
Whites Creek	0	0	0	1	2	-21	0	0	0	-0	-0	-1	32	0	0	0	0	0	-18	-5	-0	0	1	0	10	0
Total	**1**	**13**	**117**	**-7**	**34**	**-3869**	**0**	**17**	**24**	**-37**	**129**	**341**	**443**	**15**	**1**	**10**	**248**	**0**	**1267**	**-3**	**173**	**5**	**344**	**-0**	**739**	**-3**

Appendix 5. Change in land use and surface type in Lake Simcoe's watersheds, 2008 to 2013 (ha). Negative numbers are shown in red

	Aggregate			Agriculture				Estate Residential			ICI				Manicured Open Space				Natural Heritage Feature	Rail	Road		Urban			
Subwatershed	Building	Paved	Unpaved	Building	Paved	Unpaved	Storm Pond	Building	Paved	Unpaved	Building	Paved	Unpaved	Storm Pond	Building	Paved	Unpaved	Storm Pond	Unpaved	Paved	Paved	Unpaved	Building	Paved	Unpaved	Storm Pond
Barrie Creeks	-0	-3	-48	0	1	-15	0	-0	0	-1	-1	8	62	1	0	2	27	0	-34	-3	9	0	-10	0	3	0
Beaver River	-0	-1	28	1	83	-80	0	-0	1	6	0	7	29	0	-0	-1	-4	0	-67	-4	6	-0	3	0	-5	0
Black River	-1	-2	43	8	97	-50	-1	2	5	4	1	0	7	-2	0	-3	-23	1	-88	-4	16	-1	7	0	-21	2
East Holland	0	0	23	4	59	-159	-0	3	-3	23	20	45	-41	-4	-1	6	3	1	-32	-2	63	-0	46	0	-62	4
Fox Island	0	0	0	0	0	-6	0	0	0	0	0	0	0	0	0	0	0	0	-0	0	0	0	0	0	6	0
Georgina Creeks	-0	-0	-1	2	5	-11	0	-1	-1	-3	1	3	-11	0	0	2	20	1	-13	0	4	0	8	0	-5	0
Georgina Island	0	0	-1	-1	-1	-39	0	0	0	0	0	0	2	0	0	0	0	0	-3	0	0	0	4	0	38	0
Hawkestone Creek	-0	7	-1	-1	17	12	0	-0	0	-5	-0	2	-23	0	-0	2	-0	0	-17	0	7	0	0	0	-1	0
Hewitts Creek	0	0	0	0	8	-38	0	-0	-0	-6	2	5	6	-1	-0	1	9	1	-5	1	4	0	7	0	6	1
Innisfil Creeks	-0	-0	6	3	29	-106	1	0	2	5	2	-1	-15	0	0	2	35	0	-90	-0	18	0	15	0	94	-0
Lovers Creek	0	0	-1	-0	11	-14	1	-0	-0	-18	12	43	-39	-1	0	1	37	-0	-38	1	19	0	4	0	-19	2
Maskinonge River	0	0	0	0	21	-10	0	0	0	2	2	1	11	0	0	0	1	0	-30	0	3	-0	1	0	-3	0
Oro Creeks North	-0	5	-33	1	25	8	0	0	-0	-3	-1	21	-33	3	0	0	22	0	-34	0	10	0	4	2	2	0
Oro Creeks South	0	0	0	3	28	53	0	-3	-4	-37	-0	4	-6	0	-0	9	-19	-0	-30	0	3	-0	1	0	-2	0
Pefferlaw Brook	-0	7	65	5	63	66	0	-2	0	-3	1	0	-9	0	-0	1	-44	1	-112	-21	7	-0	7	0	-32	0
Ramara Creeks	0	0	1	-1	27	-42	0	0	0	2	3	-0	11	0	-0	2	4	0	-3	-0	19	-0	2	0	-24	-0
Snake Island	0	0	0	-1	0	-14	0	1	0	8	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0
Talbot River	-0	-3	-7	-1	16	-15	0	-0	0	1	-0	-1	-10	0	0	-2	9	0	4	-0	4	-0	-3	0	8	0
Thorah Island	0	0	0	-1	0	1	0	-0	0	0	0	0	0	0	0	0	0	0	-0	0	0	0	0	0	0	0
Upper Talbot River	-0	-4	10	1	19	-242	0	0	1	52	0	0	12	0	-0	-1	-4	0	146	0	-3	-0	-1	0	12	0
Uxbridge Brook	-0	1	18	3	43	-28	0	-1	1	-1	1	5	-14	0	-0	1	-9	0	-33	-0	2	-0	4	0	8	0
West Holland	0	0	-0	15	152	-511	0	-1	-2	-42	9	19	16	-7	-1	-2	36	3	-6	-1	58	-11	56	0	219	-0
Whites Creek	0	-0	0	-1	15	-36	0	-0	1	6	1	3	-26	0	0	-0	9	0	19	-6	6	0	1	0	9	0
Total	**-2**	**8**	**101**	**41**	**717**	**-1277**	**1**	**-2**	**2**	**-8**	**52**	**163**	**-71**	**-9**	**-2**	**21**	**110**	**7**	**-460**	**-40**	**255**	**-12**	**158**	**2**	**231**	**8**