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Supplementary materials

Investigation of the Long-Term Trends in the Streamflow due to Climate Change and Urbanization for a Great Lakes Watershed

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Table S1. Summary of the trend analysis for the temperature, precipitation, and evapotranspiration variables annually, seasonally, and monthly.

	Temperature						Precipitation						Evapotranspiration		
	Orangeville			**Georgetown**			Orangeville			Georgetown			Watershed average		
Time	Tau	*p*-value	Slope	Tau	p-value	Slope	Tau	*p*-value	Slope	Tau	*p*-value	Slope	Tau	*p*-value	Slope
January	–0.001	0.992	0.000	0.102	0.214	0.023	0.2580	0.0016	0.5464	0.0890	0.2780	0.1704	–0.184	0.023	–0.057
February	0.075	0.364	0.015	0.351	0.000	0.093	0.2166	0.0081	0.3970	0.1213	0.1388	0.2537	–0.172	0.033	–0.063
March	0.140	0.087	0.021	–0.008	0.927	–0.001	0.0157	0.8512	0.0378	0.0211	0.7999	0.0370	–0.129	0.110	–0.049
April	0.040	0.630	0.006	0.088	0.285	0.012	0.0083	0.9233	0.0140	0.1193	0.1457	0.2593	0.119	0.141	0.046
May	0.122	0.137	0.018	0.035	0.670	0.006	0.1859	0.0231	0.3400	0.2108	0.0100	0.4938	0.257	0.001	0.157
June	0.080	0.330	0.008	0.526	0.000	0.065	0.1362	0.0963	0.2435	0.0882	0.2825	0.2250	0.178	0.028	0.097
July	0.149	0.069	0.014	0.319	0.000	0.036	0.0812	0.3228	0.2150	0.0174	0.8353	0.0594	0.141	0.081	0.086
August	0.108	0.189	0.011	0.310	0.000	0.037	–0.1010	0.2180	–0.2116	–0.1126	0.1695	–0.2964	0.065	0.422	0.027
September	0.205	0.012	0.020	0.446	0.000	0.055	0.0990	0.2276	0.1667	0.0489	0.5531	0.1108	–0.025	0.759	–0.015
October	–0.057	0.487	–0.007	0.381	0.000	0.050	0.2468	0.0026	0.7264	0.1391	0.0894	0.3906	–0.002	0.988	0.000
November	–0.048	0.556	–0.007	0.172	0.036	0.022	0.2455	0.0027	0.5352	0.0745	0.3641	0.1791	–0.178	0.027	–0.041
December	0.106	0.198	0.018	0.234	0.004	0.042	0.2944	0.0003	0.8111	0.0791	0.3354	0.1636	–0.165	0.041	–0.040
Winter	0.161	0.013	0.013	0.275	0.001	0.038	0.2120	0.0096	0.9205	0.1188	0.1471	0.5000	–0.208	0.010	–0.156
Spring	0.223	0.006	0.016	0.318	0.000	0.028	0.1164	0.1557	0.4158	0.1892	0.0208	1.0167	0.285	0.000	0.334
Summer	0.223	0.006	0.016	0.413	0.000	0.040	0.0224	0.7882	0.0857	–0.0145	0.8631	–0.1086	0.130	0.107	0.138
Autumn	0.006	0.943	0.000	0.388	0.000	0.039	0.3259	0.0001	1.8659	0.1371	0.0943	0.6586	–0.146	0.071	–0.082
Annual	0.164	0.046	0.009	0.441	0.000	0.033	0.3694	0.0000	3.3775	0.1876	0.0219	1.6972	0.071	0.382	0.128

Table S2. Summary of the trend analysis of the streamflow. Period A, 1920–1939; Period B, 1940–1959; Period C, 1960–1979; Period D, 1980–1999; Period E, 2000–2019.

	Period A			**Period B**			**Period C**			**Period D**			**Period E**		
													Streamflow		
	Tau	*p*-value	Sen's slope	Tau	*p*-value	Sen's slope	Tau	*p*-value	Sen's slope	Tau	*p*-value	Sen's slope	Tau	*p*-value	Sen's slope
Cataract	0.187	0.29	0.009	0.167	0.327	0.012	0.404	0.016	0.034	–0.116	0.495	–0.01	0.301	0.069	0.018
Orangeville										–0.258	0.132	–0.005	0.463	0.004	0.01
Erindale							0.434	0.009	0.114						
WB Norval							0.404	0.016	0.013	–0.242	0.146	–0.013	0.147	0.386	0.008
								Winter							
Cataract	0.241	0.161	0.046	0.058	0.746	0.017	0.368	0.029	0.041	0.058	0.746	0.004	0.284	0.086	0.024
Orangeville										–0.059	0.753	–0.001	0.347	0.034	0.011
Erindale							0.411	0.011	0.189						
WB Norval							0.27	0.115	0.018	0.042	0.823	0.007	0.063	0.725	0.008
								Spring							
Cataract	0.112	0.528	0.008	0.054	0.769	0.002	0.439	0.008	0.068	–0.053	0.773	–0.013	0.322	0.052	0.047
Orangeville										0.018	0.945	0.001	0.442	0.006	0.015
Erindale							0.263	0.113	0.213						
WB Norval							0.411	0.016	0.05	–0.011	0.975	–0.002	0.19	0.26	0.021
								Summer							
Cataract	–0.06	0.752	–0.002	0.115	0.512	0.005	0.333	0.049	0.027	–0.211	0.209	–0.015	0.232	0.165	0.022
Orangeville										–0.17	0.332	–0.004	0.453	0.005	0.009
Erindale							0.364	0.027	0.07						
WB Norval							0.252	0.143	0.009	–0.269	0.105	–0.011	0.126	0.461	0.003
								Autumn							
Cataract	0.177	0.309	0.01	0.076	0.671	0.004	0.359	0.036	0.034	–0.296	0.074	–0.022	0.147	0.386	0.01
Orangeville										–0.34	0.046	–0.009	0.168	0.319	0.006
Erindale							0.253	0.128	0.098						
WB Norval							0.228	0.186	0.018	–0.368	0.024	–0.031	0.126	0.461	0.008

Table S3. Summary of the trend analysis of the baseflow. Period A, 1920–1939; Period B, 1940–1959; Period C, 1960–1979; Period D, 1980–1999; Period E, 2000–2019.

		Period A			**Period B**			**Period C**			**Period D**			**Period E**		
Baseflow																
		Tau	*p*-value	Sen's slope	Tau	*p*-value	Sen's slope	Tau	*p*-value	Sen's slope	Tau	*p*-value	Sen's slope	Tau	*p*-value	Sen's slope
Annual																
Cataract		0.24	0.164	0.004	0.19	0.26	0.007	0.462	0.005	0.032	–0.147	0.386	–0.007	0.263	0.113	0.013
	Orangeville										–0.146	0.406	–0.003	0.474	0.003	0.007
Erindale								0.358	0.028	0.066						
	WB Norval							0.333	0.049	0.011	–0.284	0.086	–0.011	0.19	0.26	0.007
Winter																
Cataract		0.345	0.041	0.039	0.042	0.823	0.005	0.275	0.108	0.027	0.011	0.975	0	0.19	0.26	0.015
	Orangeville										–0.158	0.368	–0.004	0.379	0.02	0.007
Erindale								0.295	0.074	0.112						
	WB Norval							0.064	0.73	0.003	–0.2	0.233	–0.012	0.011	0.975	0.001
Spring																
Cataract		0.053	0.783	0.004	0.168	0.319	0.017	0.427	0.01	0.044	0.021	0.924	0.002	0.295	0.074	0.026
	Orangeville										0.193	0.267	0.006	0.505	0.001	0.011
Erindale								0.358	0.028	0.174						
	WB Norval							0.509	0.002	0.038	0.042	0.823	0.003	0.158	0.351	0.015
Summer																
Cataract		–0.158	0.368	–0.004	0.211	0.209	0.011	0.427	0.01	0.024	–0.116	0.501	–0.005	0.337	0.04	0.023
	Orangeville										–0.018	0.945	0	0.432	0.007	0.009
Erindale								0.295	0.074	0.295						
	WB Norval							0.252	0.143	0.007	–0.179	0.288	–0.004	0.179	0.288	0.005
Autumn																
Cataract		0.216	0.211	0.009	0.195	0.243	0.012	0.462	0.005	0.032	–0.232	0.165	–0.014	0.158	0.351	0.008
	Orangeville										–0.24	0.164	–0.003	0.232	0.165	0.005
Erindale								0.347	0.034	0.082						
	WB Norval							0.287	0.093	0.013	–0.368	0.024	–0.021	0.105	0.542	0.005

Table S4. Summary of the FDC 10% exceedance and 10:90% exceedance ratio. Period A, 1920–1939; Period B, 1940–1959; Period C, 1960–1979; Period D, 1980–1999; Period E, 2000–2019.

Period	Annual	Winter	Spring	Summer	Autumn
Cataract					
10% exceedance					
POR	3.11	4.31	4.57	1.65	2.11
A	3.17	5.15	4.64	1.15	1.90
B	3.00	3.99	5.04	1.39	2.01
C	2.76	3.43	4.19	1.61	2.11
D	3.07	3.79	3.91	1.78	2.49
E	3.31	3.51	4.69	2.04	2.25
10:90% exceedance					
POR	4.42	5.85	5.04	3.03	2.76
A	5.09	7.91	5.46	2.26	2.79
B	4.82	5.64	6.59	2.73	2.63
C	3.84	4.57	4.77	2.72	2.77
D	3.30	3.64	3.55	2.21	2.44
E	3.25	3.11	3.49	2.41	2.21
Erindale					
10% exceedance					
POR	15.60	25.25	21.74	5.97	10.60
C	16.30	27.60	23.75	5.54	9.88
10:90% exceedance					
POR	6.64	8.46	6.82	3.23	4.25
C	6.68	9.86	6.99	2.87	3.92
Orangeville					
10% exceedance					
POR	1.00	1.17	1.39	0.64	0.78
D	0.94	1.17	1.17	0.58	0.81
E	1.08	1.13	1.52	0.72	0.77
10:90% exceedance					
POR	3.66	3.76	4.54	2.74	2.56
D	3.90	3.69	4.42	2.78	3.26
E	3.15	3.17	3.69	2.30	2.27
WB Norval					
10% exceedance					
POR	2.77	3.86	3.99	1.07	1.94
C	2.74	4.13	4.178	0.951	1.68
D	2.75	4.035	3.53	1.24	2.095
E	2.8	3.345	4.185	1.08	1.93
10:90% exceedance					
POR	7.05	7.61	6.63	3.26	4.90
C	7.33	8.69	7.64	3.03	4.59
D	7.16	8.52	6.10	3.88	5.36
E	6.67	5.69	5.83	3.05	4.66

Table S5. Summary of the BFI for different periods. Period A, 1920–1939; Period B, 1940–1959; Period C, 1960–1979; Period D, 1980–1999; Period E, 2000–2019.

	Period A	**Period B**	**Period C**	**Period D**	**Period E**
Annual					
Cataract	0.559	0.557	0.635	0.675	0.686
Orangeville				0.622	0.667
Erindale			0.515		0.574
WB Norval			0.523	0.539	0.571
Winter					
Cataract	0.530	0.4975	0.5806	0.599	0.647
Orangeville				0.576	0.639
Erindale			0.424		0.540
WB Norval			0.459	0.465	0.520
Spring					
Cataract	0.486	0.4977	0.5787	0.663	0.637
Orangeville				0.587	0.602
Erindale			0.505		0.552
WB Norval			0.514	0.567	0.559
Summer					
Cataract	0.679	0.6852	0.7402	0.753	0.770
Orangeville				0.670	0.739
Erindale			0.691		0.638
WB Norval			0.631	0.586	0.671
Autumn					
Cataract	0.693	0.6843	0.725	0.738	0.747
Orangeville				0.690	0.739
Erindale			0.605		0.623
WB Norval			0.586	0.577	0.614

Table S6. Summary of the POT analysis parameters and return level for 2 years, 10 years, 20 years, 100 years, and its derivative. Period A, 1920–1939; Period B, 1940–1959; Period C, 1960–1979; Period D, 1980–1999; Period E, 2000–2019.

	Scale	Shape	2-year	10-year	20-year	100-year	100/2 year	EVI
Cataract								
POR	4.78	0.13	23.68	36.39	42.77	60.07	2.54	0.35
Period A	7.46	–0.01	28.33	39.74	44.57	55.63	1.96	0.29
Period B	5.34	0.13	27.19	41.71	48.98	68.70	2.53	0.35
Period C	4.71	–0.06	18.96	25.01	27.44	32.70	1.73	0.24
Period D	3.64	0.15	17.97	27.65	32.58	46.18	2.57	0.35
Period E	2.94	0.07	15.19	21.19	23.97	30.97	2.04	0.28
Winter	5.44	0.11	30.05	44.24	51.18	69.51	2.31	0.32
Summer	0.64	0.37	6.98	12.45	16.00	28.80	4.12	0.44
Spring	4.60	0.12	27.33	39.72	45.81	61.98	2.27	0.31
Autumn	1.59	0.29	8.51	14.52	18.13	29.95	3.52	0.41
Erindale								
POR	16.12	0.22	118.25	189.93	229.39	347.50	2.94	0.38
Period C	15.33	0.22	117.65	188.36	227.43	344.82	2.93	0.38
Winter	17.02	0.13	126.66	182.59	210.65	286.76	2.26	0.31
Summer	4.32	0.39	40.57	78.16	103.05	194.28	4.79	0.48
Spring	16.97	0.23	148.47	240.13	291.60	448.93	3.02	0.38
Autumn	11.04	0.52	94.48	219.24	314.98	730.51	7.73	0.57
Orangeville								
POR	0.95	0.14	5.24	7.75	9.02	12.46	2.38	0.32
Period D	0.87	0.23	5.34	8.52	10.30	15.68	2.93	0.37
Period E	1.02	0.09	5.29	7.61	8.72	11.60	2.19	0.30
Winter	1.13	0.13	6.68	9.78	11.33	15.49	2.32	0.32
Summer	0.55	0.08	2.96	4.18	4.76	6.23	2.10	0.29
Spring	0.97	0.06	5.68	7.71	8.66	11.02	1.94	0.26
Autumn	0.36	0.23	2.94	4.50	5.37	8.01	2.73	0.35
WB Norval								
POR	2.02	0.09	13.22	18.36	20.82	27.19	2.06	0.28
Period C	2.36	0.04	13.80	18.54	20.68	25.93	1.88	0.26
Period D	2.01	0.14	14.32	20.84	24.14	33.19	2.32	0.31
Period E	1.78	0.06	11.30	15.06	16.79	21.07	1.86	0.25
Winter	2.47	0.02	15.09	19.60	21.60	26.37	1.75	0.23
Summer	1.22	0.28	7.93	13.60	16.94	27.65	3.49	0.42
Spring	1.91	0.09	14.42	19.55	22.01	28.36	1.97	0.26
Autumn	1.24	0.19	13.50	15.91	15.91	22.87	1.69	0.15

Table S7. Summary of the trend analysis for the period 1971–2019.

	Orangeville			**Georgetown**			**Orangeville**			**Georgetown**			**Watershed average**		
	Tau	*p*-value	Sen's slope	Tau	*p*-value	Sen's slope	Tau	*p*-value	Sen's slope	Tau	*p*-value	Sen's slope	Tau	*p*-value	Sen's slope
	Temperature						Precipitation						Evapotranspiration		
Annual	0.224	0.023	0.02	0.512	0	0.059	0.119	0.231	1.453	0.134	0.176	1.78	0.106	0.29	0.36
Winter	0.206	0.038	0.02	0.327	0.001	0.068	–0.052	0.605	–0.285	0.138	0.165	0.748	–0.094	0.351	–0.103
Spring	0.252	0.011	0.02	0.252	0.011	0.02	0.174	0.079	0.842	0.173	0.08	1.292	0.362	0	0.711
Summer	0.252	0.011	0.02	0.514	0	0.071	0.011	0.918	0.047	–0.005	0.966	–0.058	0.043	0.67	0.055
Autumn	0.026	0.803	0.004	0.43	0	0.061	0.003	0.979	0.016	0.059	0.558	0.358	–0.279	0.005	–0.246

Table S8. Summary of the trend analysis for the period 1971–2019.

Period	**Cataract**			WB Norval		
	Tau	*p*-value	Sen's slope	Tau	*p*-value	Sen's slope
Annual	0.219	0.027	0.006	0.049	0.625	0.001
Winter	0.202	0.042	0.006	0.088	0.379	0.004
Spring	0.237	0.017	0.014	0.095	0.339	0.005
Summer	0.187	0.060	0.005	0.057	0.569	0.001
Autumn	0.065	0.518	0.002	0.009	0.938	0.001