Technical Reports in Support of the Duffins Creek and Carruthers Creek Watershed Plan

1. Dry and Wet Weather Modelling of Water Quality Under Alternative Land Use Scenarios in the Duffins and Carruthers Creek Watershed: A Simple Spreadsheet Approach
2. Duffins Creek Watershed Hydrogeology and Assessment of Land Use Change on the Groundwater Flow System
3. Duffins Creek Hydrology Update
4. Agricultural Non-Point Source (AGNPS) Modelling of the Duffins and Carruthers Creek Watersheds
5. Duffins and Carruthers Creeks Low Flow Management Study
6. Water Budget in Urbanizing Watersheds, Duffins Creek Watershed
7. Technical Analysis and Integration Process, Summary Report
8. Ratings Report for the 2002 Duffins and Carruthers Creek Watersheds Report Card
9. Water Quality Modelling Based on Changes in Water Quantity, Final Report.
10. A Watershed Plan for Duffins Creek and Carruthers Creek - Executive Summary

If you would like to receive a CD copy of the Duffins and Carruthers Watershed Plan and State of the Watershed reports please contact Toronto and Region Conservation at 416-661-6600.

Dry and Wet Weather Modelling of Water Quality Under Alternative Land Use Scenarios in the Duffins and Carruthers Creek Watersheds: A Simple Spreadsheet Approach

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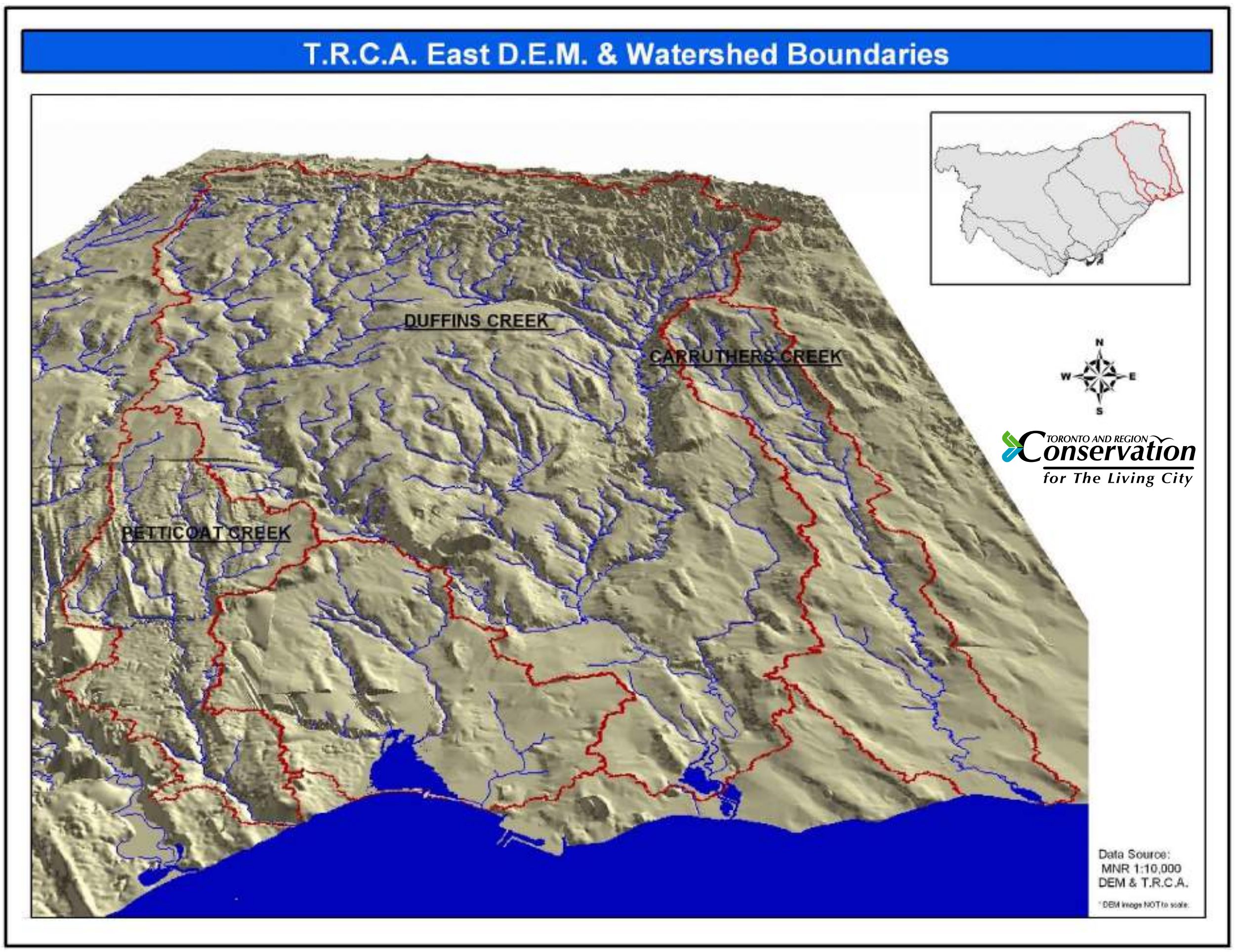
January 2003

Duffins Creek Watershed

Hydrogeology
and
Assessment of land use change on the groundwater flow system



For: **Toronto and Region Conservation**
Gary Bowen

By: **R.E. Gerber**
Gerber Geosciences Inc.

March 10, 2003

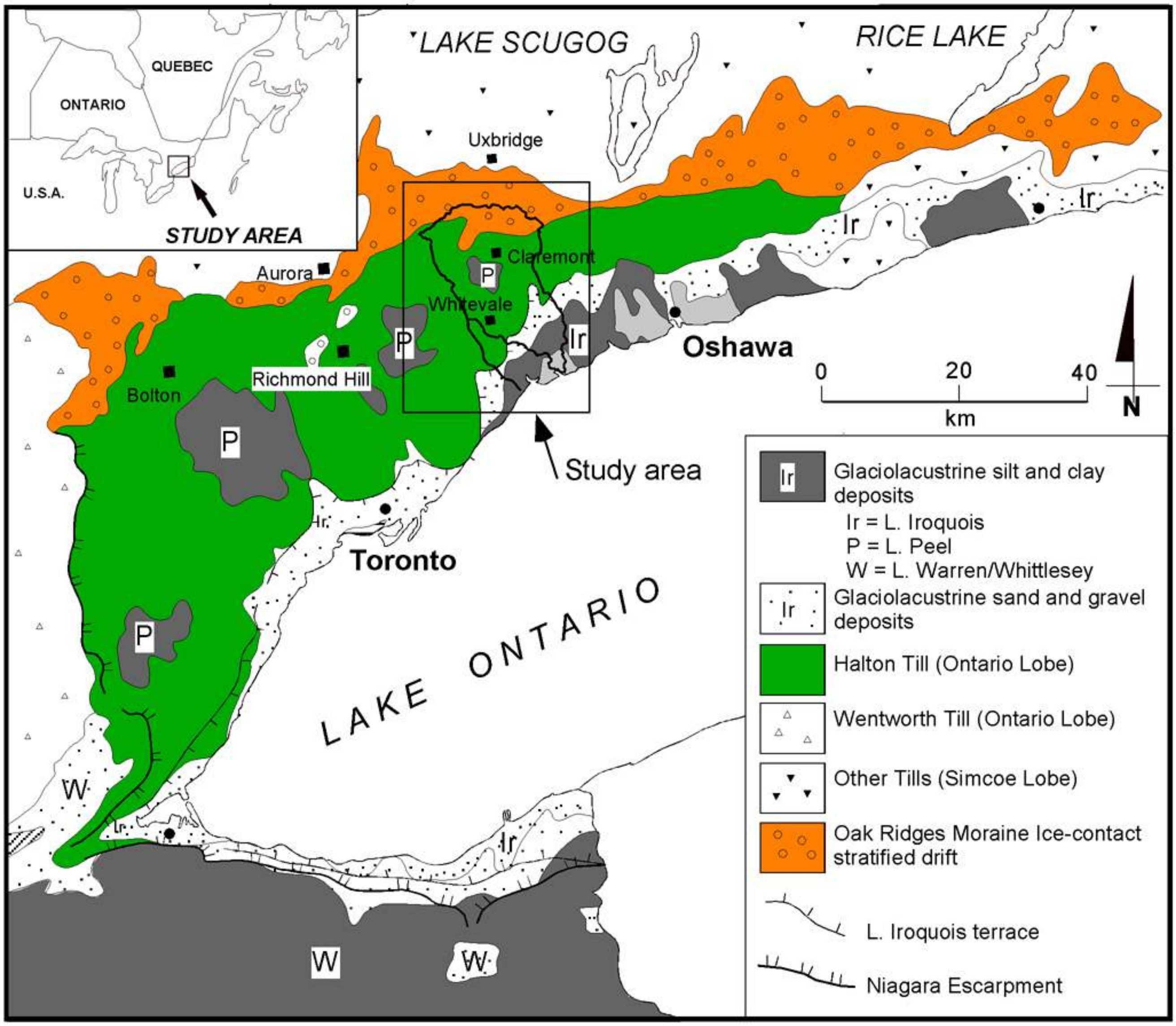


Figure 1: Study area and regional geologic setting. Surficial deposits from Barnett et al. (1991).

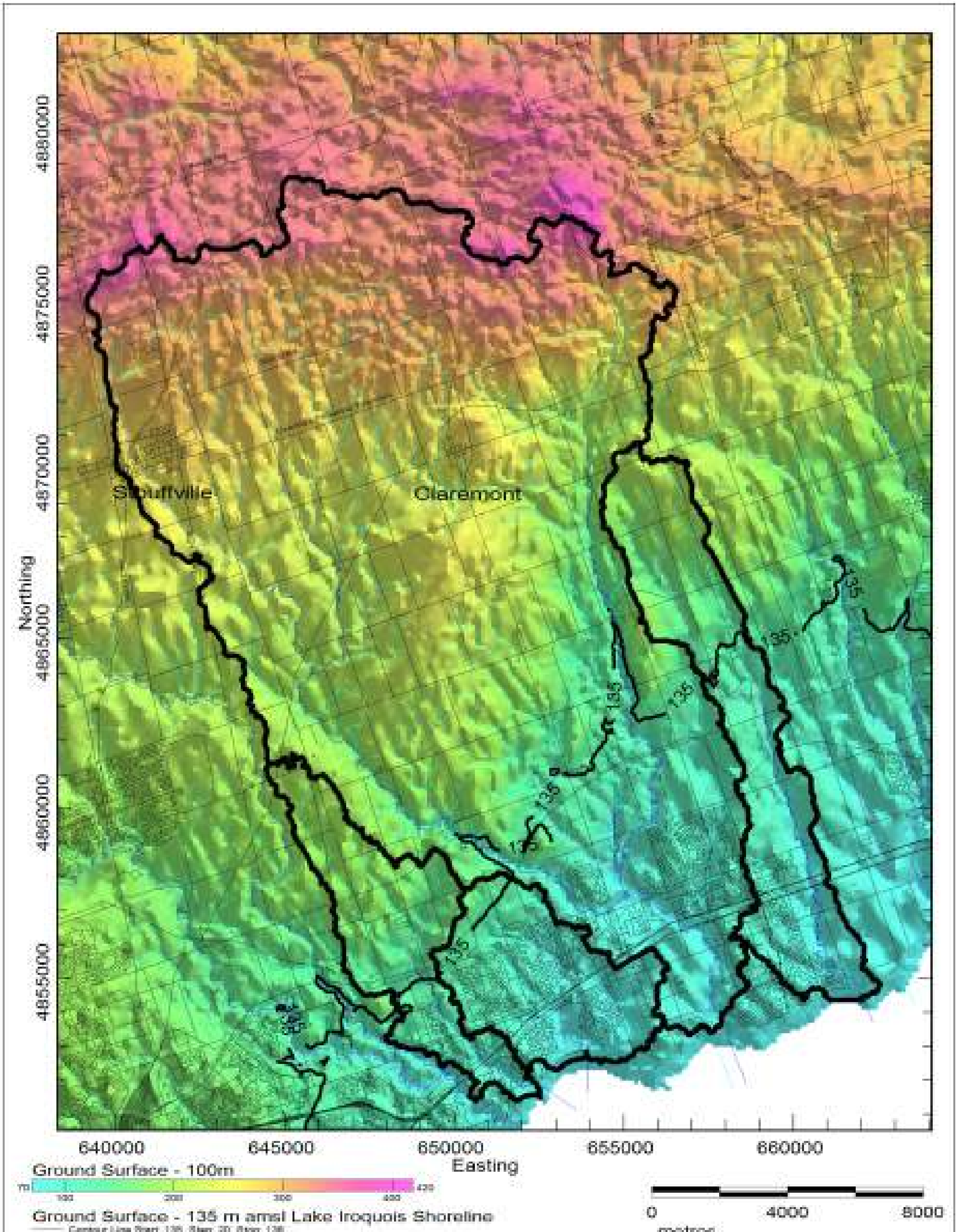


Figure 2: Ground surface topography. From MNR 10m DEM re-sampled to 100m grid.

Table 1. Annual water balance summary for the Duffins watershed area from existing information.

Parameter	mm/year	Source
Precipitation	864	Stouffville WPCP #6158084 (1972-1991)
Rain	709	Stouffville WPCP #6158084 (1972-1991)
Snowmelt	155	(1); Stouffville WPCP #6158084 (1972-1991)
Potential Evapotranspiration	608	(1); Stouffville WPCP #6158084 (1972-1991)
	584-610	Brown et al., 1980.
Actual Evapotranspiration	533-559	Brown et al., 1980.
	552	Morton, 1983.
Streamflow	357	1949-1997 (n=43); Duffins Creek at Pickering. (02HC006/049; 250 km^2).

Note:

Stouffville municipal groundwater pumping = 4170 m^3/d in 1990.
(6 mm/year over drainage area of 250 km^2).

(1) calculated using method of Johnstone and Louie, 1983.

Precipitation data from Meteorological Service of Canada.

Snowmelt reported as water equivalent.

Streamflow data from Water Survey of Canada, 1992.

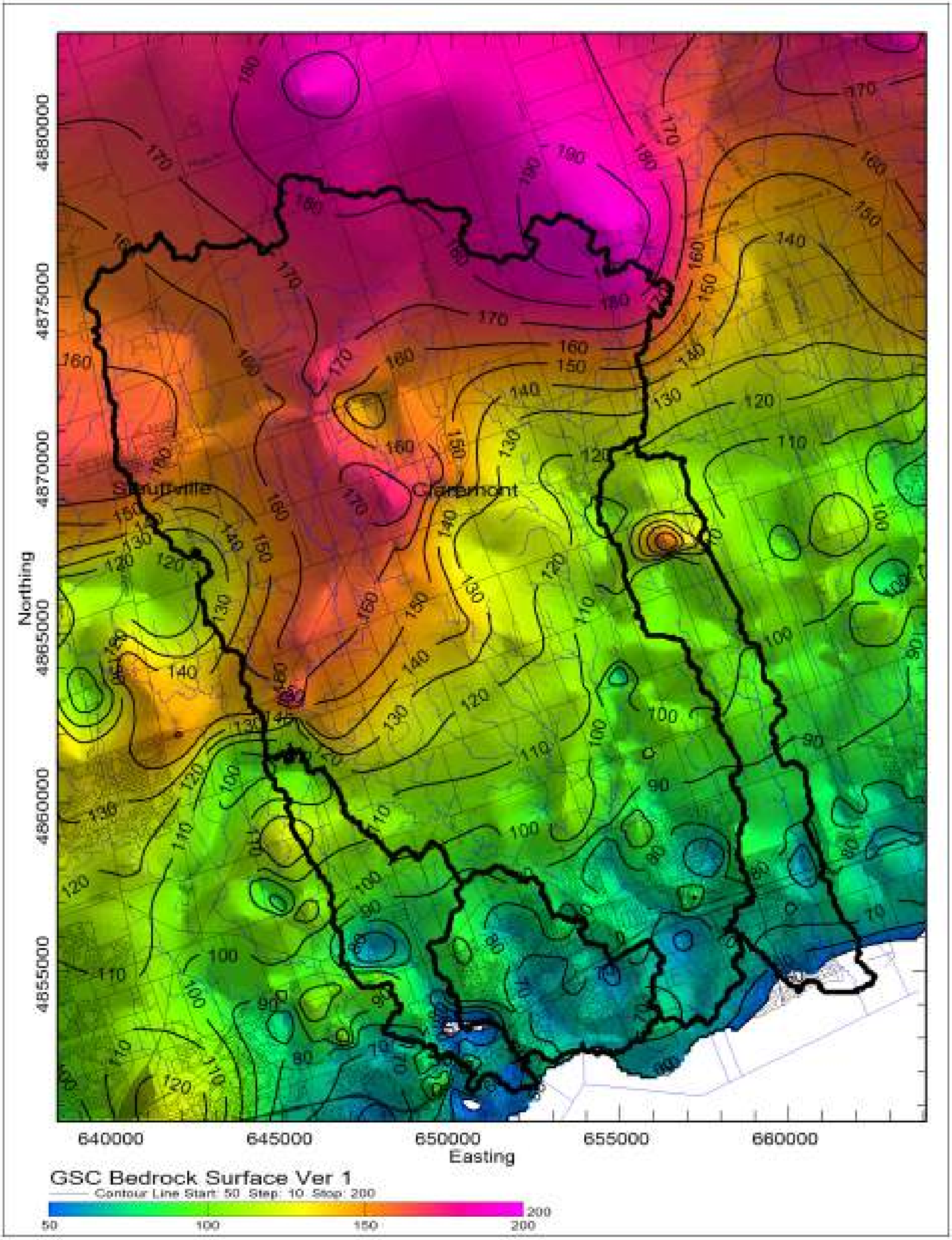


Figure 3: Bedrock surface topography. Bedrock surface from Brennand et al., 1998 (30 m grid) re-sampled to a 100 m grid.

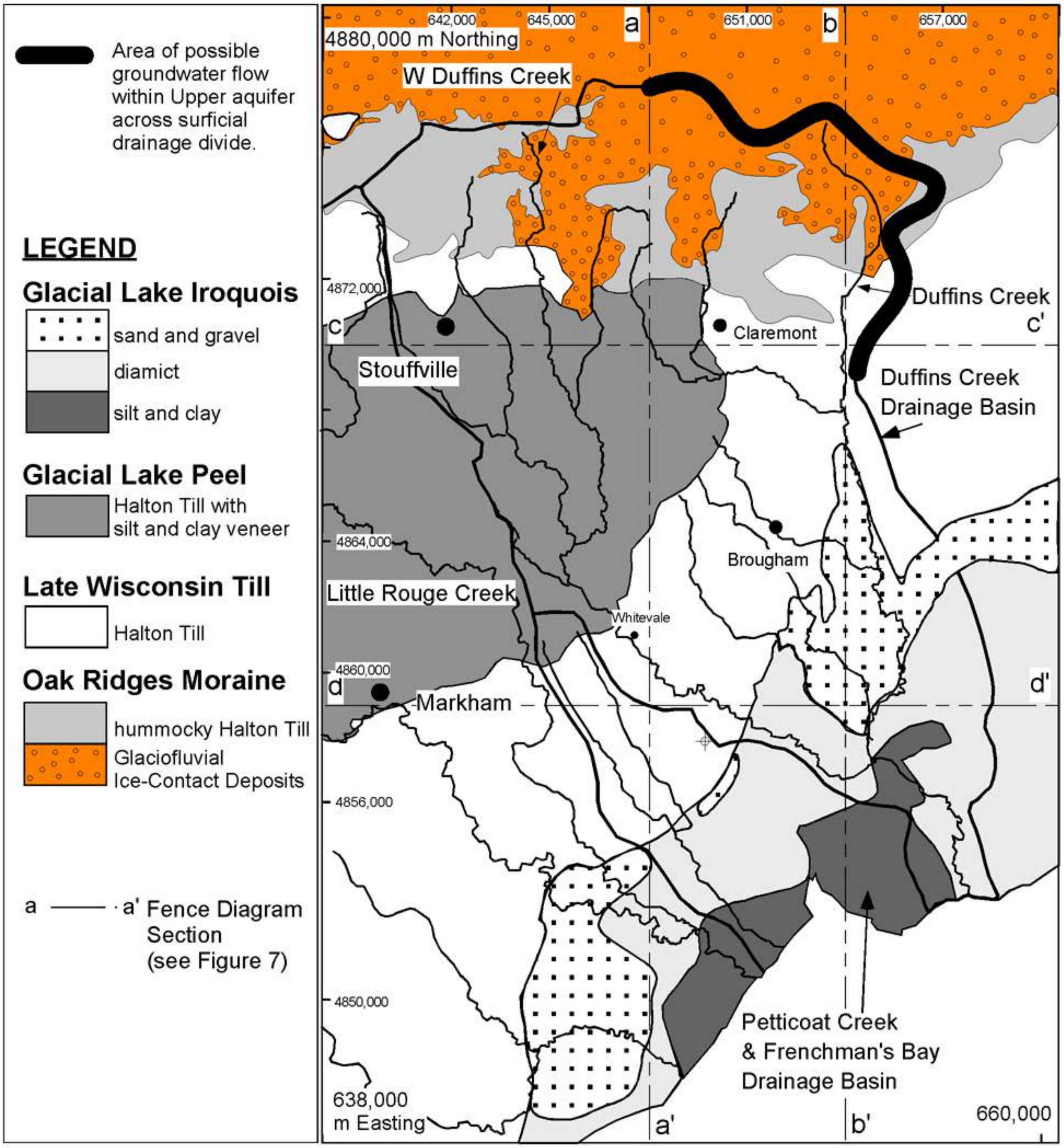


Figure 4: Simplified surficial geology for study area. From Sharpe and Barnett (1997) and J. Westgate (unpublished data) as described in Gerber and Howard (2000).

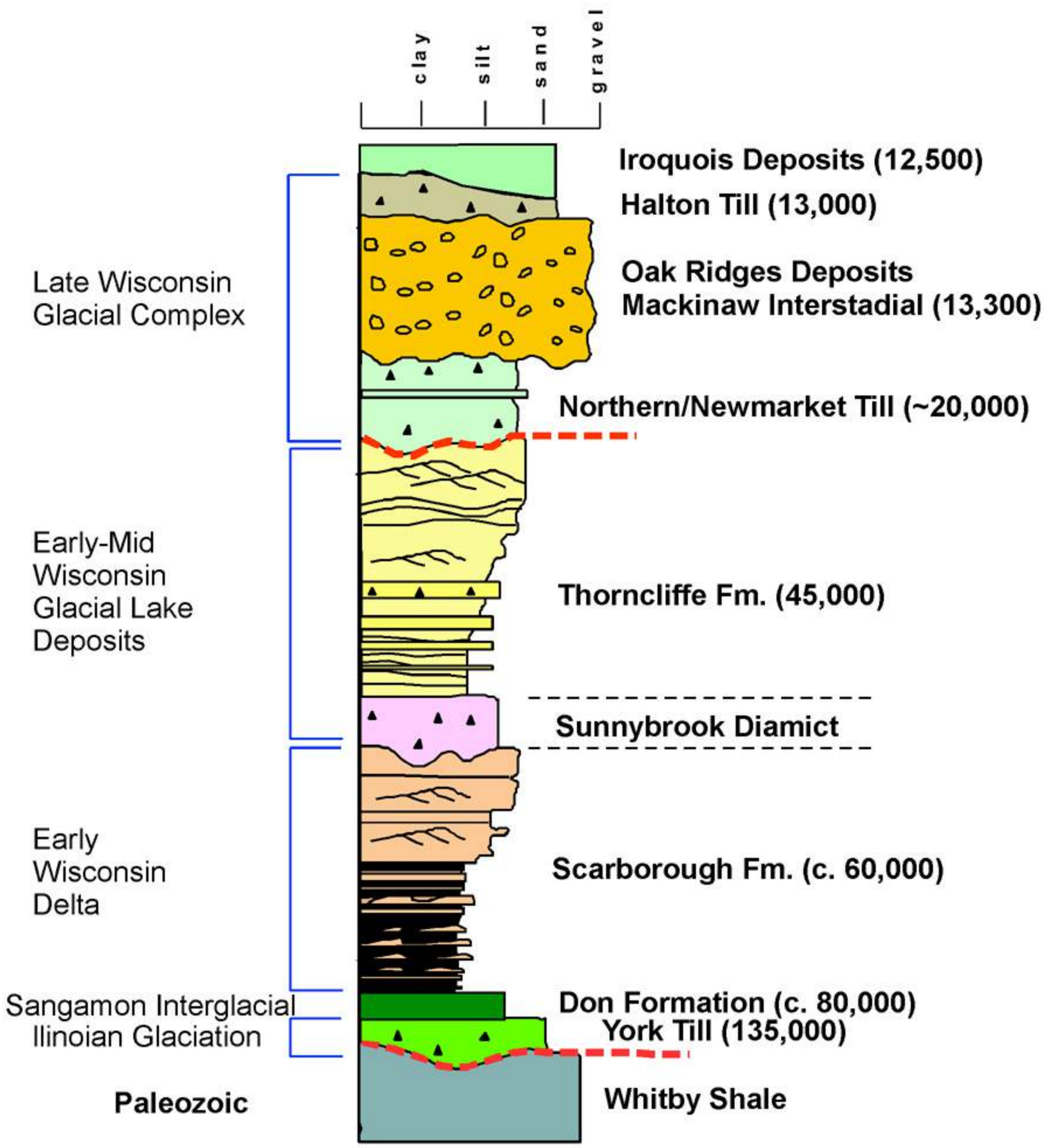


Figure 5: Quaternary deposits found in the Toronto area. Figure from Eyles (2002).

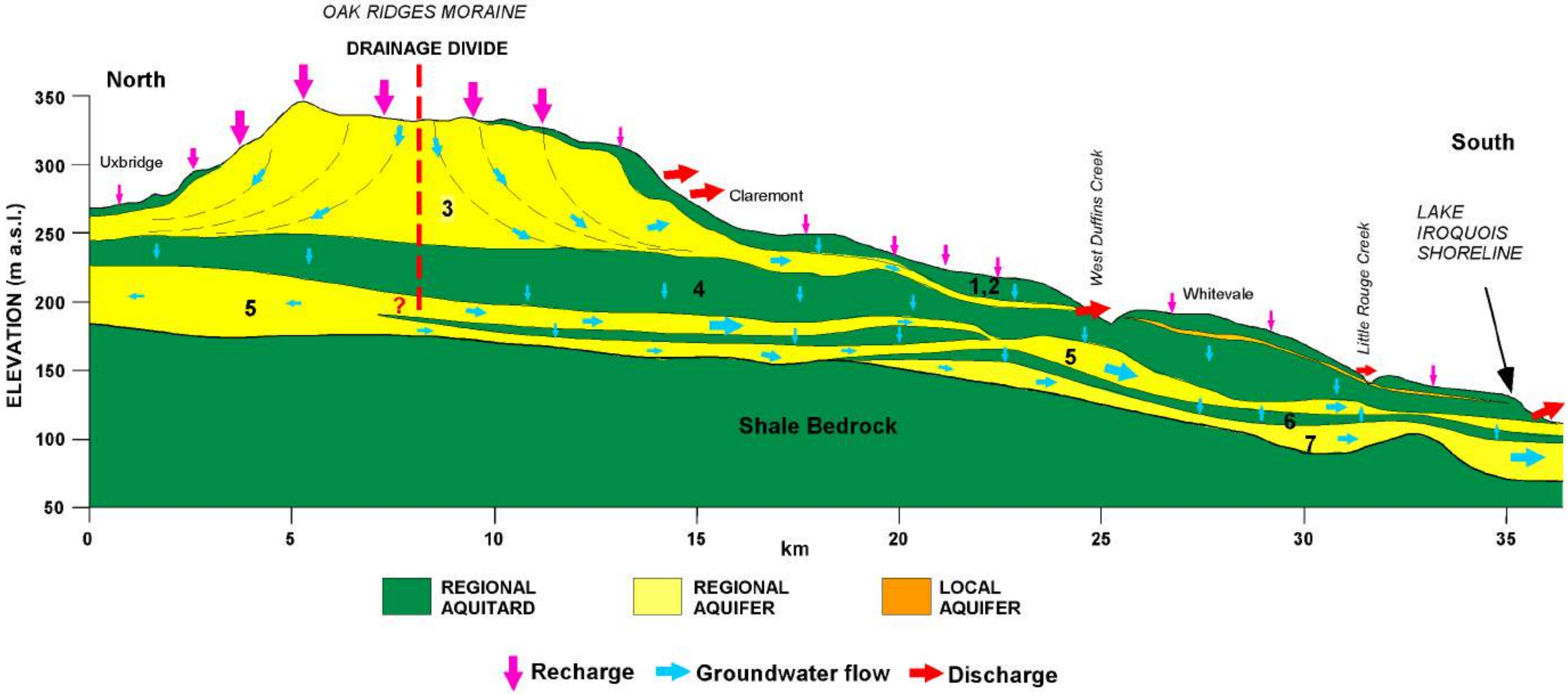
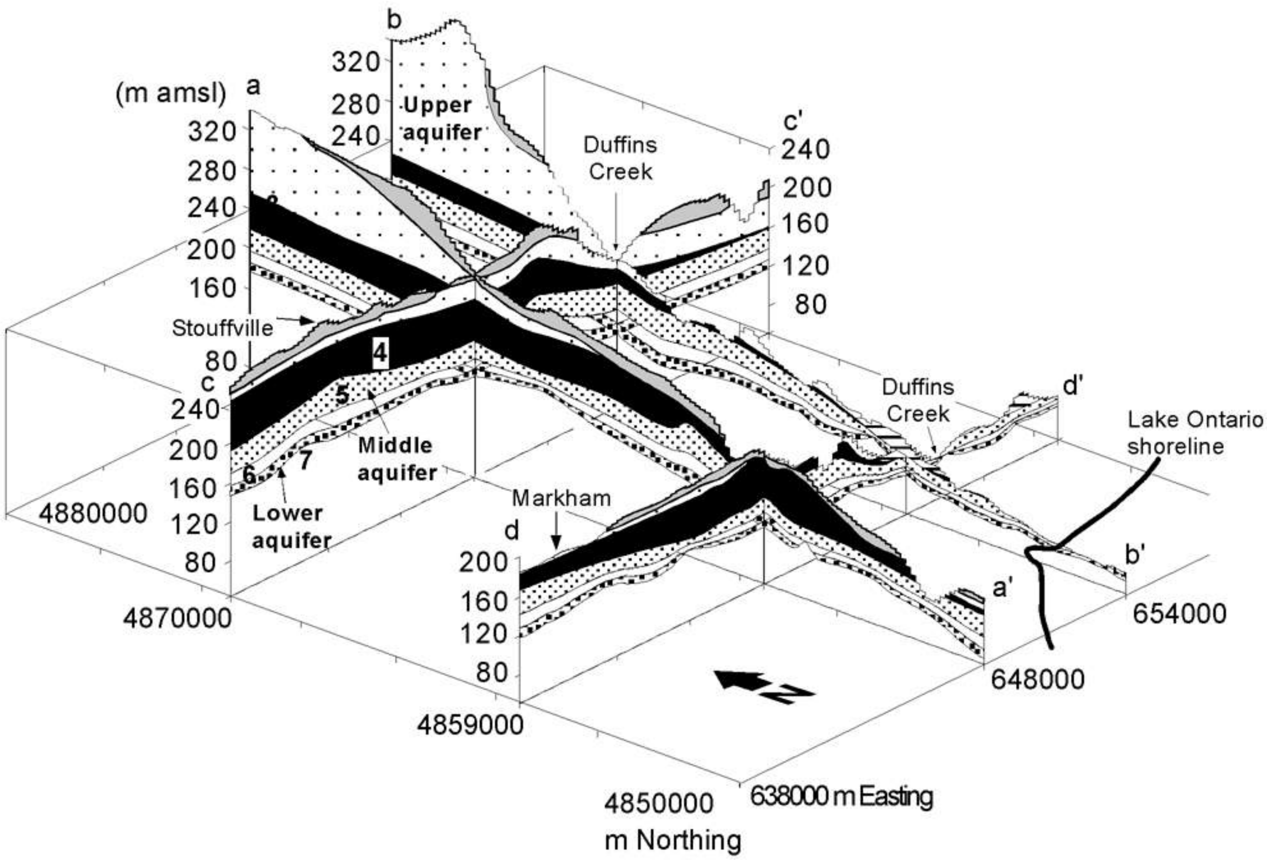


Figure 6: Cross section through the Duffins Creek watershed showing conceptual groundwater flow system.



Late Wisconsinan	Model#1 Layer #
Lake Iroquois	**1,2**
Halton Till	**1,2**
Mackinaw Interstadial/Oak Ridges Complex (**Upper aquifer)** Glaciofluvial and glaciolacustrine with sand and gravel outwash.	**3**
Northern/Newmarket till (23-18,000 y BP)	**4**
Middle Wisconsinan	
Thorncliffe Fm. (**Middle aquifer**) Deltaic sand and lacustrine silt and clay interbedded with diamict (<50,000 y BP)	**5**
Early Wisconsinan	
Sunnybrook Diamict	**6**
Scarborough Fm. (**Lower Aquifer**) Deltaic sands and glaciolacustrine silt and clay (~70,000 y BP)	**7**

Figure 7: Duffins watershed fence diagram (from Gerber and Howard, 2002).

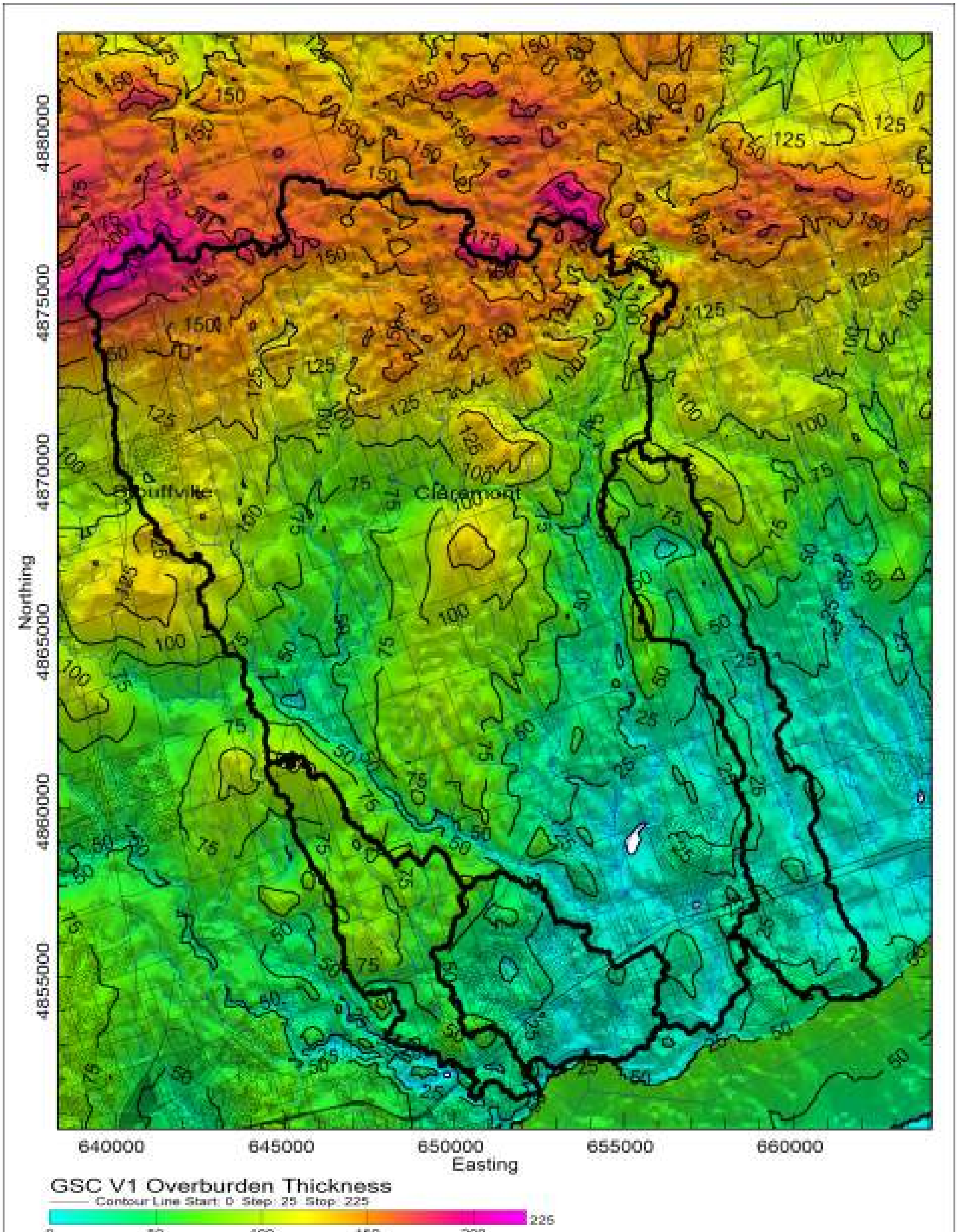


Figure 8: Overburden thickness (m). MNR 10 m DEM re-sampled to 100 m grid minus bedrock from Brennand et al. (1998; 10 m grid) re-sampled to 100 m grid.

Table 2

a) Summary of unit recharge rates (mm/year) from other studies.

	Gerber 1994	Meriano 1999	Hunter 1996	Smart 1994	Singer 1981	IWA, 1994e Site EE11 2-D	IWA, 1994e Site EE11 3-D	M.M. Dillon 1990 Site P1 3-D
Oak Ridges Moraine								
ice contact	300-400	400	300-400	350	280-380			
hummocky till		335						
Halton Till Plain	150-250	150-200		170-250	150-200	126	189	100-150
Glacial Lake Peel								
silty clay		35		50				
sand		200						
Glacial Lake Iroquois								
sand and gravel		200		150				
clay and silt				0-40	50-100			
diamict					50-100			
Urban		50		0-40				

Note: Hunter et al. (1996) estimate for Oak Ridges Moraine > 275 m amsl.

b) Numerical model calibrated recharge for the study area (Gerber and Howard, 2000).

	total area km^2	recharge area km^2	% of recharge area	recharge mm/year	recharge m^3/d	% of total recharge
Duffins Basin	282					
Petticoat Basin	54					
Oak Ridges Moraine						
ice-contact	40	35	13%	400	38,800	31%
hummocky till	39	36	13%	325	31,800	25%
Halton Till Plain	111	85	30%	150	34,900	27%
Glacial Lake Peel	58	50	18%	50	6,800	5%
Glacial Lake Iroquois						
sand and gravel	24	20	7%	200	10,800	9%
silt and clay	34	32	11%	25	2,200	2%
diamict	30	25	9%	25	1,700	1%
	336	282	100%		127,000	100%

recharge area = total area minus area of river & river valley cells where discharge occurs.
see Figure 4 for various deposit locations.

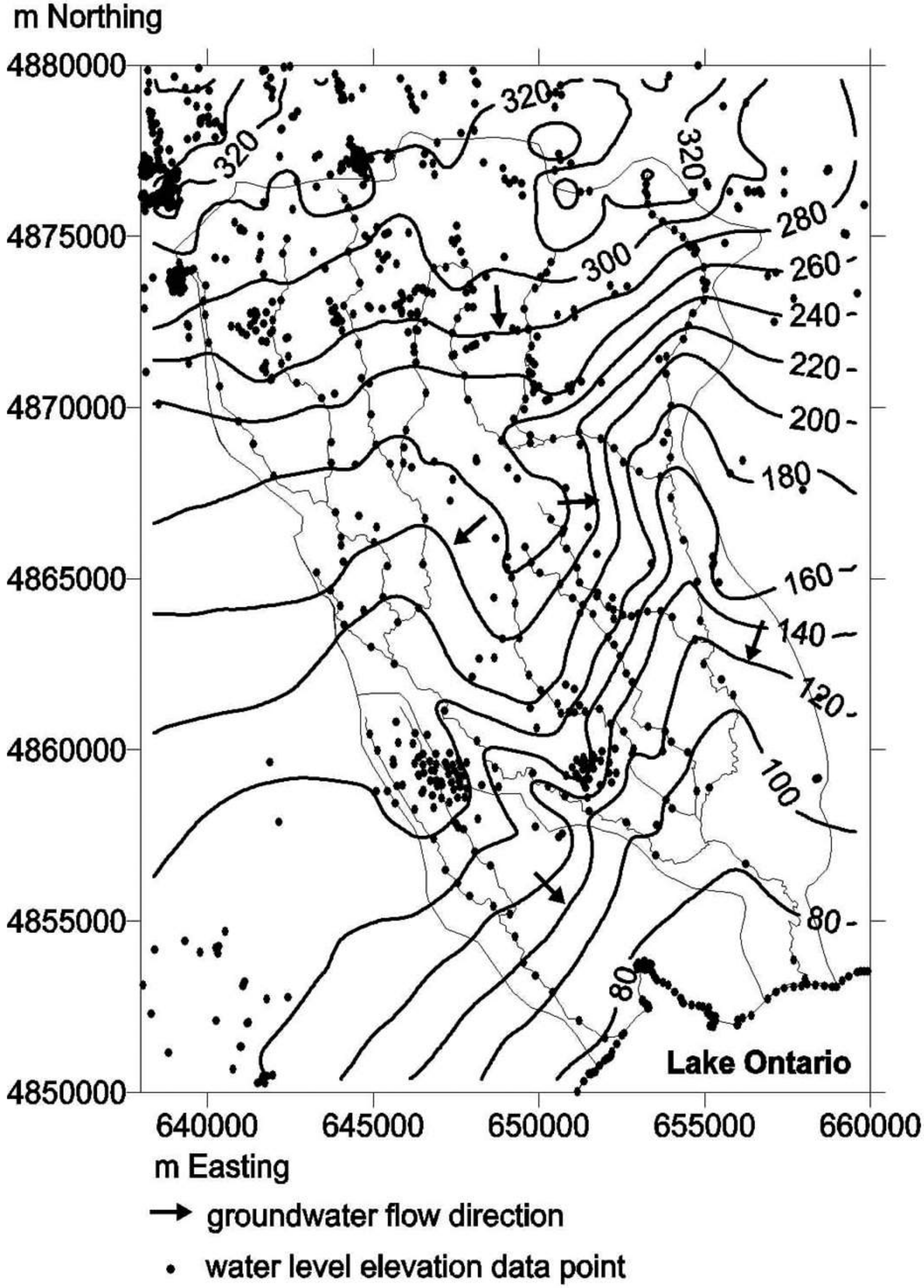
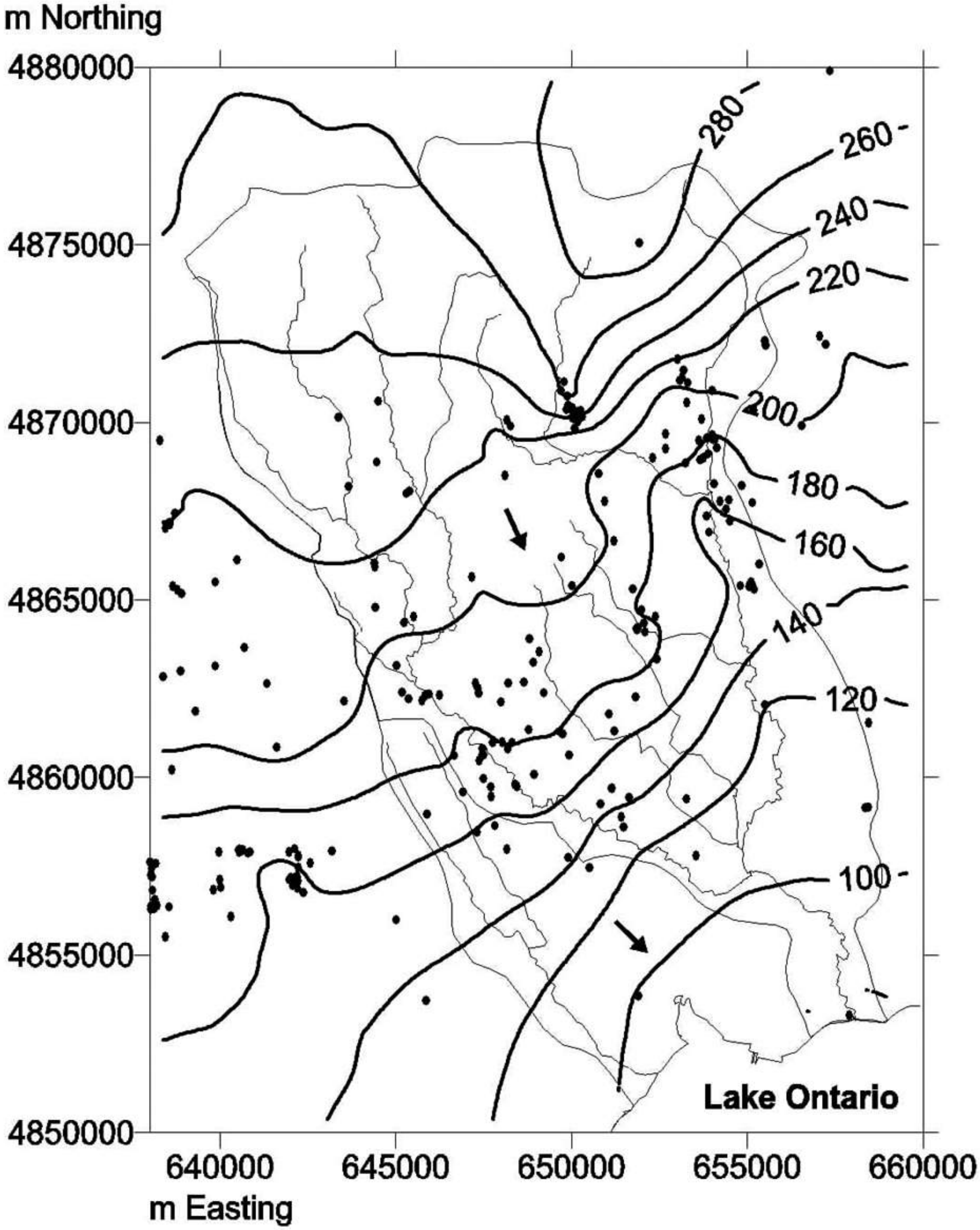


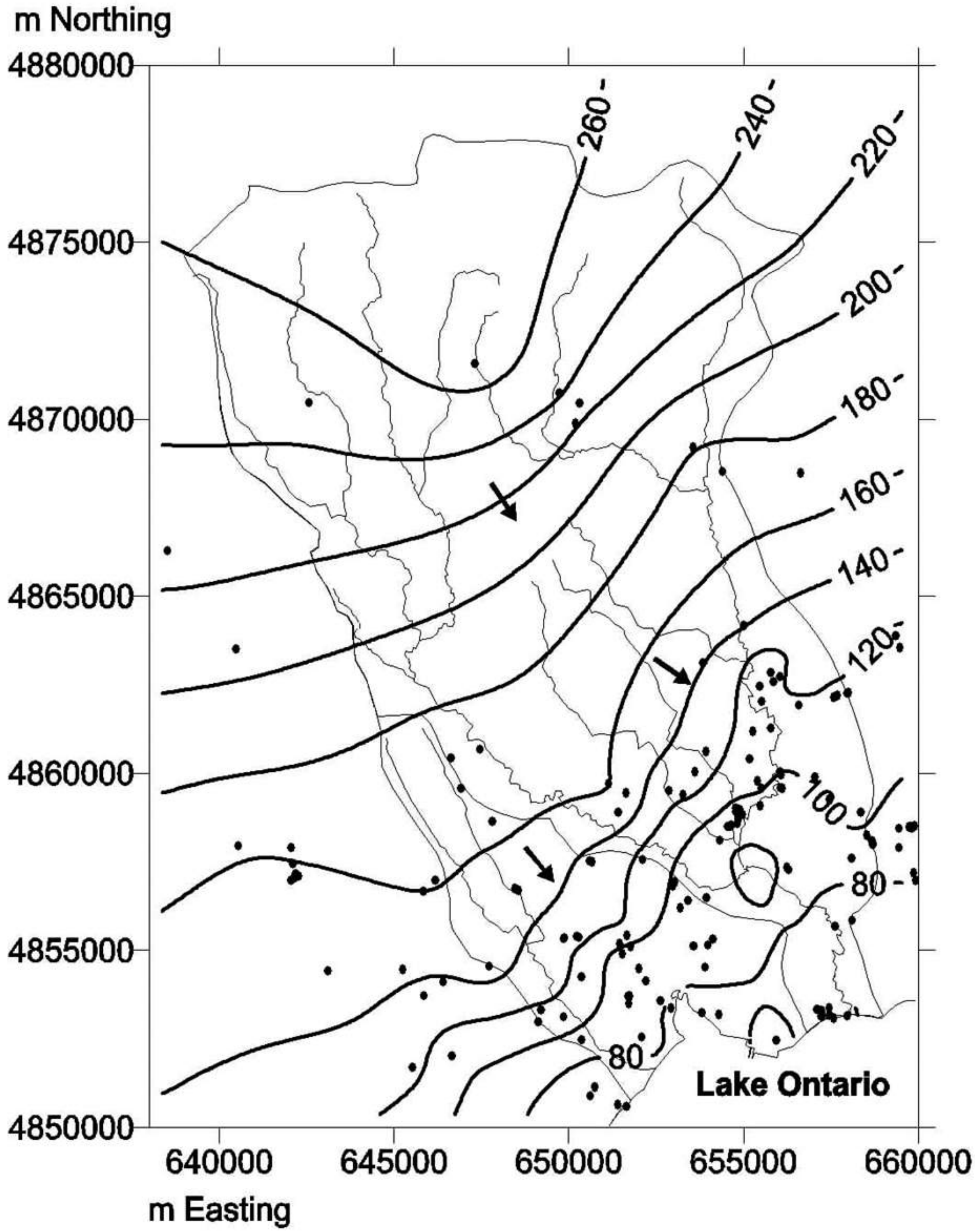
Figure 9: Water table and Upper aquifer potentiometric surface elevation. (from Gerber and Howard, 2000).



→ groundwater flow direction

• water level elevation data point

Figure 10: Middle aquifer (Thorncliffe Fm.) potentiometric surface elevation. (from Gerber and Howard, 2000).



→ groundwater flow direction

• water level elevation data point

Figure 11: Lower aquifer (Scarborough Fm) potentiometric surface elevation. (from Gerber and Howard, 2000).

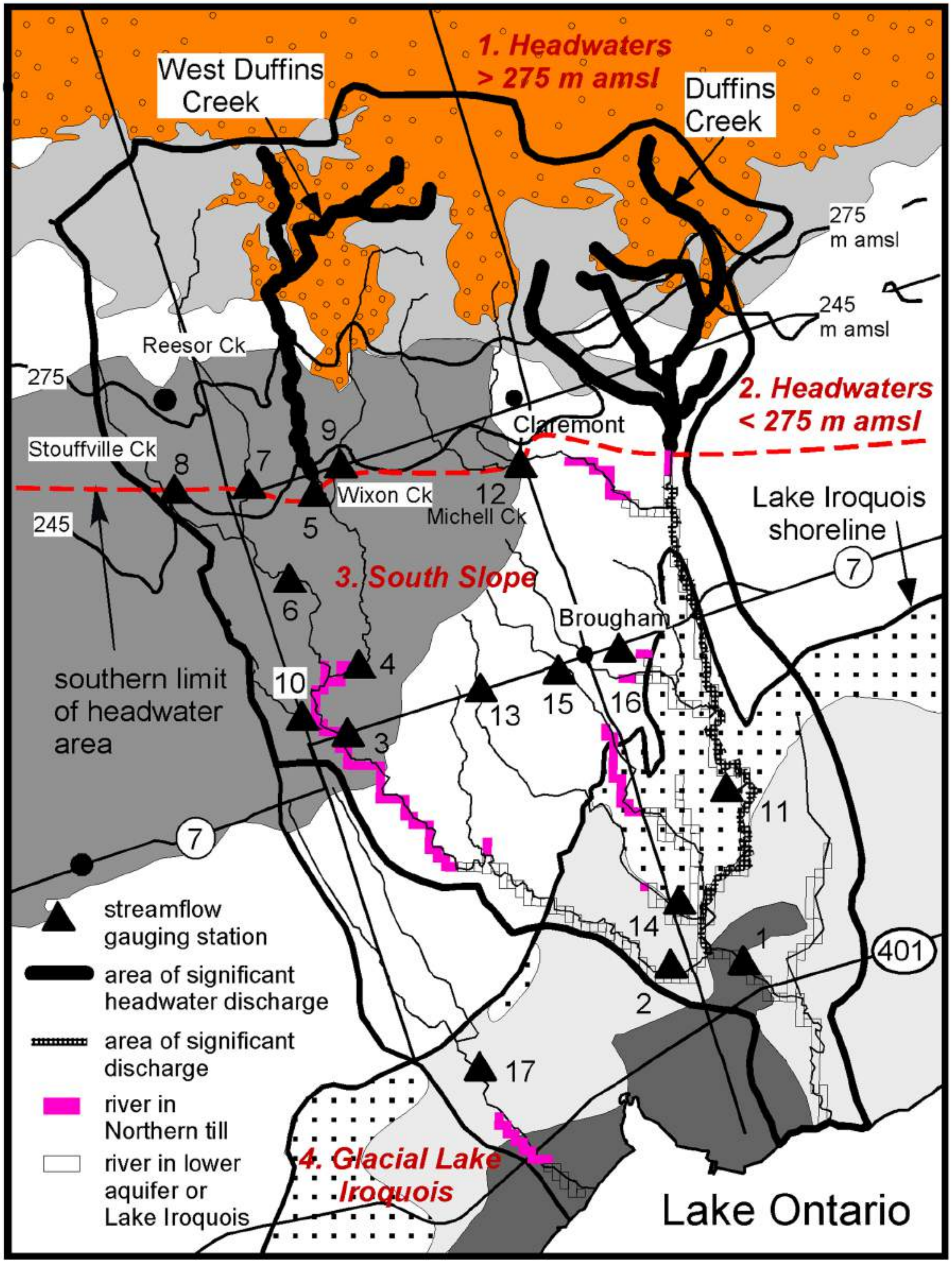


Figure 12: Areas of significant groundwater discharge to streams. Four hydrogeologic settings labelled in red. Surficial geology as per Figure 4.

Table 3: Summary of field measured hydraulic conductivity (m/s) estimates within study area.

		Minimum	Maximum	Average	no.	s	Geometric Mean
Upper Deposits							
Halton Till	slug K_h	$2x10^{-9}$	$2x10^{-5}$	$3x10^{-6}$	54	$4x10^{-6}$	$4x10^{-7}$
	pump K_h			$6x10^{-6}$	1		
	pump K_v	$1x10^{-8}$	$1x10^{-7}$		1		
ORM	spec-cap K_h	$2x10^{-6}$	$7x10^{-3}$		1287		$5x10^{-5}$
MIS	slug K_h	$3x10^{-8}$	$5x10^{-4}$	$5x10^{-5}$	16	$1x10^{-4}$	$6x10^{-6}$
Northern/Newmarket till							
	lab K_v	$1x10^{-11}$	$7x10^{-10}$	$5x10^{-11}$	40	$1x10^{-10}$	$3x10^{-11}$
	slug K_h	$3x10^{-12}$	$3x10^{-6}$	$3x10^{-7}$	39	$7x10^{-7}$	$8x10^{-10}$
	pump K_h			$6x10^{-6}$	1		
	pump K_v	$3x10^{-11}$	$3x10^{-7}$		4		
Middle Aquifer							
	slug K_h	$1x10^{-8}$	$3x10^{-4}$	$2x10^{-5}$	42	$6x10^{-5}$	$2x10^{-6}$
	pump K_h	$1x10^{-7}$	$9x10^{-5}$	$3x10^{-5}$	4	$4x10^{-5}$	$5x10^{-6}$
	spec-cap K_h	$1x10^{-6}$	$2x10^{-3}$		286		$4x10^{-5}$
Sunnybrook Diamict							
	slug K_h (1)	$3x10^{-7}$	$4x10^{-7}$		2		
Lower Aquifer							
	slug K_h	$2x10^{-8}$	$2x10^{-4}$	$5x10^{-5}$	5	$8x10^{-5}$	$2x10^{-6}$
	spec-cap K_h	$6x10^{-7}$	$7x10^{-4}$		311		$2x10^{-5}$

ORM = Oak Ridges Moraine MIS = Mackinaw Interstadial σ = standard deviation
K_h = horizontal hydraulic conductivity K_v = vertical hydraulic conductivity
Data from M.M. Dillon Limited, 1990; Interim Waste Authority Limited, 1994a-e; Gerber, 1999.
spec-cap = Specific Capacity estimates from water well records.
Specific capacity estimated according to Bradbury and Rothschild (1985) from Boyce, 1997.
(1) piezometers in sand layers in aquitard unit.

Table 4: Groundwater recharge and discharge quantities by hydrogeologic setting.

Hydrogeologic Setting	IN	OUT		IN - OUT	
Surficial Geology	Recharge	Springs	River Discharge		
1. Headwaters >275 m amsl					
ORM deposits	36,200	0	16,600	19,600	
Hummocky Halton Till	27,900	0	7,200	20,700	
Halton Till	4,200	0	6,200	-2,000	
Glacial Lake Peel	200	0	0	200	
subtotal	68,500	0	30,000	38,500	net recharge
2. Headwaters < 275 m amsl					
ORM deposits	2,600	0	9,700	-7,100	
Hummocky Halton Till	3,900	0	8,900	-5,000	
Halton Till	6,100	100	16,100	-10,100	
Glacial Lake Peel	2,100	0	8,000	-5,900	
subtotal	14,700	100	42,700	-28,100	net discharge
3. South Slope					
Halton Till	24,600	5,400	15,500	3,700	
Glacial Lake Peel	4,500	1,000	6,200	-2,700	
subtotal	29,100	6,400	21,700	1,000	net recharge
4. Glacial Lake Iroquois					
Lake Iroquois	14,700	2,500	20,100	-7,900	net discharge
	127,000	9,000	114,500	3,500	

Note:

Quantities from calibrated flow scenario described in Gerber and Howard, 2002.
Hydrogeologic settings shown on Figure 12.

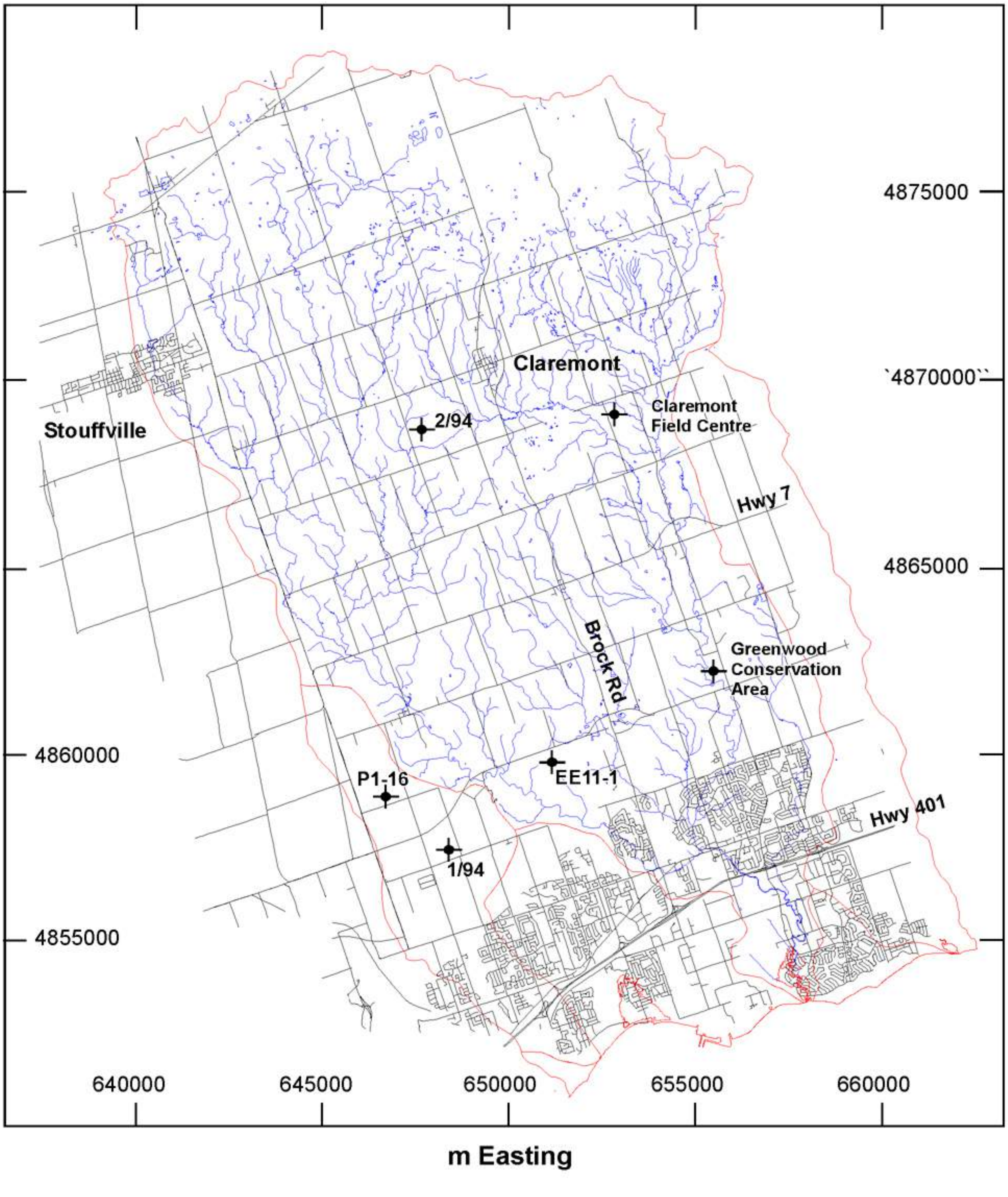


FIGURE 13: Groundwater monitoring locations in Duffins watershed.

Duffins Hydrogeology	Gerber Geosciences Inc.; March 10, 2003

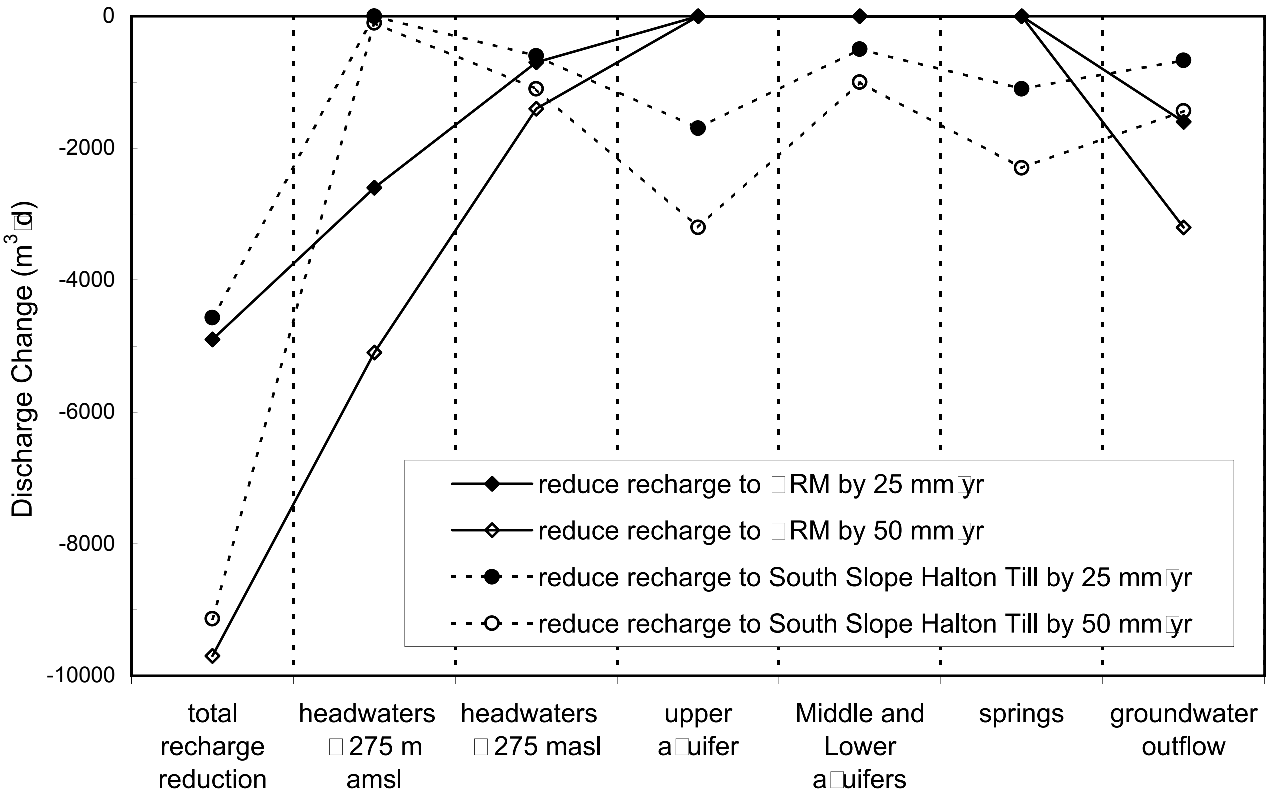
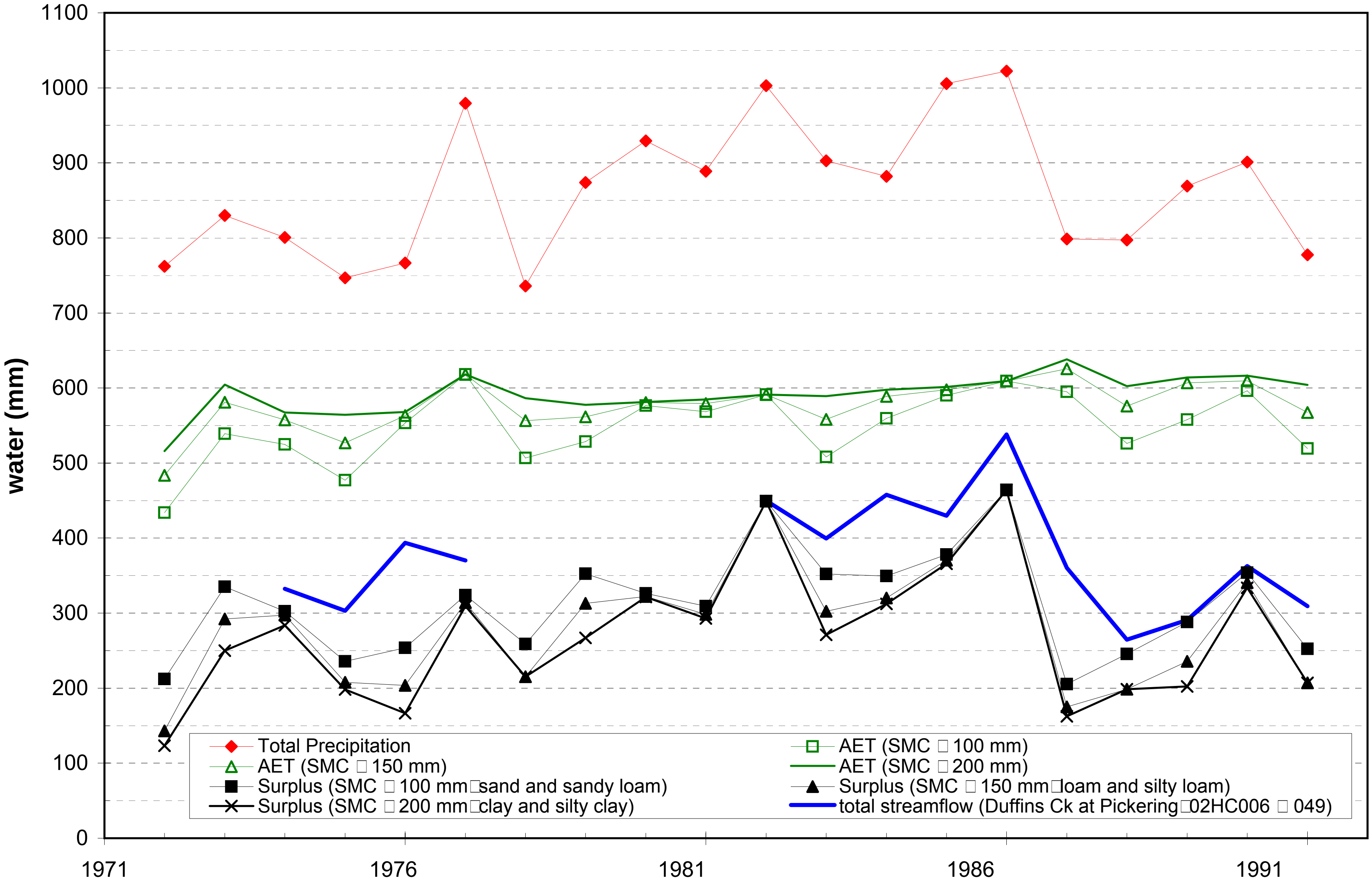


Figure 14: Recharge reduction influence on spatial distribution of groundwater discharge.

Figure 15: AES Thornthwaite - Stouffville WPCP climate station



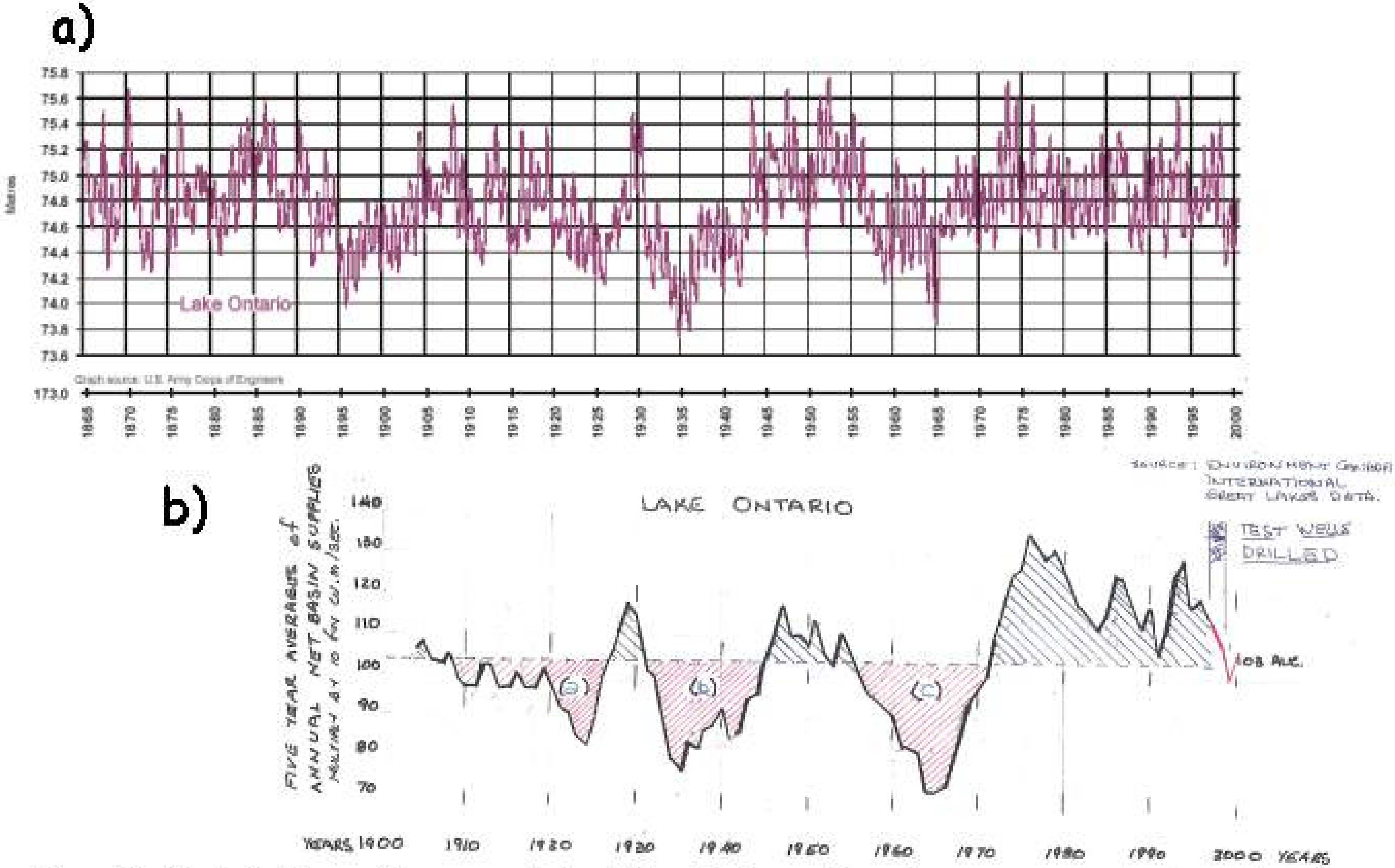


Figure 16: a) Lake Ontario monthly mean water levels (from Environment Canada, www.on.ec.gc.ca/water/factsheets).
b) Five year average of net basin surplus (Foulds, 2000). See text for details.

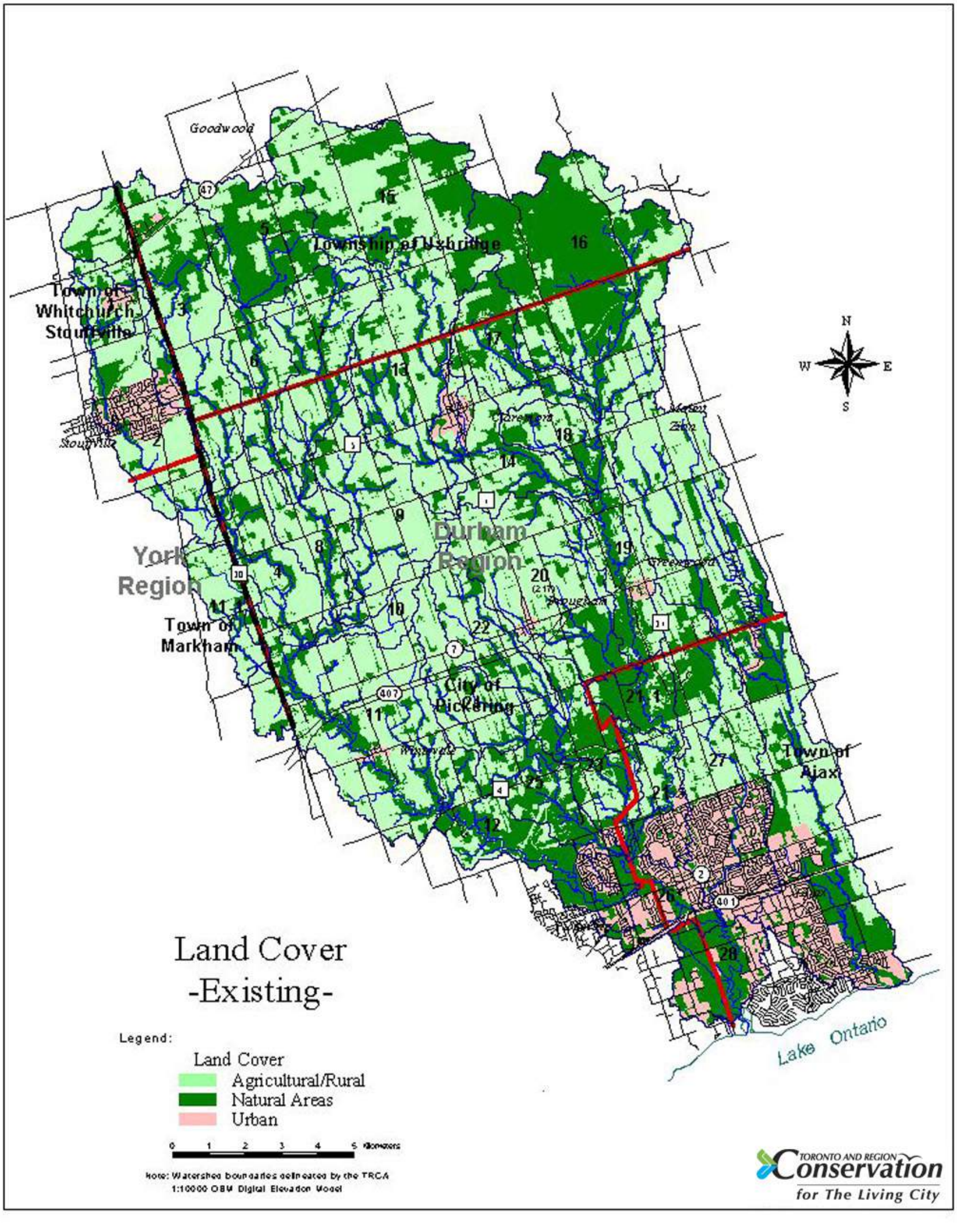


Figure 17: Scenario #1: Existing land cover - Duffins Creek watershed. Figure provided by TRCA.

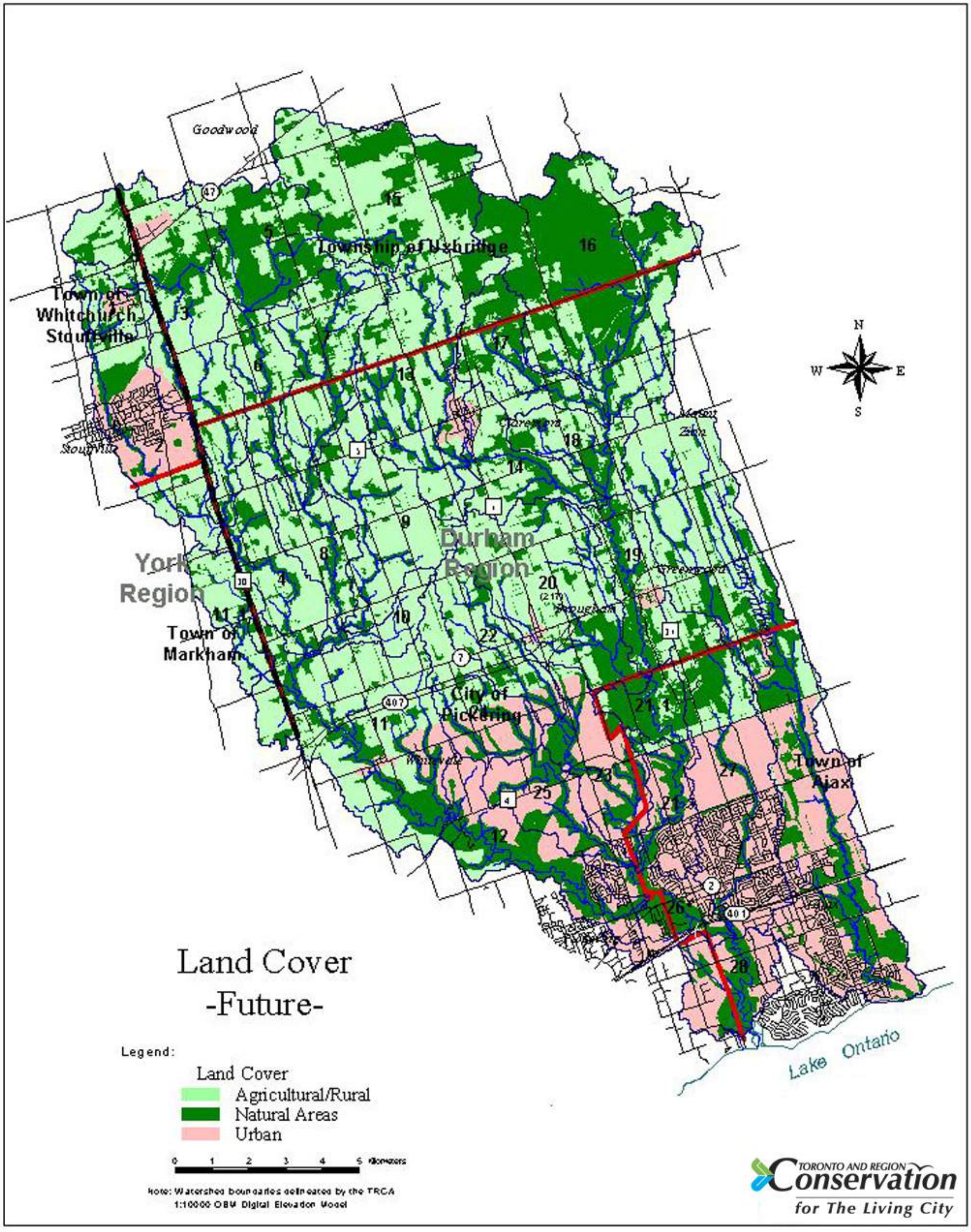


Figure 18: Scenario #2: Future land cover – Duffins Creek watershed. Figure provided by TRCA.

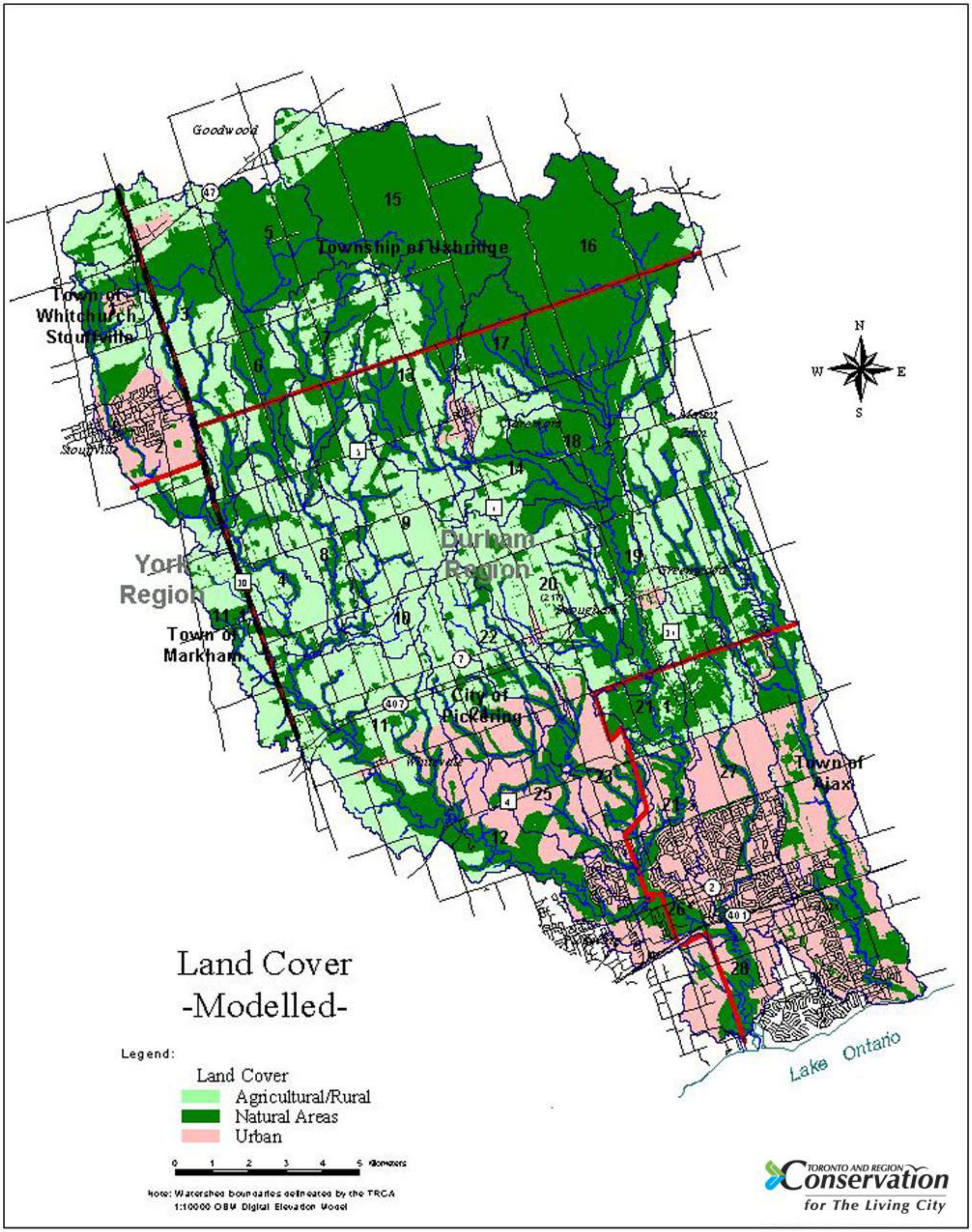


Figure 19: Scenario #3: Future Municipal Official Plans+ TRCA Natural Heritage Strategy – Duffins Creek watershed. Figure from TRCA.

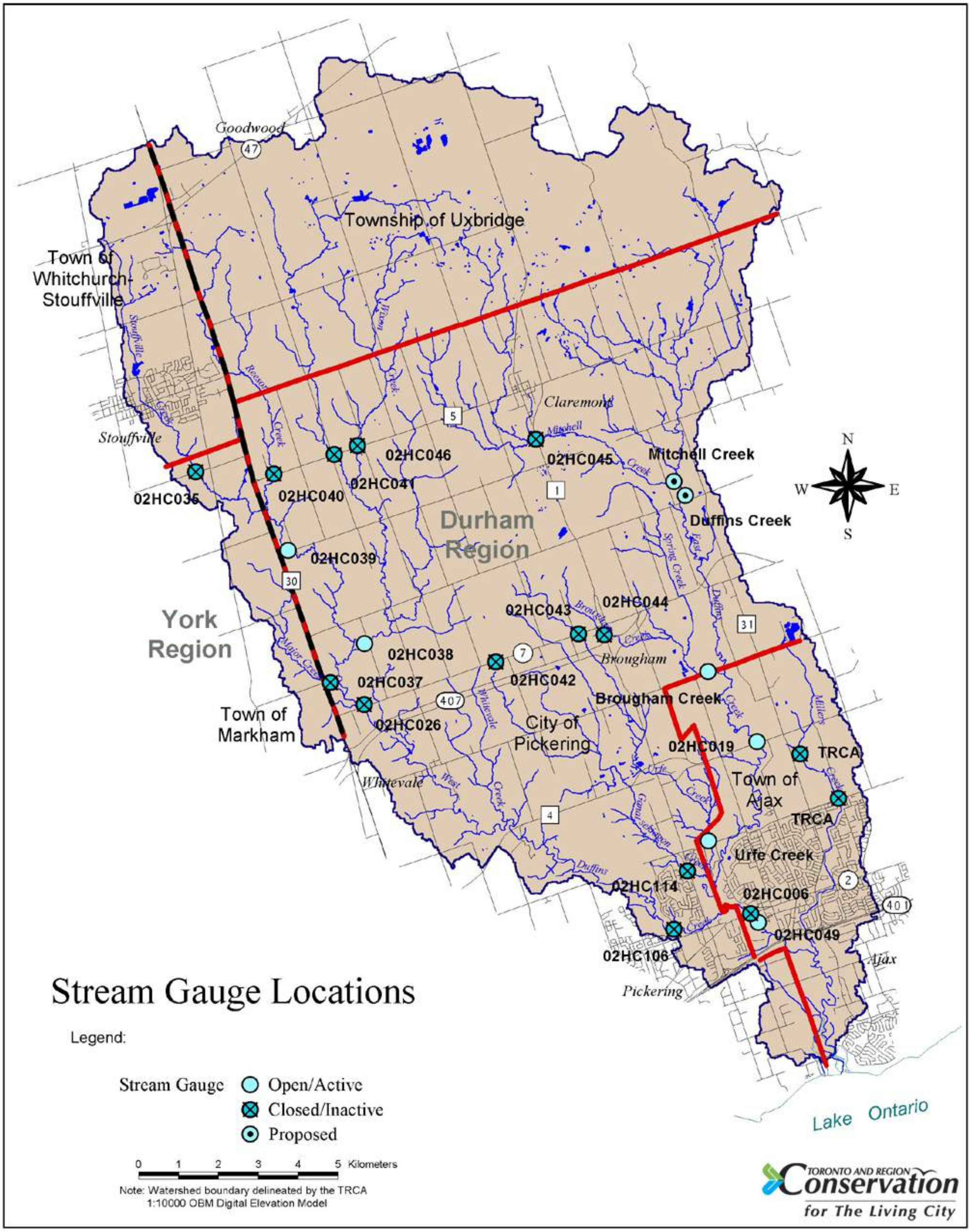


Figure 20: Streamflow gauging stations (figure provided by TRCA). The two stations marked proposed were initiated in the summer of 2002.

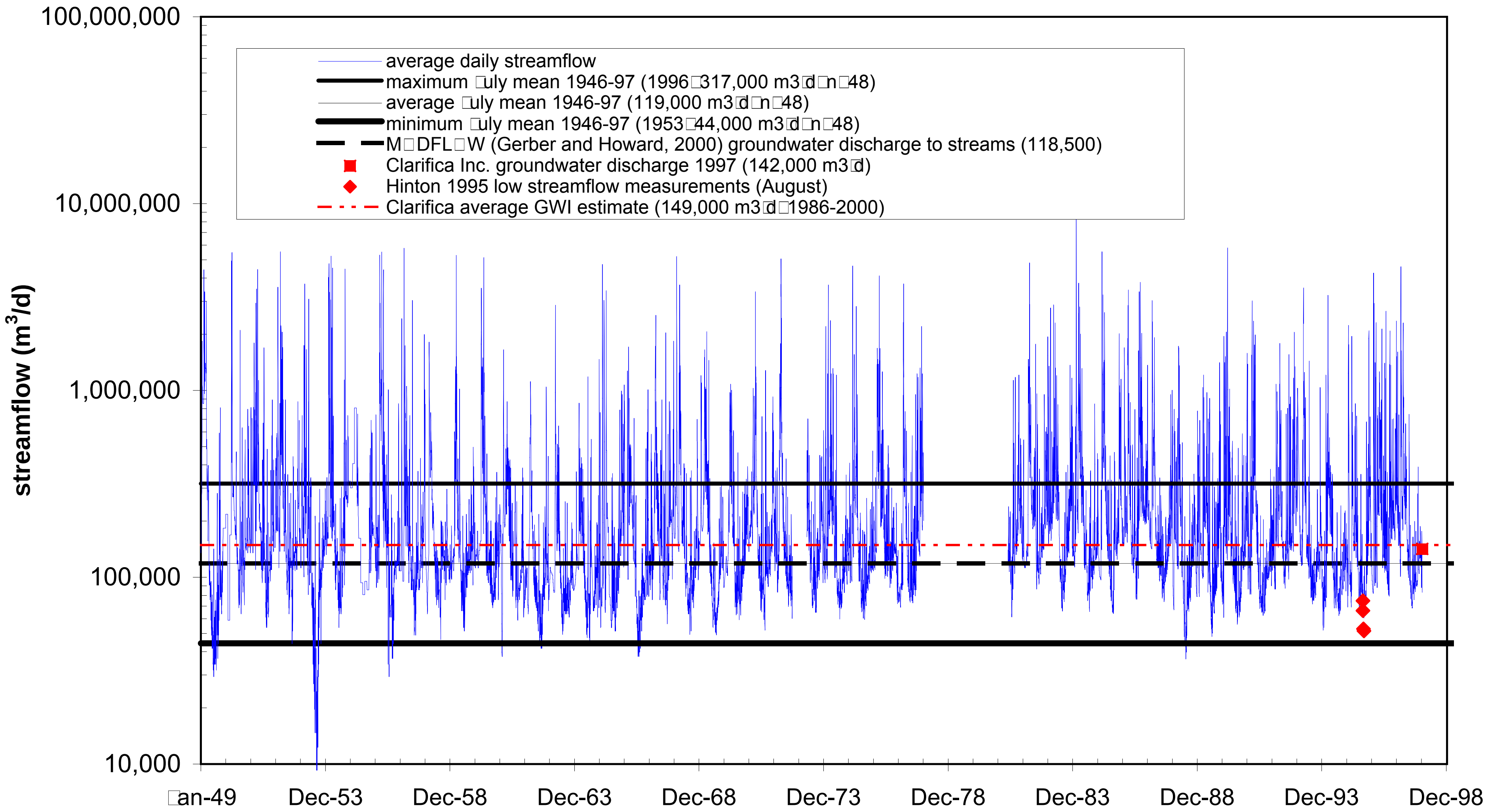


Figure 21. Average daily streamflow - Duffins Creek at Pickering 02HC006 until 1989, then changed to Duffins Creek at Ajax 02HC049. For the period 1946 to 1988, the month with the lowest average flow is July (Water Survey of Canada, 1992).

Figure 22: Average daily streamflow - West Duffins Creek above Green River (02HC038)

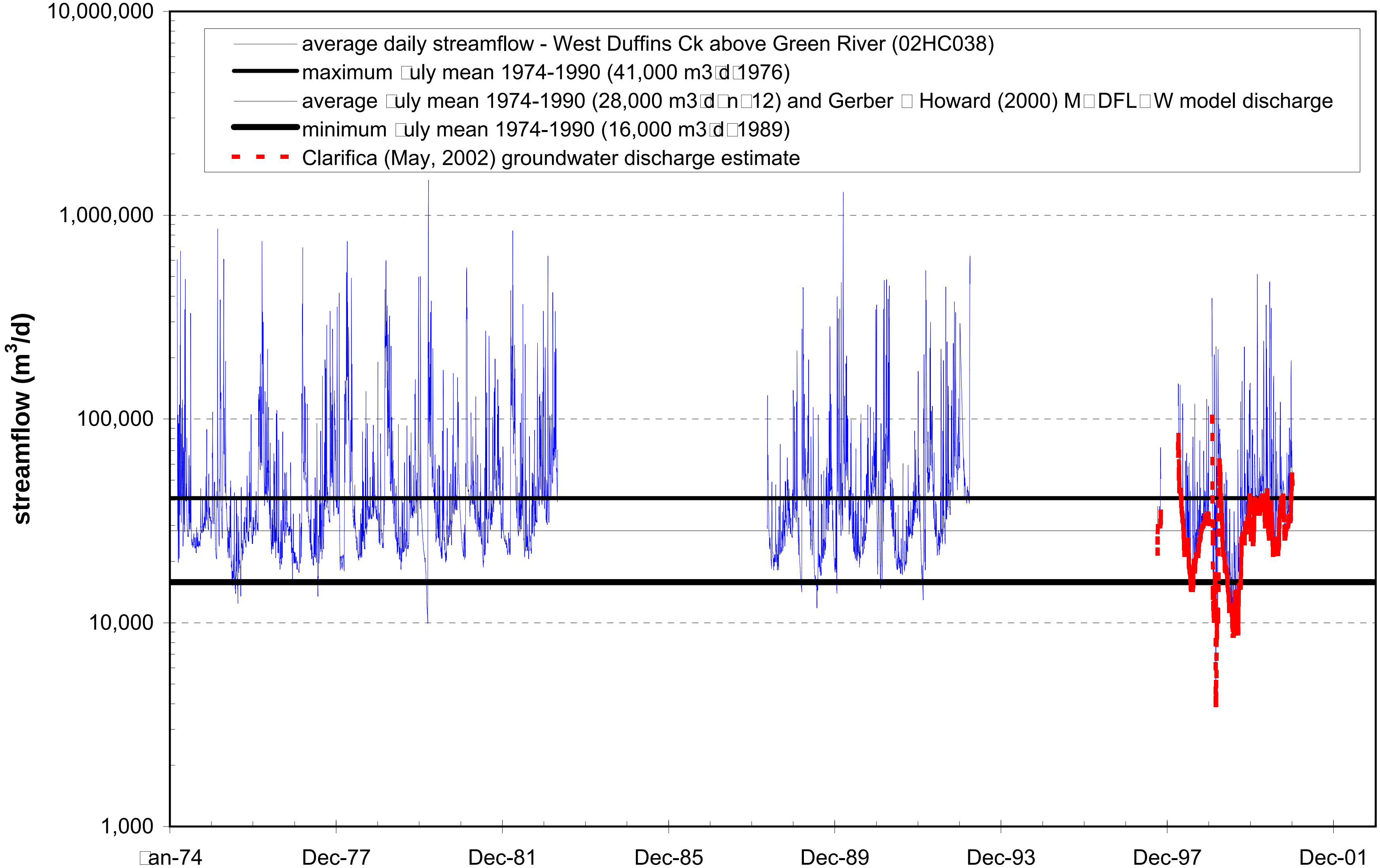


Figure 23: Average daily streamflow - Reesor Creek above Green River (02HC039)

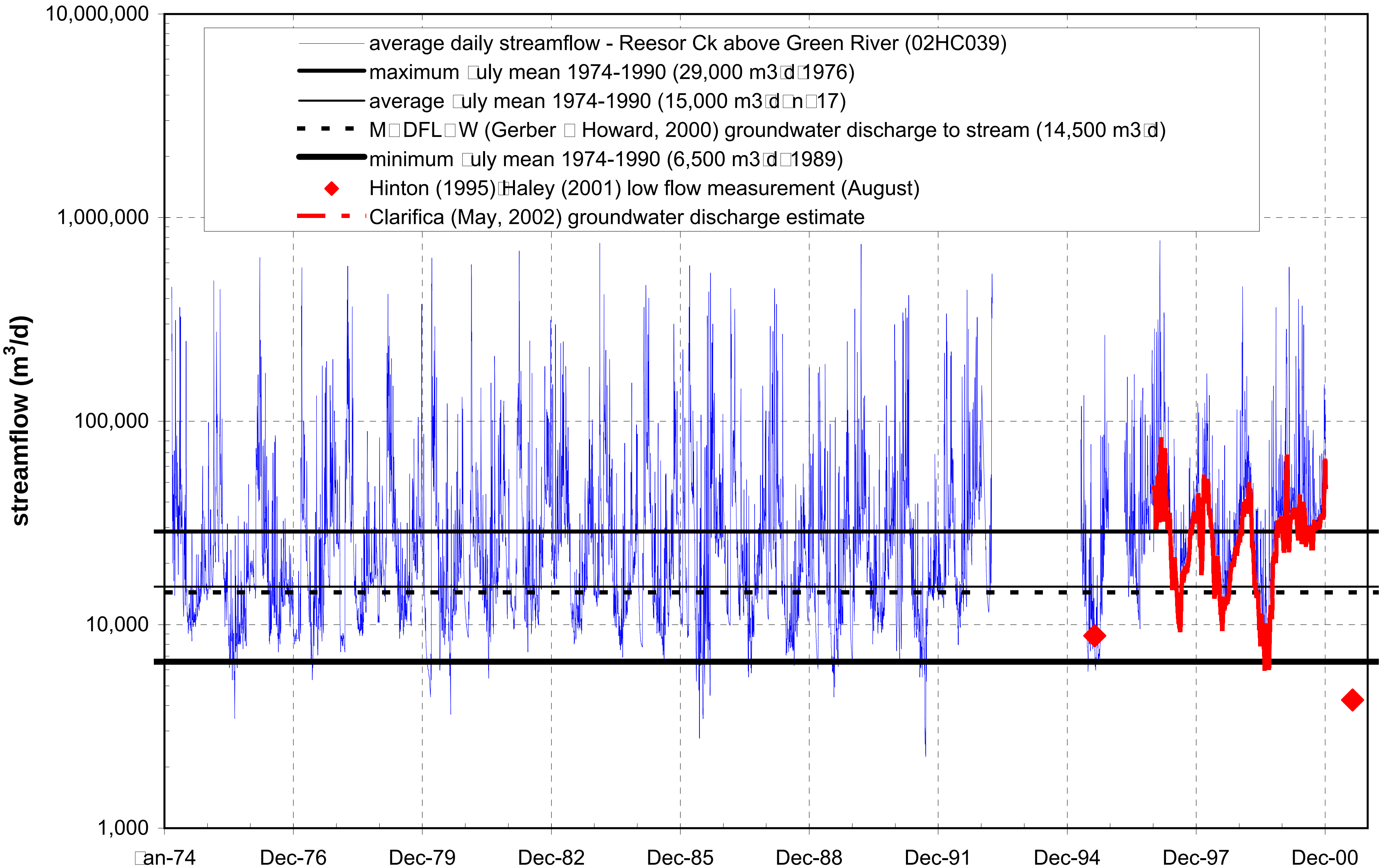
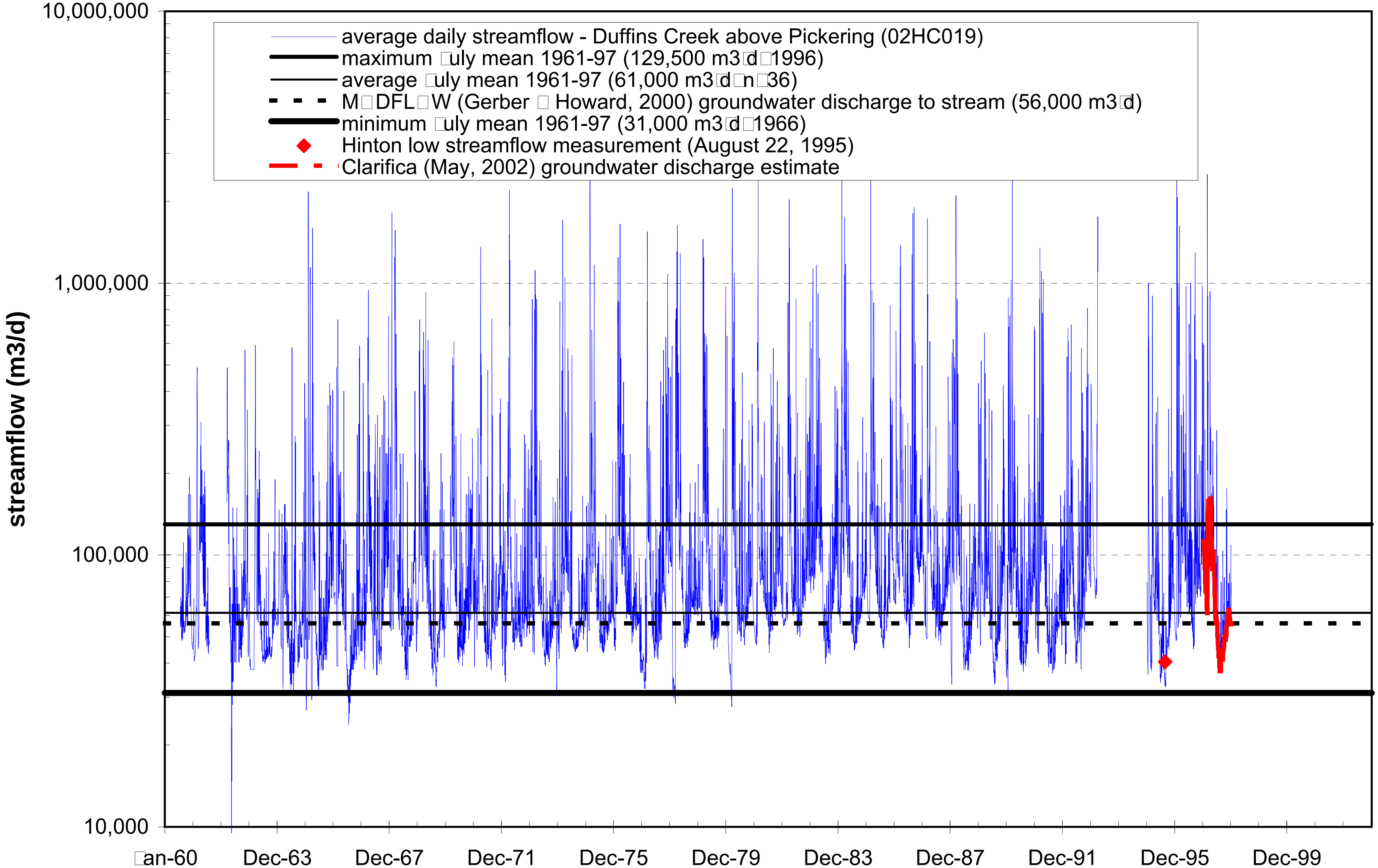


Figure 24: Average daily streamflow - Duffins Creek above Pickering (02HC019)



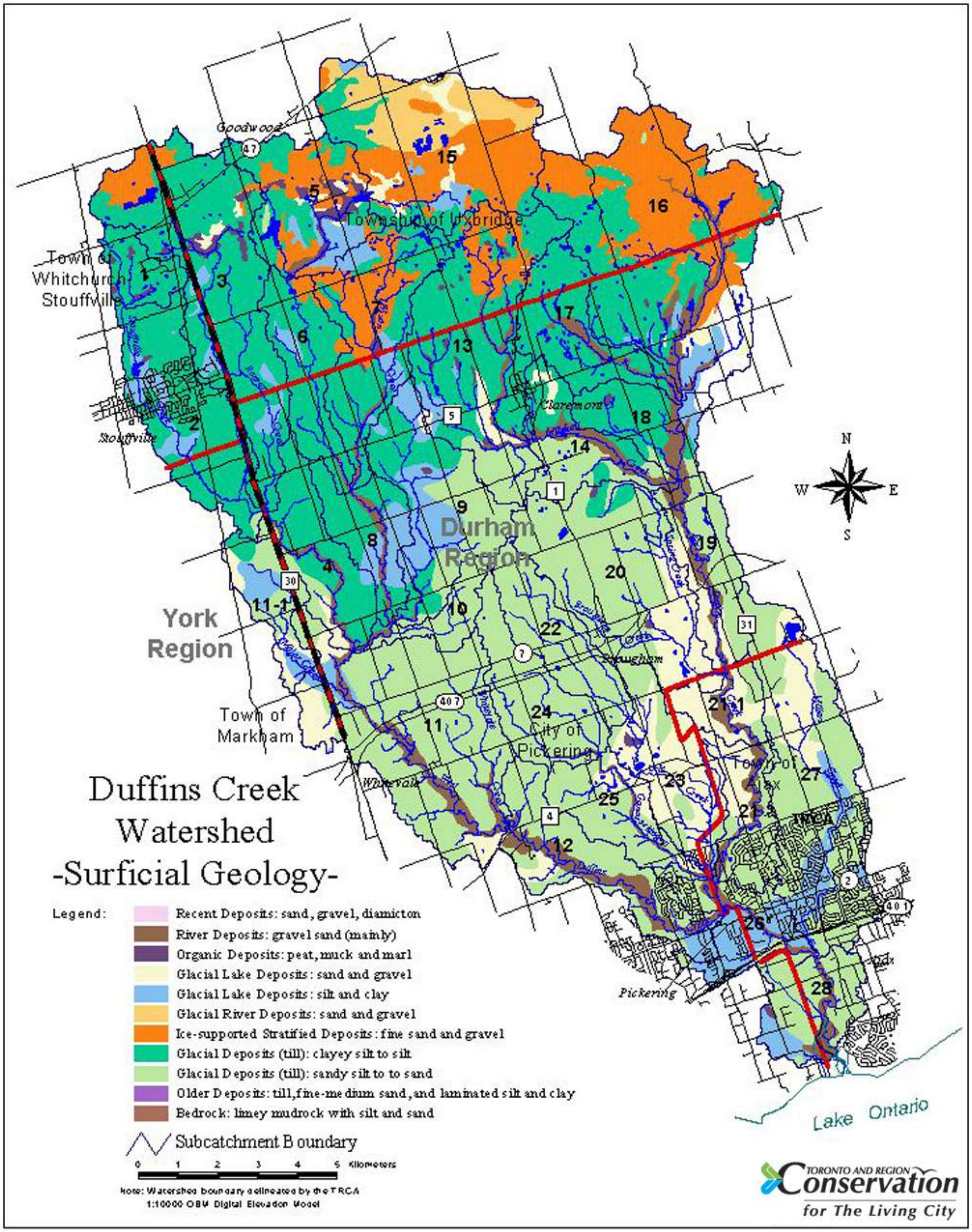


Figure 25: 30 sub-catchments and GSC surficial geology. Figure provided by TRCA.

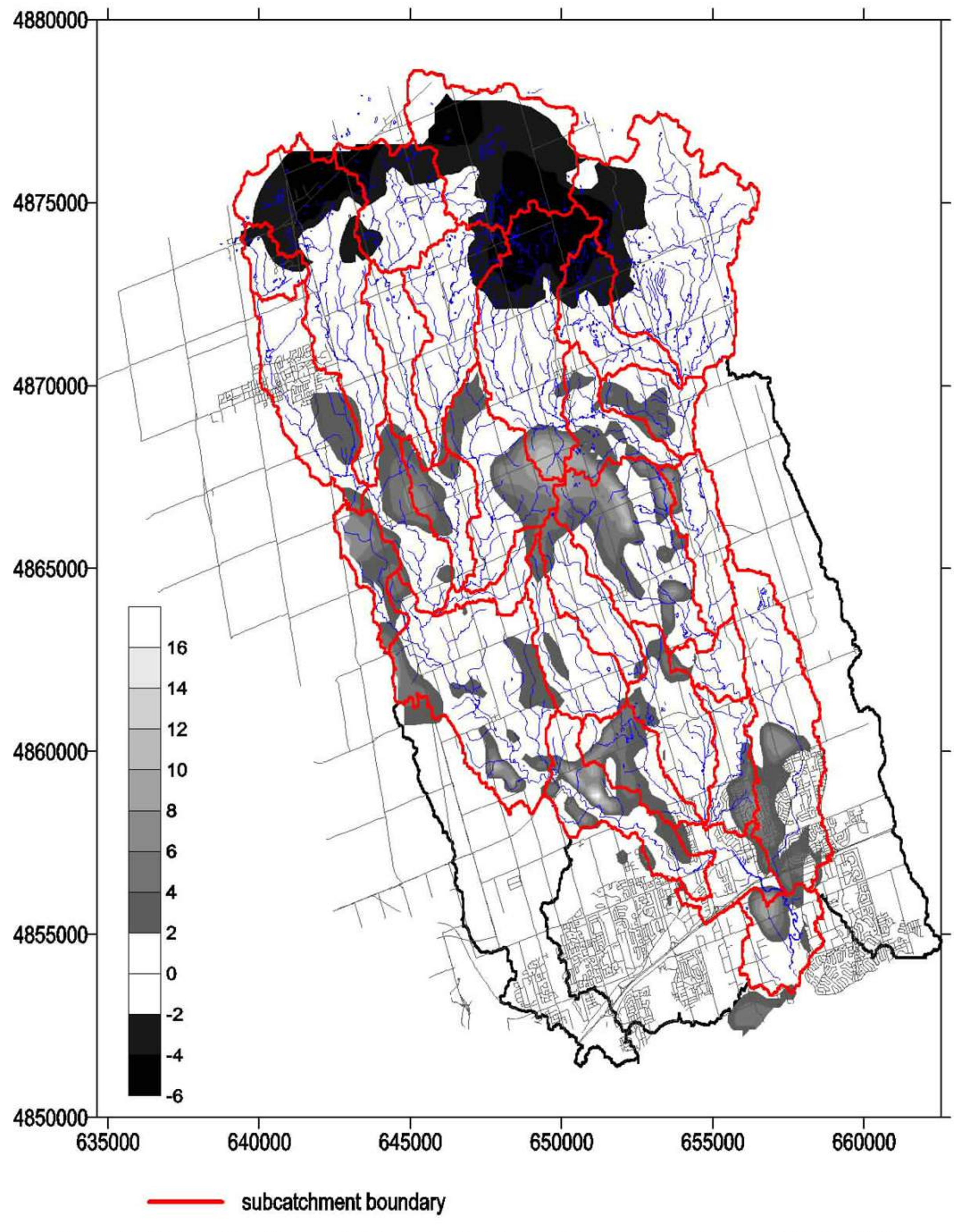
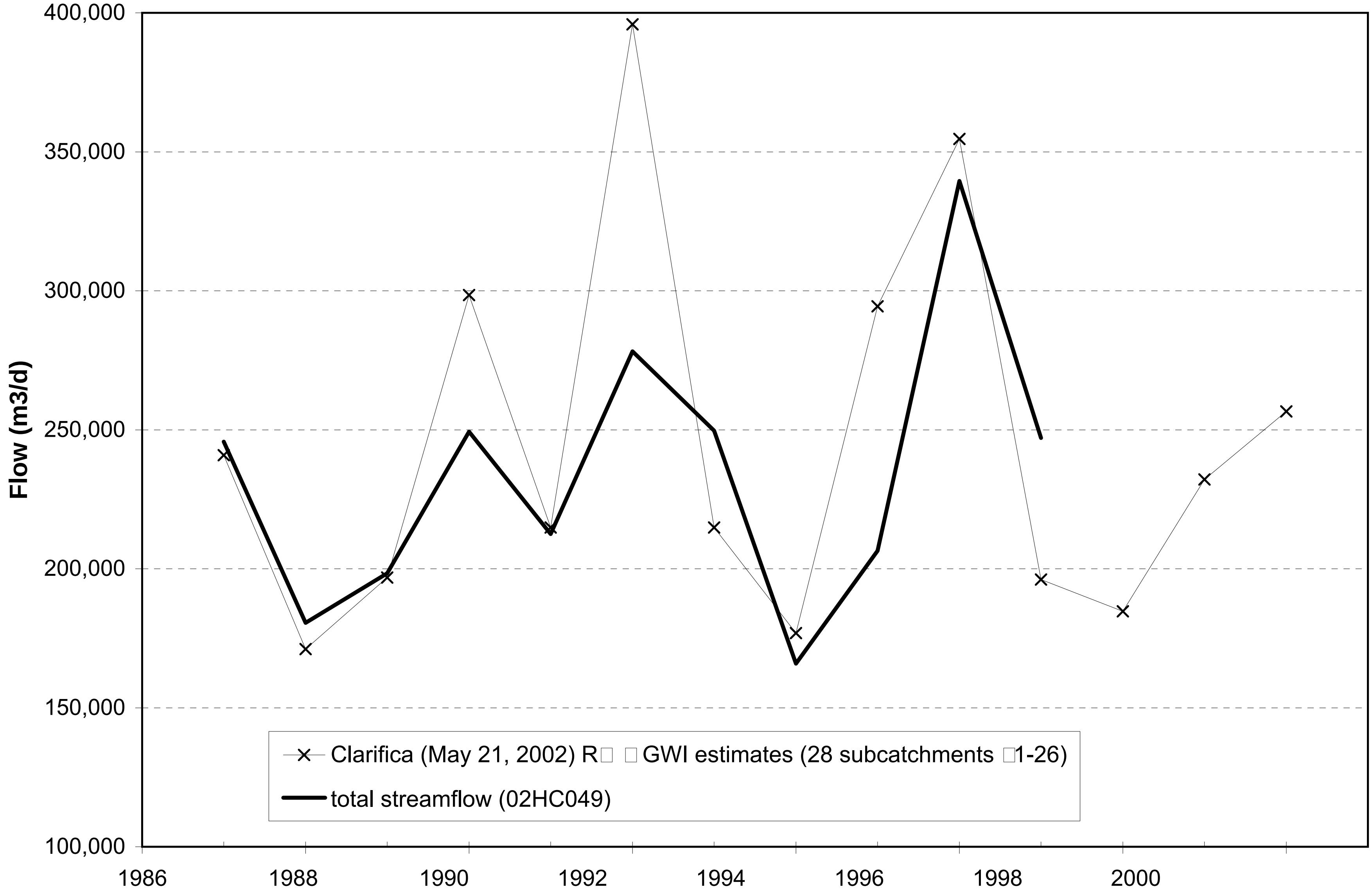


Figure 26: Water table difference (m) between Clarifica Inc Existing versus Gerber and Howard, 2000 existing. Negative values indicate that Clarifica surface is lower (less recharge) and positive values indicate that Clarifica surface is higher (more recharge).

Figure 27: Duffins water balance/streamflow comparison.



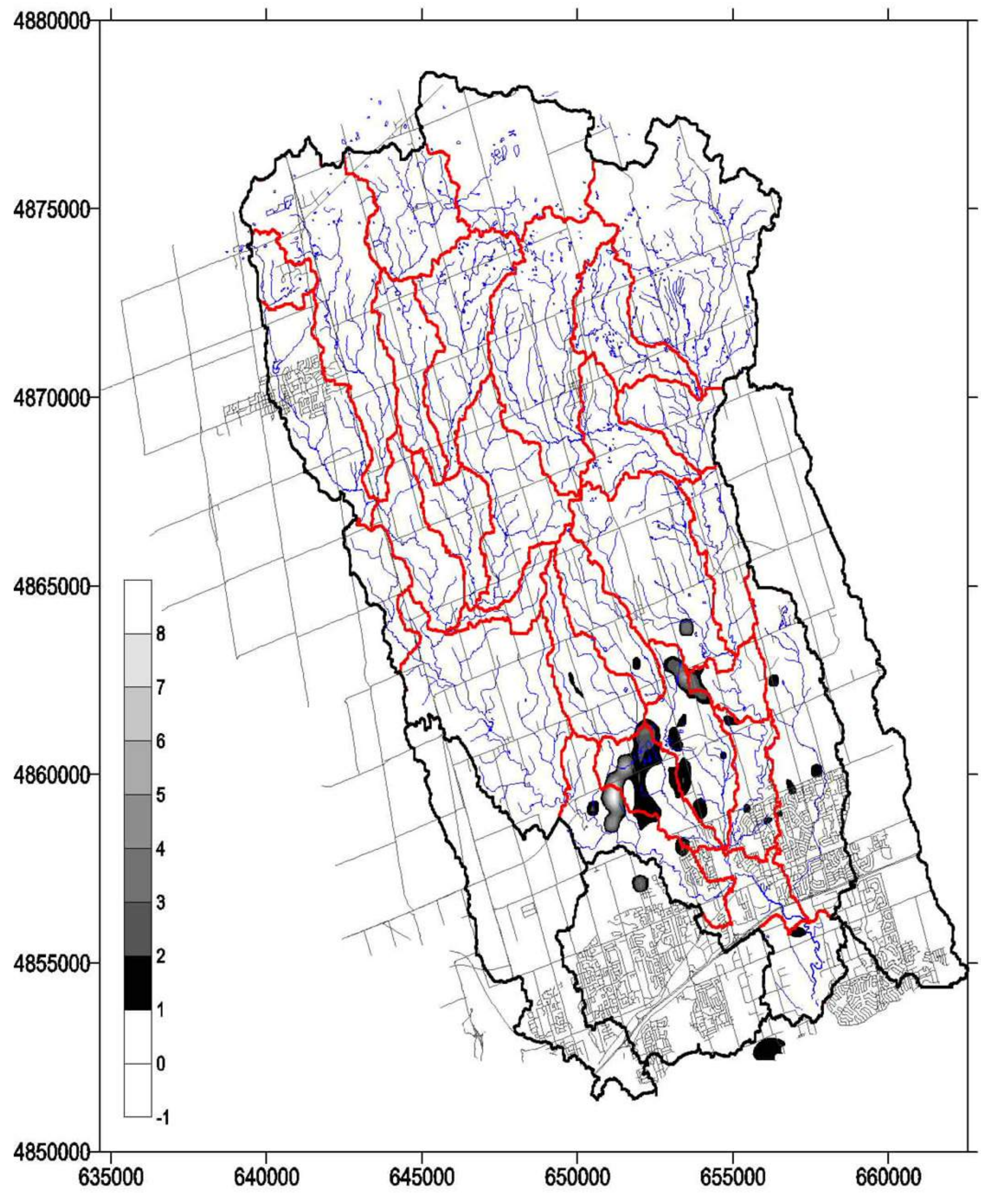


Figure 28: Water table difference (m) between Clarifica Scenario#1 and Scenario#2.
Positive values indicate a decline in water table elevation.

Table 5 Summary of Clarifica (May, 2002) annual average water balance estimates for the Duffins Creek watershed (1986-2000).

Basin	Area [ha]	PRECIP	RAIN	SNOW	Impervious (fraction) #1	#2	#3	#4	RO #1	#2	#3	#4	GWI #1	#2	#3	#4	ET #1	#2	#3	#4
1	282	844	702	142	0.022	0.022	0.022	0.022	156	156	141	156	200	200	201	200	483	483	498	483
2	1085	844	702	142	0.091	0.182	0.182	0.219	219	290	277	312	177	**151**	157	144	443	398	406	384
3	1898	844	702	142	0.023	0.034	0.034	0.042	145	155	145	161	208	205	204	203	485	479	489	475
4	682	844	702	142	0.000	0.000	0.000	0.360	150	150	149	420	197	197	197	103	492	492	493	319
5	921	844	702	142	0.000	0.000	0.000	0.000	60	60	51	60	231	231	218	231	549	549	571	549
6	644	844	702	142	0.000	0.000	0.000	0.028	139	139	125	159	185	185	181	179	515	515	533	502
7	1082	844	702	142	0.000	0.000	0.000	0.007	95	95	84	100	215	215	210	213	530	530	545	526
8	517	844	702	142	0.000	0.000	0.000	0.390	108	108	107	384	210	210	209	123	521	521	522	335
9	1073	844	702	142	0.000	0.000	0.000	0.343	140	140	137	388	184	184	183	107	514	514	518	348
10	263	844	702	142	0.000	0.000	0.000	0.398	109	109	109	377	208	208	208	126	522	522	522	339
11	2069	844	702	142	0.004	0.025	0.025	0.372	149	163	160	414	200	198	197	109	489	479	482	319
11.1	425	844	702	142	0.000	0.000	0.000	0.433	177	177	172	543	180	180	181	48	482	482	487	255
12	895	844	702	142	0.053	0.192	0.192	0.217	145	250	250	268	214	**180**	180	174	480	410	409	398
13	1737	844	702	142	0.016	0.016	0.016	0.074	142	142	119	183	210	210	212	196	488	488	508	461
14	623	844	702	142	0.023	0.023	0.023	0.242	143	143	133	298	209	209	209	156	487	487	497	386
15	1703	844	702	142	0.000	0.000	0.000	0.000	62	62	46	62	237	237	222	237	540	540	572	540
16	2625	844	702	142	0.000	0.000	0.000	0.070	94	94	83	144	232	232	228	217	513	513	528	478
17	708	844	702	142	0.002	0.002	0.002	0.055	102	102	87	141	228	228	225	217	509	509	528	482
18	507	844	702	142	0.000	0.000	0.000	0.217	120	120	95	268	217	217	215	170	502	502	529	402
19	619	844	702	142	0.021	0.021	0.021	0.311	125	125	118	332	217	217	216	150	497	497	505	359
20	1547	844	702	142	0.007	0.007	0.007	0.401	132	132	129	417	217	217	215	115	490	490	495	310
21	509	844	702	142	0.134	0.231	0.231	0.269	247	316	316	348	175	**151**	151	140	418	373	373	354
21.1	327	844	702	142	0.000	0.007	0.007	0.201	90	95	95	237	236	235	229	190	513	509	514	413
22	633	844	702	142	0.000	0.028	0.028	0.386	175	196	193	508	185	179	179	63	478	465	466	274
23	804	844	702	142	0.008	0.222	0.222	0.262	135	320	320	355	216	**150**	150	137	488	371	370	350
24	714	844	702	142	0.000	0.119	0.119	0.356	140	225	224	396	206	**179**	180	119	494	435	436	328
25	591	844	702	142	0.022	0.255	0.255	0.255	119	300	300	300	226	**165**	166	165	494	375	375	375
26	523	844	702	142	0.337	0.337	0.337	0.337	392	388	388	388	120	124	124	124	328	329	329	329
27	1698	844	702	142	0.230	0.271	0.271	0.399	257	287	287	379	171	163	163	133	412	390	390	330
28	601	844	702	142	0.230	0.416	0.416	0.416	258	393	393	393	161	**115**	114	115	420	331	332	331
	####																			

Scenarios

#1 **Existing**

#2 **Future Official Plan**

#3 **Future OP + TRCA Natural Heritage**

#4 **Future OP + 50% impervious for lands south of Oak Ridges Moraine.**

(shaded) **Subcatchment or basin with future landuse scenario (#2) GWI estimate different from existing landuse (Scenario #1).**

All values in mm/year unless noted otherwise.

See Figure 25 for subcatchment locations.

Table 6. Difference in model#1 recharge areas/net recharge for Clarifica Scenario #1 (existing landuse).

Basin #	Clarifica Inc (May 2002) GWI#1 m3/d	GWI#1 mm/year	Area ha	Gerber&Howard, 2000 calibrated model recharge values R m3/d	R area ha	Riv area ha	Tot area ha	Difference R-GWI#1 m3/d	Scenario#1 Existing Net Recharge[1] m3/d
1	1,546	200	282	2,044	263	36	299	497	1,447
2	5,252	177	1,085	2,625	1,018	160	1,178	-2,627	4,927
3	10,836	208	1,898	11,151	1,657	200	1,857	315	9,460
4	3,679	197	682	751	560	112	672	-2,928	3,023
5	5,821	231	921	8,521	849	128	977	2,699	5,367
6	3,258	185	644	1,899	505	136	641	-1,359	2,555
7	6,361	215	1,082	6,510	926	172	1,098	149	5,443
8	2,968	210	517	603	441	84	525	-2,365	2,532
9	5,420	184	1,073	1,660	1,066	0	1,066	-3,759	5,384
10	1,498	208	263	729	260	16	276	-769	1,482
11	11,349	200	2,069	4,510	1,778	284	2,062	-6,840	9,754
11.1	2,092	180	425	482	353	68	421	-1,610	1,736
12	5,238	214	895	1,416	765	180	945	-3,822	4,479
13	9,983	210	1,737	7,636	1,409	304	1,713	-2,347	8,101
14	3,557	209	623	1,764	545	100	645	-1,793	3,115
15	11,034	237	1,703	15,570	1,471	72	1,543	4,536	9,532
16	16,712	232	2,625	21,052	2,344	320	2,664	4,340	14,924
17	4,425	228	708	4,753	610	108	718	329	3,814
18	3,012	217	507	1,288	460	40	500	-1,725	2,735
19	3,687	217	619	1,958	571	116	687	-1,728	3,401
20	9,203	217	1,547	4,504	1,320	220	1,540	-4,699	7,848
21	2,439	175	509	1,496	448	88	536	-943	2,148
21.1	2,117	236	327	1,557	288	52	340	-560	1,862
22	3,209	185	633	2,186	528	144	672	-1,022	2,676
23	4,748	216	804	3,277	633	152	785	-1,471	3,740
24	4,022	206	714	2,318	559	140	699	-1,704	3,183
25	3,658	226	591	1,208	440	112	552	-2,450	2,724
26	1,718	120	523	296	432	84	516	-1,422	1,420
27	7,952	171	1,698	4,378	1,677	80	1,757	-3,575	7,852
28	2,652	161	601	373	544	56	600	-2,280	2,400
	159,446		28,301	118,513	24,720	3,764	28,484	-40,933	139,060
Petticoat Creek				6,118					6,118
Frenchman's Bay				2,296					2,296
Lower Duffins				69					68
				126,995					147,512

Note:

Values provided are for comparison/discussion purposes only and are not considered as accurate as shown.

R equals calibrated groundwater recharge value from Gerber and Howard (2000) model (model#1).

1. Scenario#1 net recharge equals GWI#1 unit rate x R area (ha).

Table 7. Comparison of Duffins MODFLOW existing (Gerber & Howard, 2000) versus Scenario #1 GWI (Existing).
Analysis conducted using Duffins MODFLOW model (Gerber & Howard, 2000).

	Scenario #1							Duffins MODFLOW (Gerber and Howard, 2000)						
Basin#	IN (m3/d)			OUT (m3/d)				IN (m3/d)			OUT (m3/d)			
	Riv	GHB	R	CH	Drains	Riv	GHB	Riv	GHB	R	CH	Drains	Riv	GHB
1	11	2,781	1,447	0	0	1,454	3,477	0	2,780	2,044	0	0	2,065	3,479
2	0	8,446	4,927	0	0	6,452	10,242	0	8,499	2,625	0	0	4,749	10,150
3	270	7,191	9,460	0	0	4,563	6,178	50	6,405	11,151	0	0	3,678	6,463
4	0	0	3,023	0	183	3,326	0	29	0	751	0	85	1,206	0
5	308	3,566	5,367	0	0	5,177	4,088	0	3,564	8,521	0	0	8,223	4,093
6	0	0	2,555	0	0	5,784	0	8	0	1,899	0	0	4,747	0
7	85	0	5,443	0	0	9,535	0	37	0	6,510	0	0	9,383	0
8	0	0	2,532	0	0	4,121	0	0	0	603	0	0	1,610	0
9	0	0	5,384	0	0	0	0	0	0	1,660	0	0	0	0
10	0	0	1,459	0	271	141	0	0	0	729	0	95	62	0
11	0	1	9,754	0	4,626	3,497	171	27	62	4,510	0	3,015	1,930	13
11.1	0	8	1,736	0	0	1,356	839	0	42	482	0	0	376	495
12	0	0	4,479	0	1,332	7,136	0	51	0	1,416	0	870	4,199	0
13	19	0	8,101	0	0	6,923	0	15	0	7,636	0	0	5,097	0
14	0	0	3,115	0	1,678	3,864	0	0	0	1,764	0	1,083	2,346	0
15	471	9,832	9,532	0	0	1,899	8,074	0	8,779	15,570	0	0	4,282	9,946
16	1,017	21,574	14,924	0	0	18,220	14,180	94	18,528	21,052	0	0	20,826	14,548
17	12	0	3,814	0	0	9,924	0	8	0	4,753	0	0	10,202	0
18	0	1,053	2,735	0	0	4,001	1,987	0	1,202	1,288	0	0	3,397	1,795
19	0	1,028	3,401	0	0	6,308	755	0	1,320	1,958	0	0	5,084	548
20	0	0	7,848	0	2,276	5,107	0	103	0	4,504	0	1,281	3,358	0
21	0	0	2,148	0	0	2,009	0	0	0	1,496	0	0	1,267	0
21.1	0	0	1,862	0	0	3,555	0	0	0	1,557	0	0	3,324	0
22	21	0	2,676	0	0	1,574	0	47	0	2,186	0	0	1,228	0
23	0	0	3,740	0	120	3,353	0	0	0	3,277	0	73	2,754	0
24	0	0	3,183	0	0	2,403	0	12	0	2,318	0	0	1,125	0
25	13	0	2,724	0	0	4,119	0	5	0	1,208	0	0	2,591	0
26	0	0	1,420	0	401	1,034	0	0	0	296	0	117	332	0
27	0	4,251	7,852	0	0	4,051	7,500	0	5,000	4,378	0	0	1,716	7,038
28	0	281	2,400	0	0	1,140	689	0	349	373	0	0	223	408
	2,228	60,011	139,038	0	10,888	132,024	58,181	486	56,530	118,515	0	6,619	111,380	58,976
Petticoat	57	502	6,118	56	88	3,283	2,074	58	662	6,118	56	87	3,039	1,640
Frenchman	0	0	2,296	769	2,634	0	0	0	0	2,296	483	2,321	0	0
Lower Duff	0	0	69	177	0	73	72	0	0	69	63	0	22	42
	2,285	60,513	147,520	1,002	13,610	135,379	60,327	544	57,192	126,997	602	9,027	114,441	60,658

Note:

Values provided are for comparison and discussion purposes only and are not considered as accurate as shown.

IN
- R = model artifact dry river cells
- GHB = groundwater flow across drainage divides
- R = groundwater recharge

OUT
- CH = flow to Lake Ontario
- Drains = flow to springs along river valleys.
- Riv = groundwater discharge to streams.

Table 8. Comparison of Clarifica GWI values for Existing landuse (Scenario#1) versus Scenario #2 (Future Official Plan). Analysis conducted using Duffins MODFLOW model (Gerber & Howard, 2000).

	Scenario #1							Scenario #2						
Basin#	IN (m3/d)			OUT (m3/d)				IN (m3/d)			OUT (m3/d)			
	Riv	GHB	R	CH	Drains	Riv	GHB	Riv	GHB	R	CH	Drains	Riv	GHB
1	11	2,781	1,447	0	0	1,454	3,477	13	2,781	1,447	0	0	1,419	3,477
2	0	8,446	4,927	0	0	6,452	10,242	0	8,449	4,203	0	0	5,988	10,236
3	270	7,191	9,460	0	0	4,563	6,178	278	7,216	9,323	0	0	4,301	6,177
4	0	0	3,023	0	183	3,326	0	0	0	3,023	0	183	3,311	0
5	308	3,566	5,367	0	0	5,177	4,088	315	3,567	5,367	0	0	5,167	4,087
6	0	0	2,555	0	0	5,784	0	0	0	2,555	0	0	5,762	0
7	85	0	5,443	0	0	9,535	0	85	0	5,443	0	0	9,533	0
8	0	0	2,532	0	0	4,121	0	0	0	2,532	0	0	4,117	0
9	0	0	5,384	0	0	0	0	0	0	5,384	0	0	0	0
10	0	0	1,459	0	271	141	0	0	0	1,459	0	270	141	0
11	0	1	9,754	0	4,626	3,497	171	0	1	9,656	0	4,577	3,398	166
11.1	0	8	1,736	0	0	1,356	839	0	9	1,736	0	0	1,349	831
12	0	0	4,479	0	1,332	7,136	0	0	0	3,768	0	1,082	6,560	0
13	19	0	8,101	0	0	6,923	0	19	0	8,101	0	0	6,921	0
14	0	0	3,115	0	1,678	3,864	0	0	0	3,115	0	1,677	3,857	0
15	471	9,832	9,532	0	0	1,899	8,074	471	9,833	9,532	0	0	1,898	8,073
16	1,017	21,574	14,924	0	0	18,220	14,180	1,017	21,575	14,924	0	0	18,219	14,179
17	12	0	3,814	0	0	9,924	0	12	0	3,814	0	0	9,923	0
18	0	1,053	2,735	0	0	4,001	1,987	0	1,053	2,735	0	0	4,000	1,986
19	0	1,028	3,401	0	0	6,308	755	0	1,029	3,401	0	0	6,290	751
20	0	0	7,848	0	2,276	5,107	0	0	0	7,848	0	2,272	4,966	0
21	0	0	2,148	0	0	2,009	0	0	0	1,853	0	0	1,806	0
21.1	0	0	1,862	0	0	3,555	0	0	0	1,854	0	0	3,351	0
22	21	0	2,676	0	0	1,574	0	26	0	2,589	0	0	1,457	0
23	0	0	3,740	0	120	3,353	0	0	0	2,597	0	98	2,796	0
24	0	0	3,183	0	0	2,403	0	0	0	2,766	0	0	2,061	0
25	13	0	2,724	0	0	4,119	0	0	0	1,989	0	0	3,351	0
26	0	0	1,420	0	401	1,034	0	0	0	1,468	0	374	978	0
27	0	4,251	7,852	0	0	4,051	7,500	0	4,327	7,485	0	0	3,886	7,371
28	0	281	2,400	0	0	1,140	689	0	299	1,714	0	0	845	620
	2,228	60,011	139,038	0	10,888	132,024	58,181	2,236	60,139	133,681	0	10,533	127,651	57,954
Petticoat	57	502	6,118	56	88	3,283	2,074	58	508	6,118	56	88	3,271	2,055
Frenchman	0	0	2,296	769	2,634	0	0	0	0	2,296	675	2,560	0	0
Lower Duff	0	0	69	177	0	73	72	0	0	69	143	0	56	62
	2,285	60,513	147,520	1,002	13,610	135,379	60,327	2,294	60,647	142,163	874	13,181	130,978	60,071

Note:

Values provided are for comparison and discussion purposes only and are not considered as accurate as shown.

IN: Riv - model artifact dry river cells; GHB = groundwater flow across surficial drainage divide; R = groundwater recharge

OUT: CH = groundwater flow to Lake Ontario; Drains = flow to springs along valleys; Riv = groundwater discharge to streams

(shaded) Subcatchment (basin) with future landuse scenario GWI estimate different from existing landuse (Scenario #1).

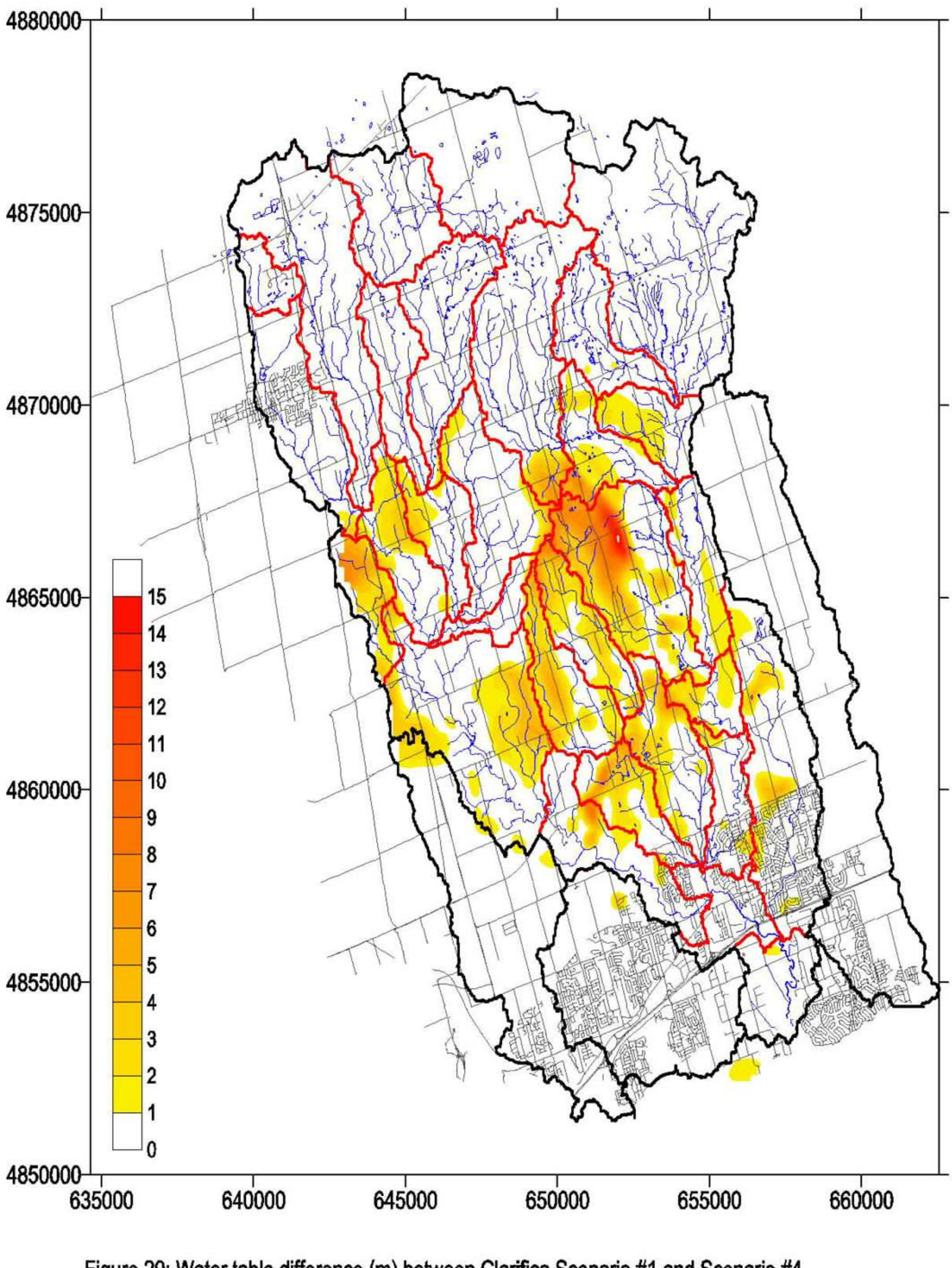


Figure 29: Water table difference (m) between Clarifica Scenario #1 and Scenario #4.
Positive values indicate a decline in water table elevation.

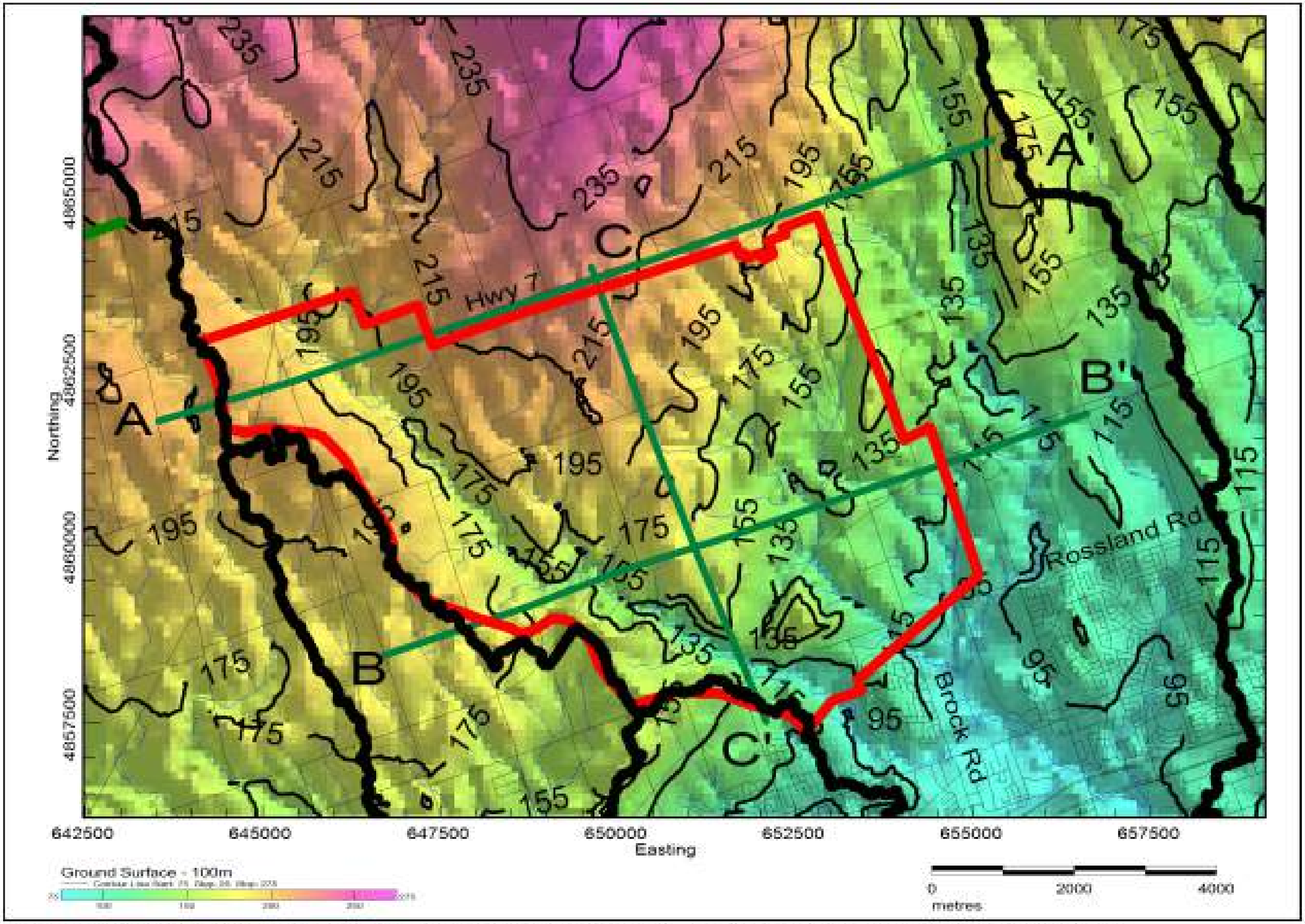


Figure 30: Seaton (outlined in red) ground surface elevation. Cross section locations shown in green.

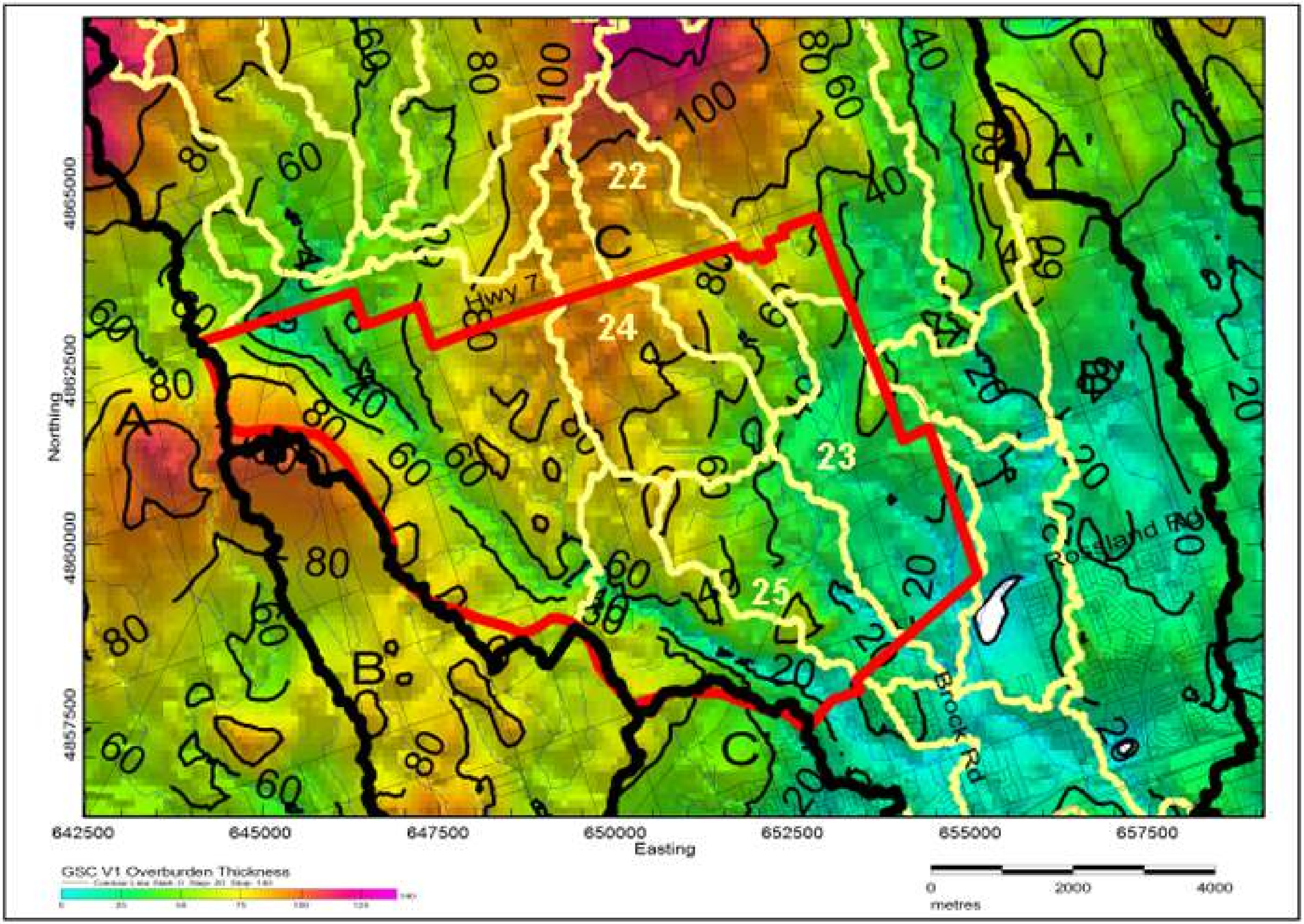


Figure 31: Seaton overburden thickness. Subcatchment numbers and boundaries shown in yellow.

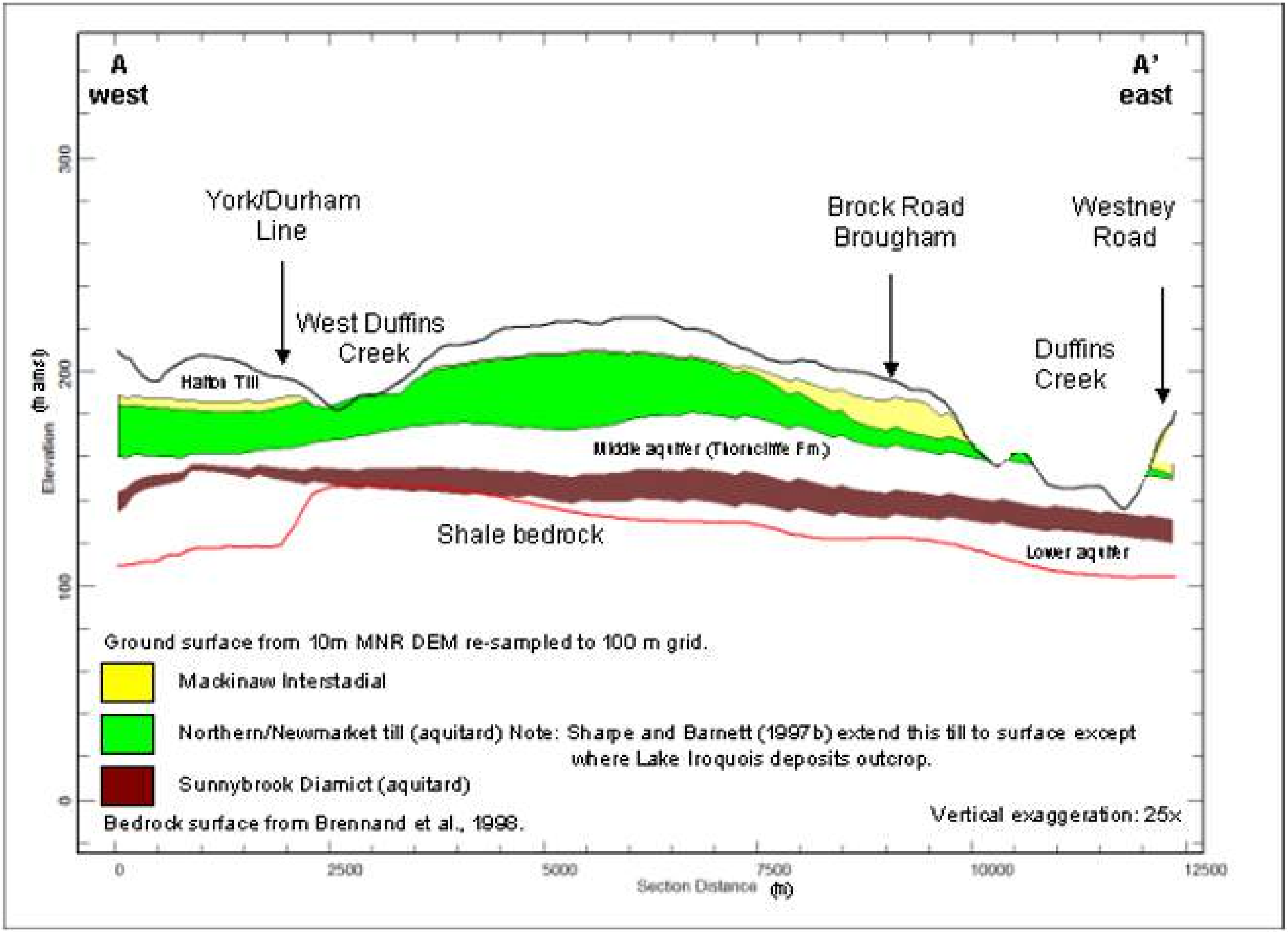


Figure 32: Seaton west-east cross section A-A' along Highway 7. See Figure 30 for cross section location.

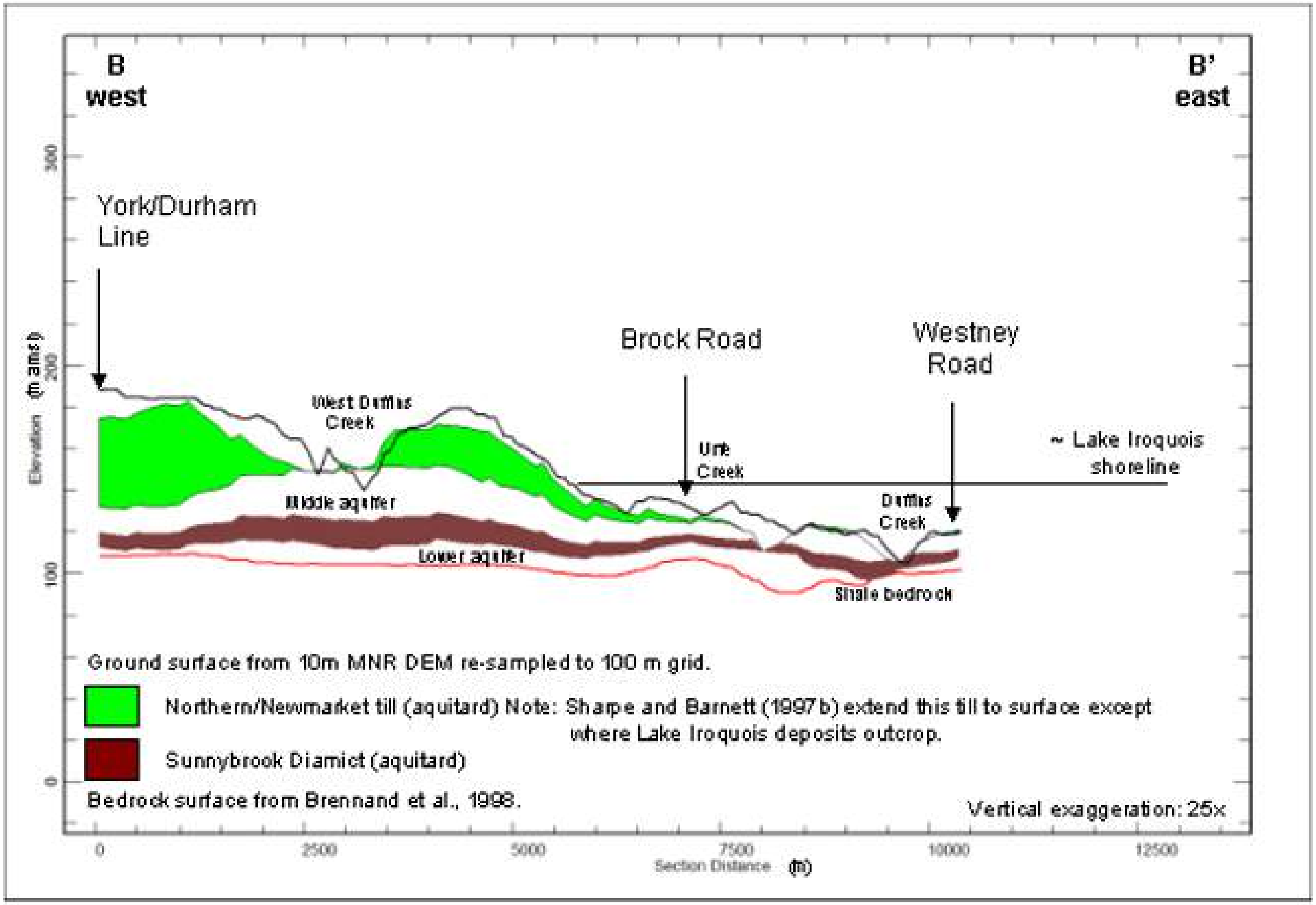


Figure 33: Seaton west-east cross section B-B' along Taunton Road. See Figure 30 for section location.

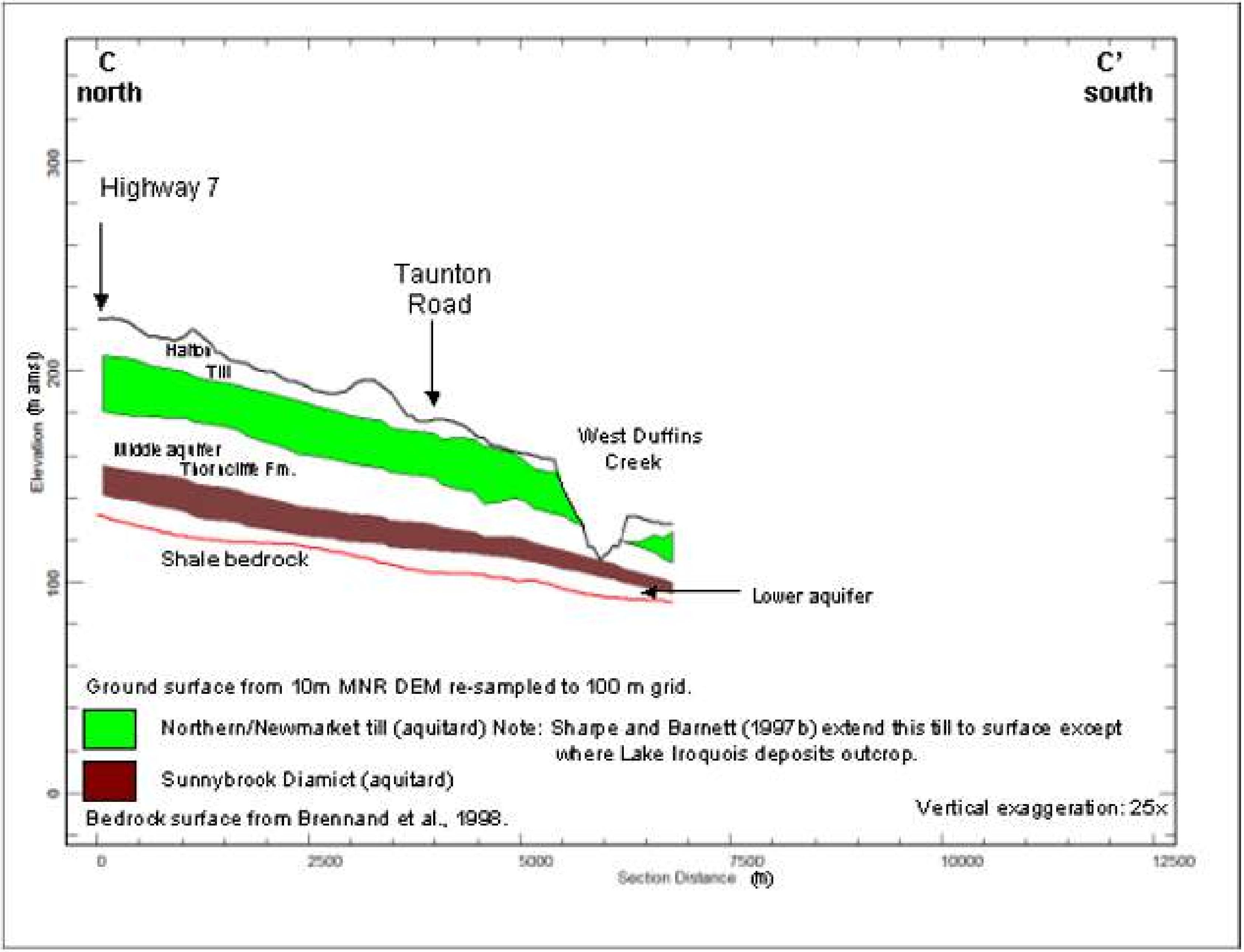


Figure 34: Seaton north-south cross section C-C'. See Figure 30 for cross section location.

Table 9. Comparison of Clarifica GWI values for Existing (Scenario#1) versus Scenario #4 (Future OP + South Slope development). Analysis conducted using Duffins MODFLOW model (Gerber & Howard, 2000).

Basin#	Scenario #1 IN (m3/d) Riv	GHB	R	Scenario #1 OUT (m3/d) CH	Drains	Riv	GHB	Scenario #4 IN (m3/d) Riv	GHB	R	Scenario #4 OUT (m3/d) CH	Drains	Riv	GHB
1	11	2,781	1,447	0	0	1,454	3,477	14	2,784	1,447	0	0	1,405	3,472
2	0	8,446	4,927	0	0	6,452	10,242	0	8,482	4,008	0	0	5,721	10,181
3	270	7,191	9,460	0	0	4,563	6,178	289	7,237	9,232	0	0	3,952	6,169
4	0	0	3,023	0	183	3,326	0	5	0	1,580	0	117	1,877	0
5	308	3,566	5,367	0	0	5,177	4,088	320	3,575	5,367	0	0	5,144	4,073
6	0	0	2,555	0	0	5,784	0	0	0	2,472	0	0	5,399	0
7	85	0	5,443	0	0	9,535	0	96	0	5,392	0	0	8,740	0
8	0	0	2,532	0	0	4,121	0	0	0	1,483	0	0	2,680	0
9	0	0	5,384	0	0	0	0	0	0	3,131	0	0	0	0
10	0	0	1,459	0	271	141	0	0	0	884	0	163	92	0
11	0	1	9,754	0	4,626	3,497	171	97	12	5,316	0	3,006	2,200	53
11.1	0	8	1,736	0	0	1,356	839	0	23	463	0	0	523	610
12	0	0	4,479	0	1,332	7,136	0	0	0	3,642	0	999	6,273	0
13	19	0	8,101	0	0	6,923	0	26	0	7,561	0	0	5,877	0
14	0	0	3,115	0	1,678	3,864	0	0	0	2,325	0	1,189	3,084	0
15	471	9,832	9,532	0	0	1,899	8,074	485	9,931	9,532	0	0	1,859	8,053
16	1,017	21,574	14,924	0	0	18,220	14,180	1,129	21,908	13,959	0	0	17,828	14,011
17	12	0	3,814	0	0	9,924	0	13	0	3,631	0	0	9,509	0
18	0	1,053	2,735	0	0	4,001	1,987	0	1,101	2,142	0	0	3,785	1,881
19	0	1,028	3,401	0	0	6,308	755	0	1,193	2,351	0	0	5,461	528
20	0	0	7,848	0	2,276	5,107	0	202	0	4,159	0	1,190	3,056	0
21	0	0	2,148	0	0	2,009	0	0	0	1,718	0	0	1,644	0
21.1	0	0	1,862	0	0	3,555	0	0	0	1,499	0	0	2,905	0
22	21	0	2,676	0	0	1,574	0	164	0	911	0	0	594	0
23	0	0	3,740	0	120	3,353	0	0	0	2,372	0	74	2,331	0
24	0	0	3,183	0	0	2,403	0	172	0	1,839	0	0	762	0
25	13	0	2,724	0	0	4,119	0	4	0	1,989	0	0	3,016	0
26	0	0	1,420	0	401	1,034	0	0	0	1,468	0	372	958	0
27	0	4,251	7,852	0	0	4,051	7,500	0	4,622	6,107	0	0	3,432	6,835
28	0	281	2,400	0	0	1,140	689	0	305	1,714	0	0	838	606
	2,228	60,011	139,038	0	10,888	132,024	58,181	3,014	61,172	109,693	0	7,108	110,946	56,472
Petticoat	57	502	6,118	56	88	3,283	2,074	58	584	6,118	56	88	3,043	1,812
Frenchman	0	0	2,296	769	2,634	0	0	0	0	2,296	675	2,546	0	0
Lower Duff	0	0	69	177	0	73	72	0	0	69	143	0	56	62
	2,285	60,513	147,520	1,002	13,610	135,379	60,327	3,072	61,756	118,175	874	9,742	114,045	58,346

Note:

Values provided are for comparison and discussion purposes only and are not considered as accurate as shown.

IN
- Riv - model artifact dry river cells
- GHB = groundwater flow across surficial drainage divide
- R = groundwater recharge

OUT
- CH = groundwater flow to Lake Ontario
- Drains = flow to springs along valleys
- Riv = groundwater discharge to streams

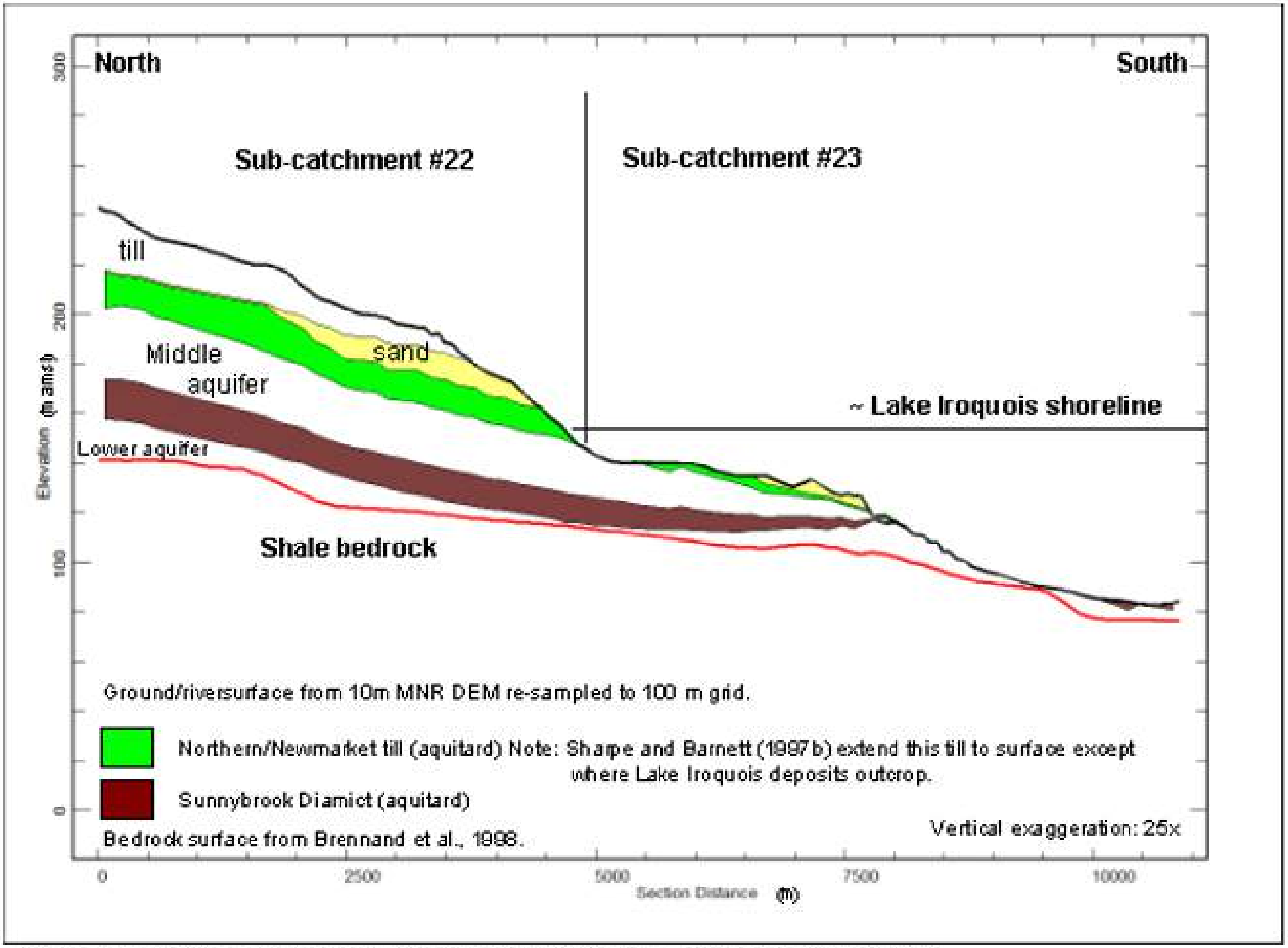
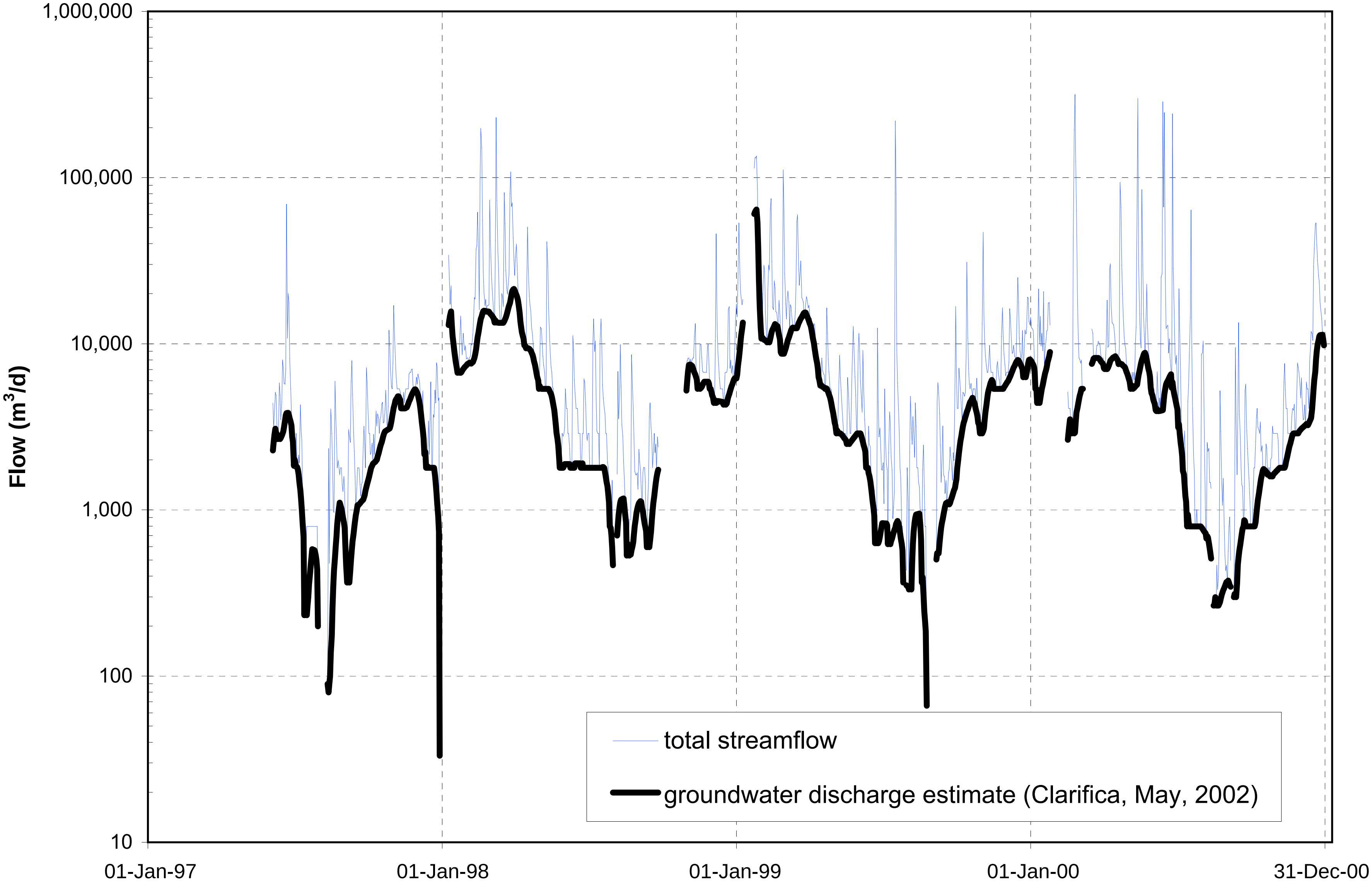


Figure 35: Profile along the Urfe Creek valley within sub-catchments #22 and 23.

Figure 36: Urfe Creek at Rossland Road - total streamflow.



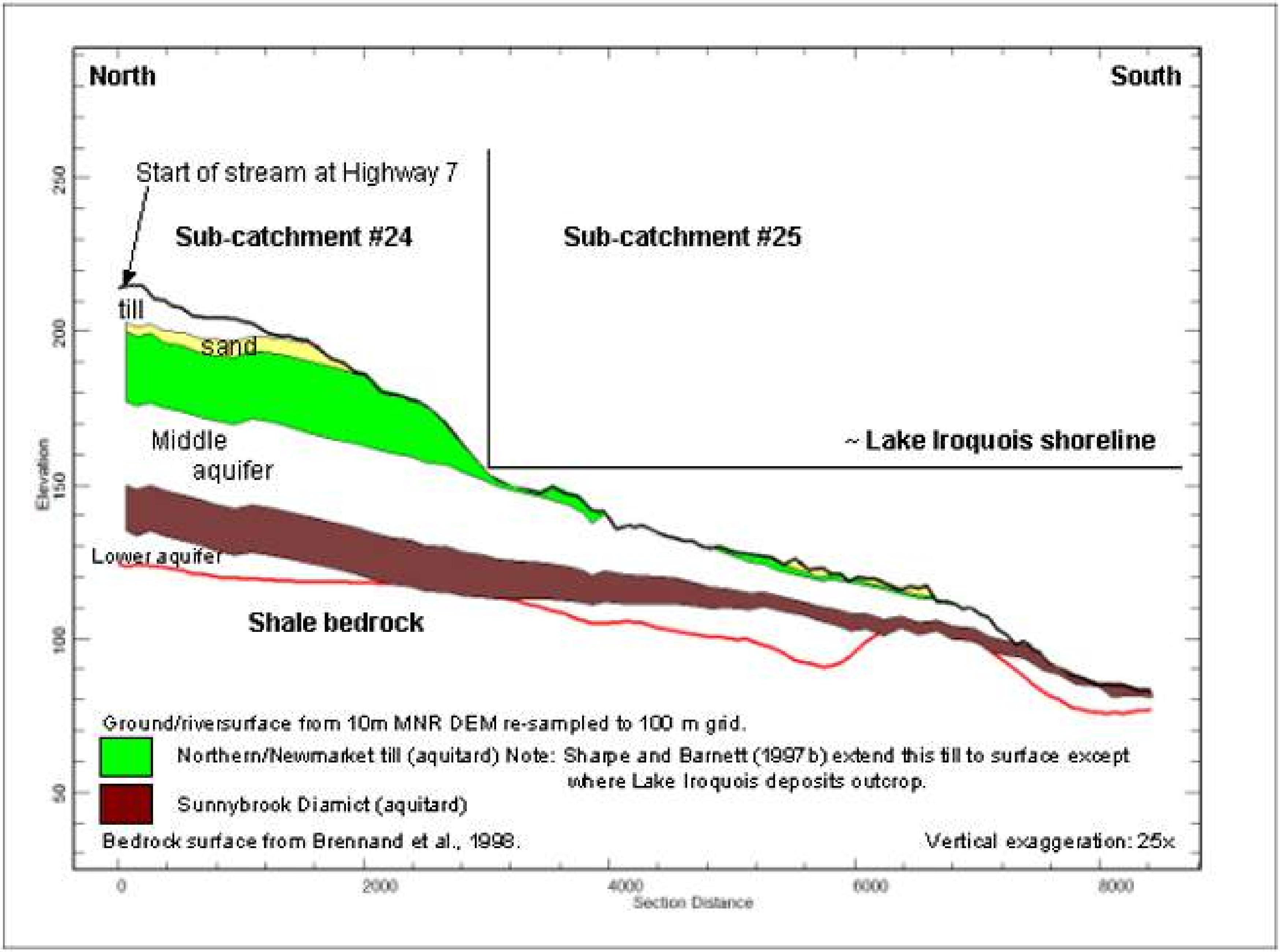


Figure 37: Profile along the Ganatsekiagon Creek valley within sub-catchments #24 and 25.

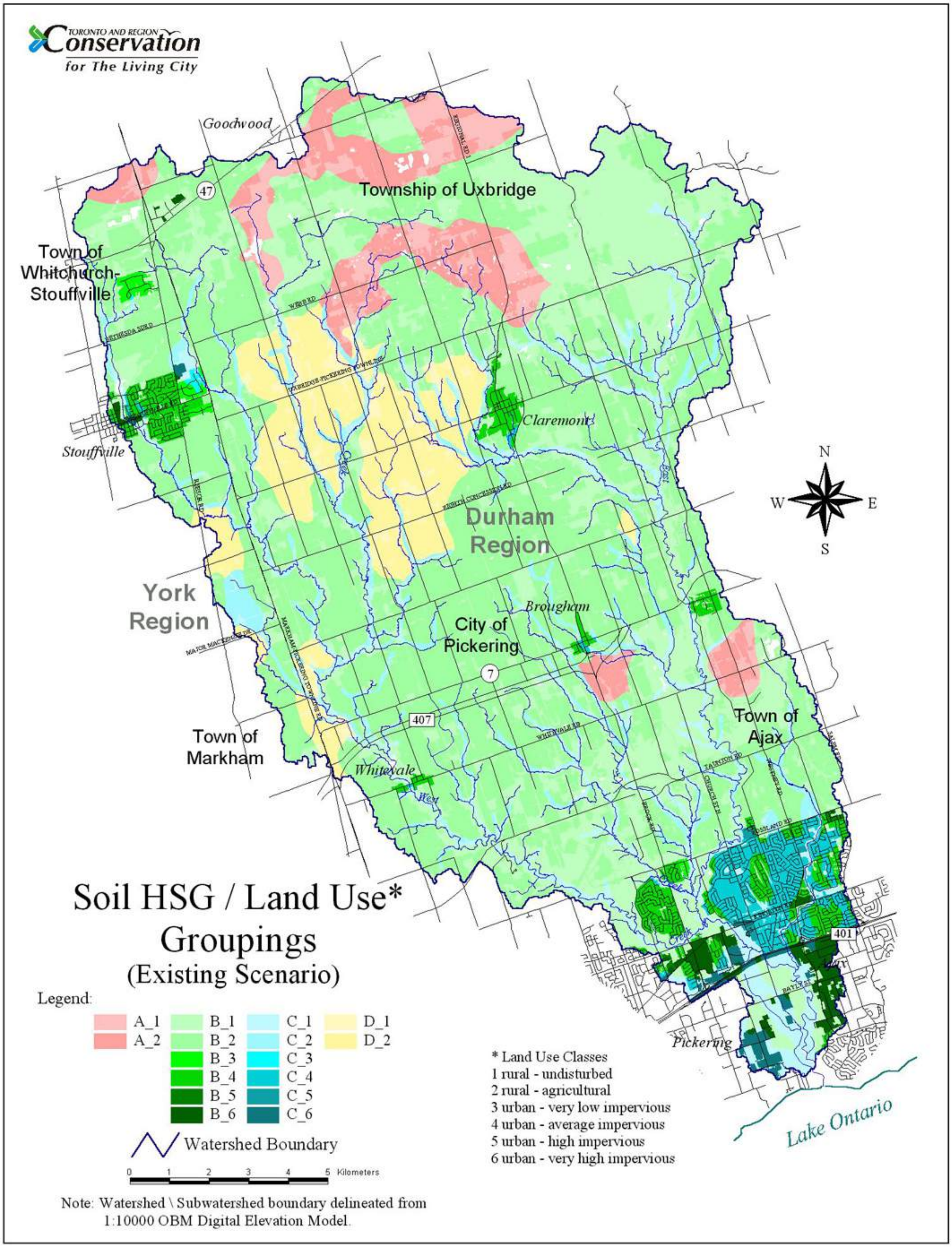


Figure 38: Clarifica existing landuse scenario URF's (soil + landuse combination). Figure provided by the TRCA.

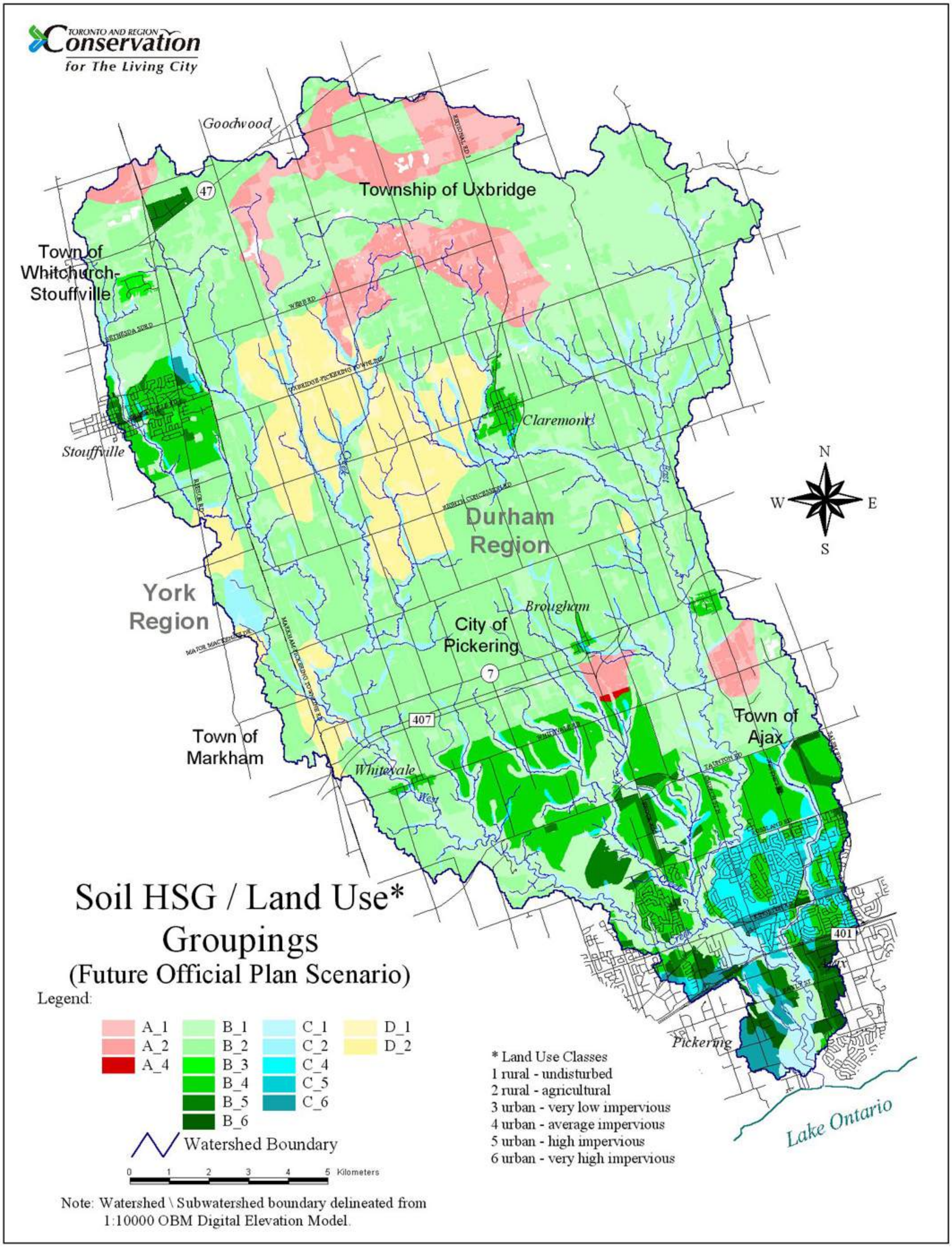


Figure 39: Clarifica future landuse scenario URF's (soil + landuse combination). Figure provided by the TRCA.

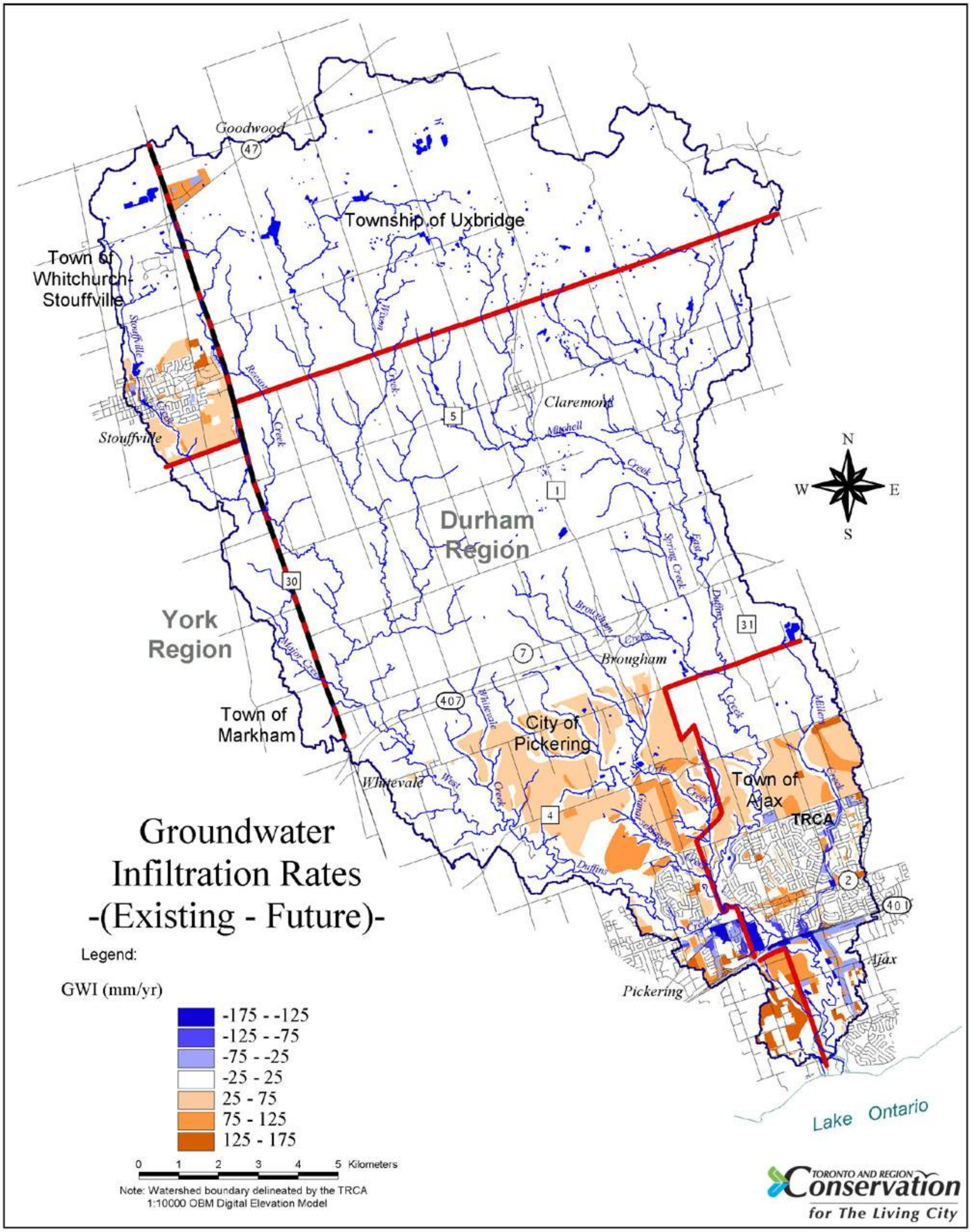


Figure 40: Clarifica URF GWI (recharge) difference. Scenario#1 (existing) minus Scenario#2 future (figure from TRCA).

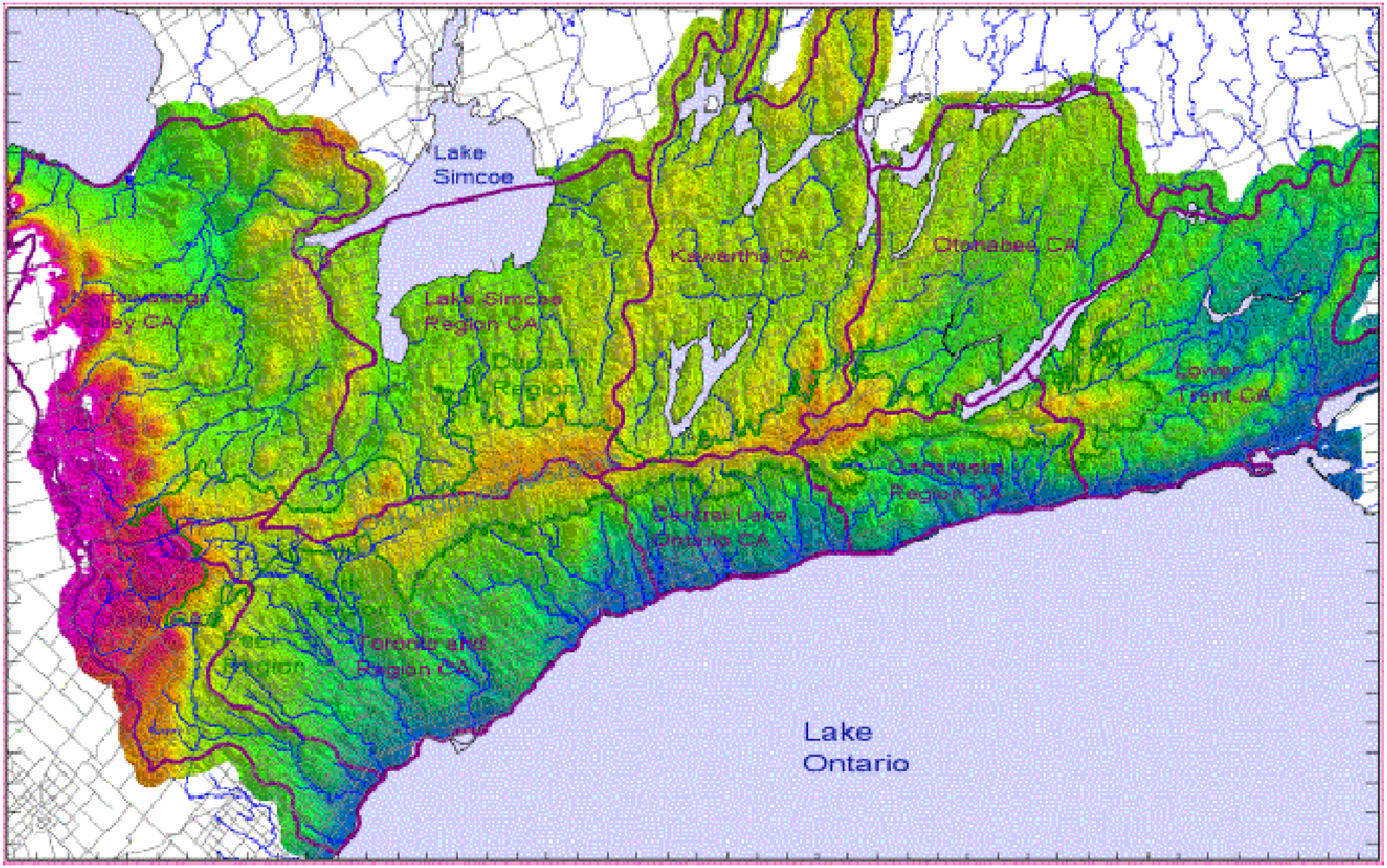


Figure 41: CAMC regional groundwater investigation study area.

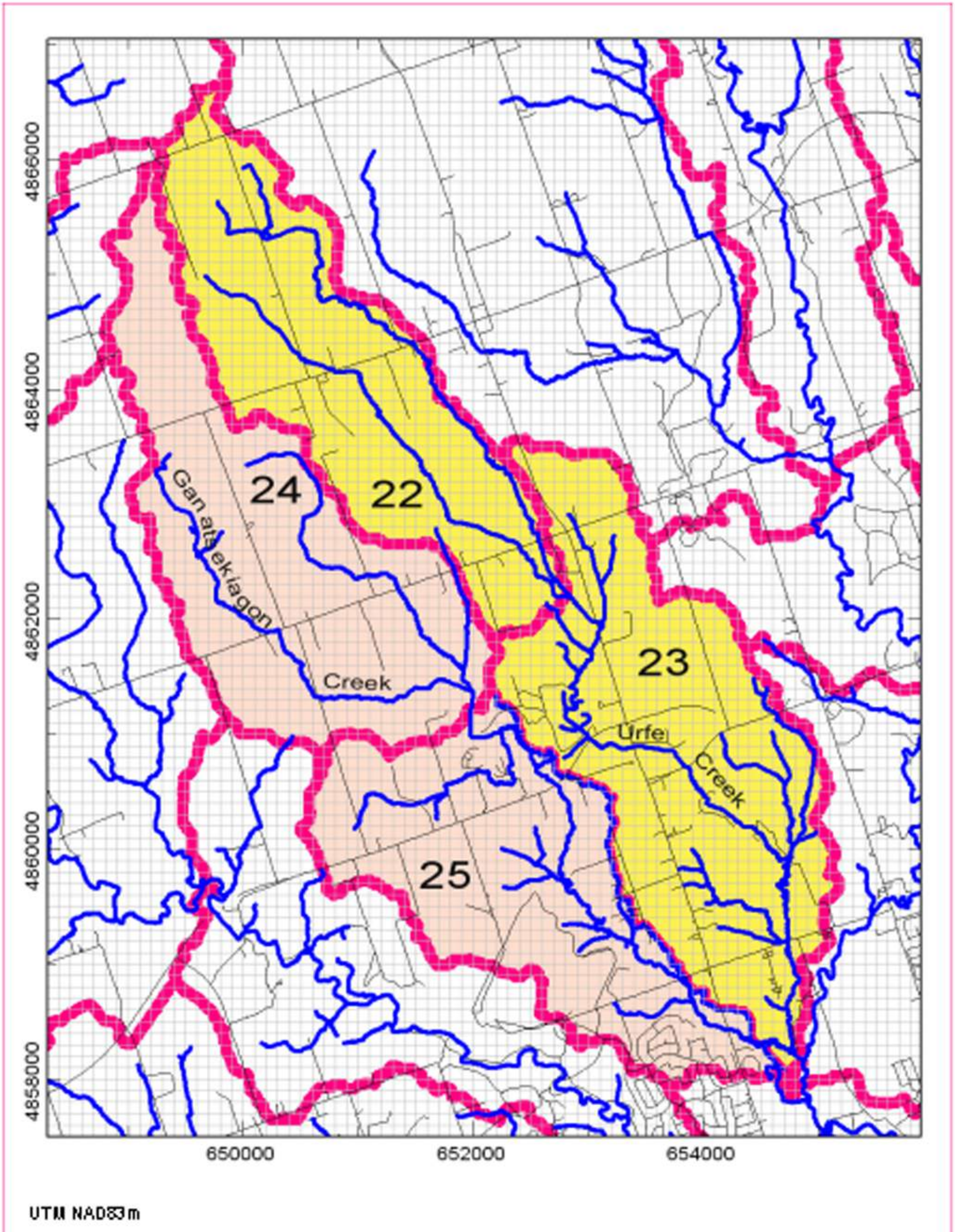


Figure 42: Model grid (100m x 100m) area for Ganatsekiagon Creek and Urfe Creek subcatchments (#22-25).

Table 10: Comparison of "Subcatchment" versus "URF" recharge estimates (Clarifica, 2002) and associated model input/output.

		model#2: uses Clarifica URF recharge values									Clarifica (2002) recharge estimates					
											30 subcatchments			URF		
		Existing			Future						Existing	Future		Existing	Future	
	basin	In-R m^3/d	Out-Drain m^3/d	In/Out m^3/d	In-R m^3/d	Out-Drain m^3/d	In/Out m^3/d	del R m^3/d	del Drain m^3/d	dIN/dOUT m^3/d	R m^3/d	R m^3/d	R diff m^3/d	R m^3/d	R m3/d	R diff m3/d
Urfe	22	3,732	1,711	2.2	3,650	1,639	2.2	-82	-72	1.14	3,209	3,104	-105	3,734	3,662	-72
	23	4,752	8,640	0.6	4,035	8,156	0.5	-717	-484	1.48	4,748	3,304	-1,444	4,704	3,987	-717
Gan	24	4,221	1,832	2.3	3,862	1,633	2.4	-359	-199	1.80	4,022	3,502	-520	4,209	3,853	-357
	25	3,439	2,877	1.2	2,860	2,652	1.1	-579	-225	2.58	3,658	2,672	-986	3,405	2,833	-572

		model#1: uses Clarifica subcatchment recharge values (corrected for recharge area, Table 6)								
		Existing			Future					
		In-R m^3/d	Out-Riv m^3/d	In/Out m^3/d	In-R m^3/d	Out-Riv m^3/d	In/Out m^3/d	del R m^3/d	del Riv m^3/d	dIN/dOUT m^3/d
Urfe	22	2,676	1,574	1.7	2,589	1,457	1.8	-87	-117	0.74
	23	3,740	3,353	1.1	2,597	2,796	0.9	-1,143	-557	2.05
Gan	24	3,183	2,403	1.3	2,766	2,061	1.3	-417	-342	1.22
	25	2,724	4,119	0.7	1,989	3,351	0.6	-735	-768	0.96

Note: Values provided are for discussion and comparison purposes only, and are not considered as accurate as shown.

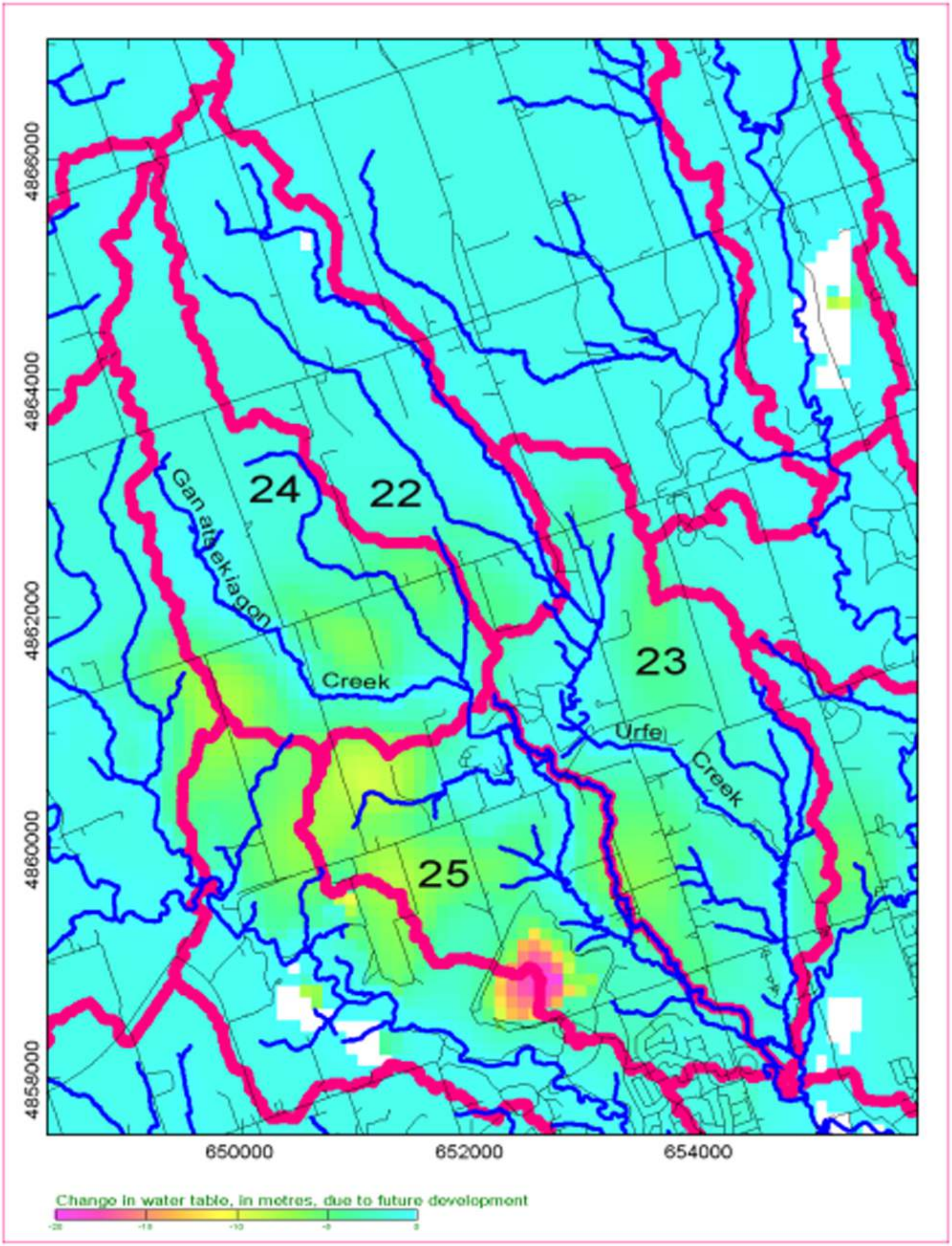


Figure 43: Estimated water table change between existing and future landuse scenarios. Scale bar colors refer to estimated magnitude of water table drop. Differences >10 m are considered numerical model artifacts where layers go dry.

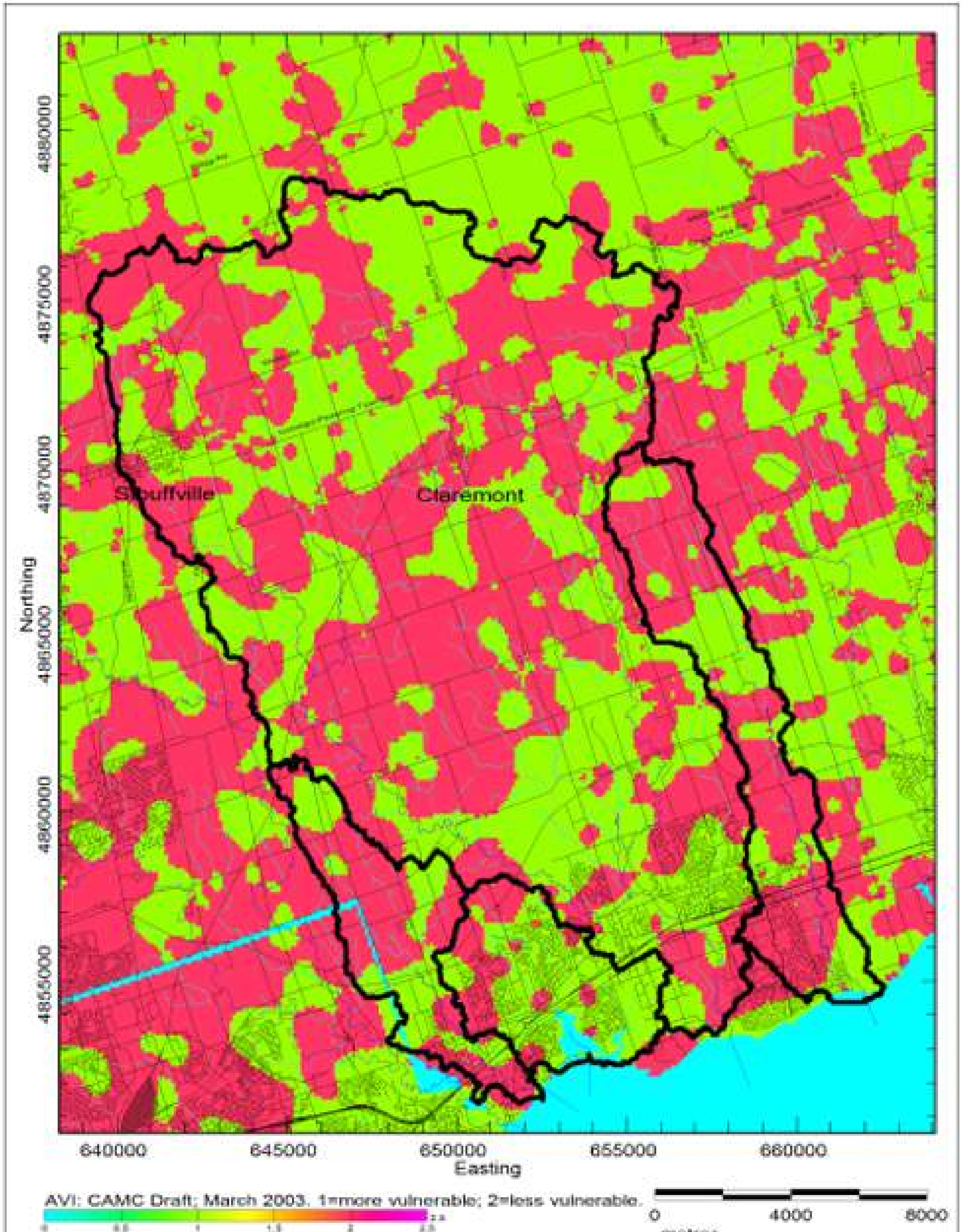


Figure 44: Aquifer vulnerability mapping as per MOE protocol and provided by Conservation Authority Moraine Coalition (CAMC). This map should be considered draft pending final review.

Table A1: Summary of Duffins area meterology data in the TRCA database (information provided by the TRCA).

Measurement_ID	Parameter_Definition	Station_ID	Station_Name	ocation_Nam	Earliest	Latest	N values
PRECIP	PRECIPITATION TOTAL	06158080	TRCA station	Duffins	01-Jul-95	01-Oct-01	1442
PRECIP	PRECIPITATION TOTAL	61526059	Frenchmans Bay		01-Dec-59	31-May-92	11673
PRECIP	PRECIPITATION TOTAL	61530209	Greenwood MTRCA	Duffins	01-Jan-60	29-May-92	10537
PRECIP	PRECIPITATION TOTAL	61558789	Oshawa WPCP		21-Aug-69	31-May-92	8248
PRECIP	PRECIPITATION TOTAL	61565159	Pickering Audley	Duffins	01-Oct-58	30-Jun-85	9570
PRECIP	PRECIPITATION TOTAL	61565169	Pickering Dunbarton	Duffins	01-Oct-86	31-Jan-90	1163
PRECIP	PRECIPITATION TOTAL	61571949	Rouge Park	Rouge	01-Jul-60	30-Apr-92	10059
PRECIP	PRECIPITATION TOTAL	6158084	Stouffville WPCP - TRCA station	Duffins	12-Nov-71	30-Mar-93	7490
PRECIP	PRECIPITATION TOTAL	615HMAK9	Toronto Buttonville	Duffins	23-May-86	30-Nov-92	2382
PRECIP	PRECIPITATION TOTAL	cherrywood	Cherrywood Hydro	Duffins	01-Jan-95	04-Dec-01	2304
PRECIP	PRECIPITATION TOTAL	Pearson	Pearson International Airport	Duffins	01-Jan-95	31-Oct-98	1338
PRECIP	PRECIPITATION TOTAL	stwilfrid	St. Wilfrid School	Duffins	26-May-01	01-Oct-01	129
RAIN	PRECIPITATION AS RAIN	06158080	TRCA station	Duffins	01-Jul-95	31-Aug-98	1030
RAIN	PRECIPITATION AS RAIN	61526059	Frenchmans Bay		01-Dec-59	31-May-92	11673
RAIN	PRECIPITATION AS RAIN	61530209	Greenwood MTRCA	Duffins	01-Jan-60	29-May-92	10509
RAIN	PRECIPITATION AS RAIN	61558789	Oshawa WPCP		21-Aug-69	31-May-92	8246
RAIN	PRECIPITATION AS RAIN	61565159	Pickering Audley	Duffins	01-Oct-58	30-Jun-85	9570
RAIN	PRECIPITATION AS RAIN	61565169	Pickering Dunbarton	Duffins	01-Oct-86	31-Jan-90	1163
RAIN	PRECIPITATION AS RAIN	61571949	Rouge Park	Rouge	01-Jul-60	30-Apr-92	10059
RAIN	PRECIPITATION AS RAIN	6158084	Stouffville WPCP - TRCA station	Duffins	12-Nov-71	30-Mar-93	7490
RAIN	PRECIPITATION AS RAIN	615HMAK9	Toronto Buttonville	Duffins	23-May-86	30-Nov-92	2376
RAIN	PRECIPITATION AS RAIN	Pearson	Pearson International Airport	Duffins	01-Jan-95	31-Oct-98	1338
SNOW	PRECIPITATION AS SNOW	61526059	Frenchmans Bay		01-Dec-59	31-May-92	11706
SNOW	PRECIPITATION AS SNOW	61530209	Greenwood MTRCA	Duffins	01-Jan-60	31-May-92	10600
SNOW	PRECIPITATION AS SNOW	61558789	Oshawa WPCP		21-Aug-69	31-May-92	8251
SNOW	PRECIPITATION AS SNOW	61565159	Pickering Audley	Duffins	01-Oct-58	30-Jun-85	9607
SNOW	PRECIPITATION AS SNOW	61565169	Pickering Dunbarton	Duffins	01-Oct-86	31-Jan-90	1181
SNOW	PRECIPITATION AS SNOW	61571949	Rouge Park	Rouge	01-Jul-60	30-Apr-92	10223
SNOW	PRECIPITATION AS SNOW	615HMAK9	Toronto Buttonville	Duffins	23-May-86	30-Nov-92	2381
SNOW	PRECIPITATION AS SNOW	Pearson	Pearson International Airport	Duffins	01-Jan-95	31-Oct-98	1338
GRNDSNOW	SNOW DEPTH ON THE GROUND (m)	61526059	Frenchmans Bay		10-Nov-80	31-May-92	2785
GRNDSNOW	SNOW DEPTH ON THE GROUND (m)	61530209	Greenwood MTRCA	Duffins	22-Apr-83	31-May-92	584
GRNDSNOW	SNOW DEPTH ON THE GROUND (m)	61558789	Oshawa WPCP		01-Dec-80	31-May-92	1471
GRNDSNOW	SNOW DEPTH ON THE GROUND (m)	61565159	Pickering Audley	Duffins	01-Jan-61	31-Oct-84	6449
GRNDSNOW	SNOW DEPTH ON THE GROUND (m)	61565169	Pickering Dunbarton	Duffins	21-Nov-86	23-Jan-90	147
GRNDSNOW	SNOW DEPTH ON THE GROUND (m)	61571949	Rouge Park	Rouge	18-Nov-80	30-Apr-92	1912
GRNDSNOW	SNOW DEPTH ON THE GROUND (m)	615HMAK9	Toronto Buttonville	Duffins	23-May-86	30-Nov-92	2381
GRNDSNOW	SNOW DEPTH ON THE GROUND (m)	Pearson	Pearson International Airport	Duffins	01-Jan-96	31-Mar-98	687

Table A1: Summary of Duffins area meterology data in the TRCA database (information provided by the TRCA).

Measurement_ID	Parameter_Definition	Station_ID	Station_Name	ocation_Nam	Earliest	Latest	N values
TMEAN	TEMPERATURE MEAN	06158080	TRCA station	Duffins	01-Jan-98	01-Oct-01	655
TMEAN	TEMPERATURE MEAN	61530209	Greenwood MTRCA	Duffins	02-May-92	31-May-92	30
TMEAN	TEMPERATURE MEAN	61558789	Oshawa WPCP		21-Aug-69	31-May-92	8220
TMEAN	TEMPERATURE MEAN	61565159	Pickering Audley	Duffins	02-Oct-58	30-Jun-85	9507
TMEAN	TEMPERATURE MEAN	61565169	Pickering Dunbarton	Duffins	01-Oct-86	29-Jan-90	1037
TMEAN	TEMPERATURE MEAN	6158084	Stouffville WPCP - TRCA station	Duffins	13-Nov-71	28-Feb-93	7518
TMEAN	TEMPERATURE MEAN	615HMAK9	Toronto Buttonville	Duffins	23-May-86	30-Nov-92	2382
TMEAN	TEMPERATURE MEAN	stwilfrid	St. Wilfrid School	Duffins	26-May-01	01-Oct-01	129
TMIN	TEMPERATURE MINIMUM	06158080	TRCA station	Duffins	01-Jul-95	01-Oct-01	1429
TMIN	TEMPERATURE MINIMUM	61530209	Greenwood MTRCA	Duffins	02-May-92	31-May-92	30
TMIN	TEMPERATURE MINIMUM	61558789	Oshawa WPCP		21-Aug-69	31-May-92	8221
TMIN	TEMPERATURE MINIMUM	61565159	Pickering Audley	Duffins	02-Oct-58	30-Jun-85	9542
TMIN	TEMPERATURE MINIMUM	61565169	Pickering Dunbarton	Duffins	01-Oct-86	31-Jan-90	1081
TMIN	TEMPERATURE MINIMUM	615HMAK9	Toronto Buttonville	Duffins	23-May-86	30-Nov-92	2379
TMIN	TEMPERATURE MINIMUM	Pearson	Pearson International Airport	Duffins	01-Jul-97	31-Oct-98	426
TMIN	TEMPERATURE MINIMUM	stwilfrid	St. Wilfrid School	Duffins	26-May-01	01-Oct-01	129
TMAX	TEMPERATURE MAXIMUM	06158080	TRCA station	Duffins	01-Jul-95	01-Oct-01	1440
TMAX	TEMPERATURE MAXIMUM	61530209	Greenwood MTRCA	Duffins	02-May-92	31-May-92	30
TMAX	TEMPERATURE MAXIMUM	61558789	Oshawa WPCP		20-Aug-69	31-May-92	8221
TMAX	TEMPERATURE MAXIMUM	61565159	Pickering Audley	Duffins	01-Oct-58	30-Jun-85	9553
TMAX	TEMPERATURE MAXIMUM	61565169	Pickering Dunbarton	Duffins	01-Oct-86	29-Jan-90	1089
TMAX	TEMPERATURE MAXIMUM	615HMAK9	Toronto Buttonville	Duffins	23-May-86	30-Nov-92	2381
TMAX	TEMPERATURE MAXIMUM	Pearson	Pearson International Airport	Duffins	01-Jul-97	31-Oct-98	426
TMAX	TEMPERATURE MAXIMUM	stwilfrid	St. Wilfrid School	Duffins	26-May-01	01-Oct-01	129
RHMAX	HUMIDITY, RELATIVE MAXIMUM (%)	Pearson	Pearson International Airport	Duffins	01-Jul-97	31-Oct-98	426
RHMIN	HUMIDTY, RELATIVE MINIMUM (%)	Pearson	Pearson International Airport	Duffins	01-Jul-97	31-Oct-98	426

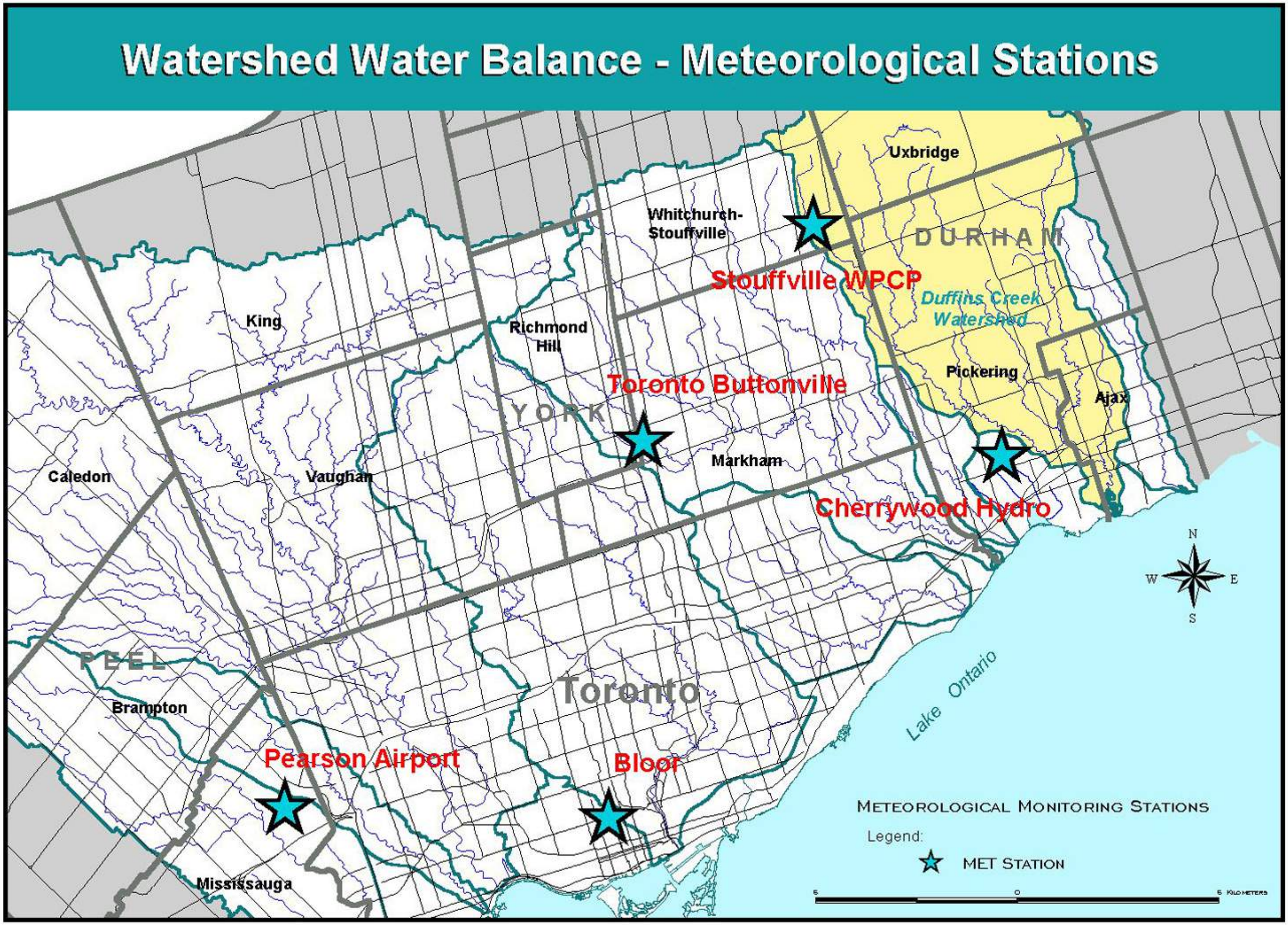


Figure A1: Meteorology station locations in the Duffins watershed area (figure from TRCA).

Table B1: Duffins watershed low flow streamflow data.

Date	Site	Q (l/s)	Error	Northing	Easting	Map Sheet	MOEE	Site description
17-Aug-95	D-001	16.7	1.5	4870429	643487	30 M/14	65	Reesor @ Ux-Pkg Twnln
18-Aug-95	D-003	113	8	4870845	644691	30 M/14	20	West Duffins Ck. @ Ux-Pkg twnln
18-Aug-95	D-005	12.6	2.5	4871385	646308	30 M/14	21	Wixon Ck. @ Ux-Pkg twnln
18-Aug-95	D-006	6.1	1.1	4871556	646806	30 M/14		E. trib to Wixon Ck. @ Ux-Pkg twnln
21-Aug-95	D-007	6.1	0.3	4871767	647416	30 M/14		Trib to Michell Ck. @ Ux-Pkg twnln, 450m E of s/l 24
21-Aug-95	D-011	6	0.7	4872318	649004	30 M/14		Trib to Michell Ck. @ Ux-Pkg twnln, 600m E of s/l 20
21-Aug-95	D-012	4.4	0.7	4872560	649692	30 M/14		Trib to Michell Ck. @ Ux-Pkg Twnln 200m W of Old Brock Rd
21-Aug-95	D-014	2.6	0.2	4872845	650502	30 M/14		Trib to Duffins Ck. @ Ux-Pkg Twnln 550m E of Brock Rd. (Dur 1)
21-Aug-95	D-015	0.14	0.02	4873022	651010	30 M/14		seep to Trib to Duffins Ck. @ Ux-Pkg Twnln 1100m E of Brock Rd. (Dur 1)
20-Aug-95	D-019	57.1	5.8	4875251	654411	31 D/3		Duffins Ck., Conc.7 500m N of Glen Major
20-Aug-95	D-020	1	0.2	4874830	654641	31 D/3		trib to Duffins Ck.Conc.7 @ Glen Major
16-Aug-95	D-021	139	13	4873647	655004	30 M/14		Duffins Ck.,Conc.7 300m N of CP tracks
20-Aug-95	D-021	139	10	4873647	655004	" "		" "
16-Aug-95	D-025	177	16	4871924	654106	30 M/14	32	Duffins Ck. @ Durham 5
20-Aug-95	D-025	211	19	4871924	654106	" "		
16-Aug-95	D-026	14.9	2.3	4871880	653973	30 M/14		Trib to Duffins Ck.@ Durham 5, 950m E of Westney Rd.
20-Aug-95	D-026	18.9	3	4871880	653973	" "		" "
16-Aug-95	D-027	24.1	1.6	4871709	653482	30 M/14		Trib to Duffins Ck.@ Durham 5, 400m E of Westney Rd.
20-Aug-95	D-027	23.8	2.4	4871709	653482	" "		" "
16-Aug-95	D-028	9.5	1	4871623	653222	30 M/14		Trib to Duffins Ck.@ Durham 5, 150m E of Westney Rd.
20-Aug-95	D-028	12.7	1.6	4871623	653222	" "		" "
16-Aug-95	D-029	6.2	0.8	4871589	653114	30 M/14		Trib to Duffins Ck.@ Durham 5, 25m E of Westney Rd.
20-Aug-95	D-029	5.9	0.2	4871589	653114	" "		" "
21-Aug-95	D-034	22.1	2.6	4870296	649469	30 M/14	66	Michell Ck. @ Durham 5, 300m E of s/l 20
21-Aug-95	D-035	0.65		4870080	648877	30 M/14		Trib to Michell Ck.@ Durham 5, 300m W of s/l 20
21-Aug-95	D-037	1.11		4869843	648197	N/A		No Description Available
16-Aug-95	D-041	56.2	4.8	4869070	645884	30 M/14	18	Wixon Ck. @ Durham 5
18-Aug-95	D-041	41.6	6.2	4869070	645884	" "		" "
31-Aug-95	D-041	45.2	6.1	4869070	645884	" "		" "
17-Aug-95	D-042	114	9	4868877	645299	30 M/14	17	West Duffins Ck. @ Durham 5
18-Aug-95	D-042	122	9	4868877	645299	" "		" "
08-Sep-95	D-042	202	16	4868877	645299	" "		" "
17-Aug-95	D-044	19.2	1.6	4868374	643801	30 M/14	16	Reesor @ Durham 5
17-Aug-95	D-046	9.4	1.4	4870995	642560	30 M/14	64	Reesor @ Durham 5, 200m N of rd. to Stouffville
17-Aug-95	D-048	8.1	1.6	4872780	641957	30 M/14		Reesor @ Durham 5 & Bethesda Sdrd.
18-Aug-95	D-048	12.9	1.8	4872780	641957	" "		" "
17-Aug-95	D-050	0.7	0.1	4874001	641543	N/A		No Description Available
17-Aug-95	D-051	0.4	0.1	4874362	641415	N/A		No Description Available
16-Aug-95	D-053	82.6	7.1	4867494	643533	30 M/14	59	Stouffville Ck @ Durham 30
17-Aug-95	D-053	84	9.2	4867494	643533	" "		" "
17-Aug-95	D-057	102	8	4866463	644194	30 M/14	37	Reesor @ Conc 8
17-Aug-95	D-060	185	15	4867228	646464	30 M/14	38	West Duffins Ck. @ Conc 8

Table B1: Duffins watershed low flow streamflow data.

Date	Site	Q (l/s)	Error	Northing	Easting	Map Sheet	MOEE	Site description
21-Aug-95	D-062	1.7	0.3	4869123	649552	30 M/14		Trib to Michell Ck. @ s/l 20, 1150m S of Durham 5
21-Aug-95	D-063	18.6	1.7	4869569	649400	30 M/14		Michell Ck. @ s/l 20, 650m S of Durham 5
21-Aug-95	D-065	20.1	1.5	4869303	650373	30 M/14	8	Michell Ck. @ Brock Rd
22-Aug-95	D-066	1.3	0.2	4868131	652779	30 M/14		Trib. to Brougham Ck. @ s/l 14, 1.7 km N of Conc 7.
21-Aug-95	D-067	45.1	3.6	4868541	652638	30 M/14		Michell Ck. @ s/l 14 (old trail, wooden bridge)
16-Aug-95	D-068	40.6	4.3	4868165	653644	30 M/14	29	Michell Ck. @ s/l 12, 1km N of Conc 7
21-Aug-95	D-068	33.3	3.4	4868165	653644	" "		" "
21-Aug-95	D-071	266	18	4869782	653928	30 M/14	31	Duffins Ck. @ Conc 8.
21-Aug-95	D-076	330	24	4867670	653977	30 M/14		Duffins Ck. @ Durham 31
21-Aug-95	D-076	328	25	4867670	653977	" "		" "
22-Aug-95	D-077	0.35		4867460	653409	N/A		No Description Available
22-Aug-95	D-078	0.5	0.1	4866519	650662	N/A		No Description Available
18-Aug-95	D-082	1	0.2	4865347	647492	N/A		No Description Available
17-Aug-95	D-083	195.1	15.3	4865064	646691	30 M/14	40	West Duffins Ck. @ Durham 31
16-Aug-95	D-085	86.3	8.1	4864595	645400	30 M/14	42	Reesor @ Durham 31
17-Aug-95	D-085	76	8.2	4864595	645400	" "		" "
16-Aug-95	D-087	0.45		4863210	645050	30 M/14		Major Ck. @ Durham 30
22-Aug-95	D-092	377	39	4865574	654697	30 M/14	7	Duffins Ck @ 6th Conc, W of Greenwood Rd.
22-Aug-95	D-094	3.99		4865355	654076	30 M/14		Trib. to Brougham Ck. @ Hwy 7, 450m E of s/l 14
22-Aug-95	D-096	10.5	1.1	4865011	653137	30 M/14		Trib. to Brougham Ck. @ Hwy 7, 250m E of s/l 16
16-Aug-95	D-108	284	20	4862571	646066	30 M/14	10	West Duffins Ck. @ Hwy 7 (Green River)
17-Aug-95	D-108	270	18	4862571	646066	" "		" "
16-Aug-95	D-112	0.41	0.07	4864722	646829	30 M/14	41	Trib. to West Duffins Ck @ s/l 30, 700m S of Dur 31
18-Aug-95	D-112	0.99		4864722	646829	" "		" "
18-Aug-95	D-114	0.73		4873657	646651	31 D/3		Wixon Ck @ Webb Rd.
18-Aug-95	D-115	83.3	7.6	4874819	645431	31 D/3		West Duffins Ck. @ Conc. 3
31-Aug-95	D-115	39.5	3.1	4874819	645431	" "		" "
16-Aug-95	D-116	14.2	1.6	4872214	646283	30 M/14		Wixon Ck @ Conc. 3
18-Aug-95	D-116	15.3	1.1	4872214	646283	" "		" "
17-Aug-95	D-121	300	24	4861011	647635	30 M/14	43	West Duffins Ck. @ Whitevale
23-Aug-95	D-129	1.8	0.3	4862626	652410	30 M/14		Urfe Ck @ Whitevale Rd., 400m W of Brock Rd.
23-Aug-95	D-130	2.5	0.2	4862687	652575	30 M/14	57	Urfe Ck @ Whitevale Rd., 250m W of Brock Rd.
16-Aug-95	D-133	41	3.5	4863438	654736	30 M/14	28	Brougham Ck @ Whitevale Rd.
22-Aug-95	D-133	30.5	2.9	4863438	654736	" "		" "
16-Aug-95	D-134	427	35	4863553	655073	30 M/14	2	Duffins Ck @ Whitevale Rd.
22-Aug-95	D-134	336	30	4863553	655073	" "		" "
22-Aug-95	D-139	468	43	4861650	655895	30 M/14	55	Duffins Ck. @ Taunton Rd.
23-Aug-95	D-143	4.3	0.7	4860716	653826	N/A		No Description Available
24-Aug-95	D-144	13.8	1.7	4860557	652730	30 M/14	22	Ganatsekiagon Ck. @ Taunton Rd, 850m W of Brock Rd.
17-Aug-95	D-146	319	21	4859280	650016	30 M/14	9	West Duffins Ck. @ Clarke's Hollow
16-Aug-95	D-147	16.8	3.6	4858869	653808	30 M/14	23	Ganatsekiagon Ck. @ Rossland Rd, 250m W of Brock Rd.
24-Aug-95	D-147	13.2	1.8	4858869	653808	" "		" "

Table B1: Duffins watershed low flow streamflow data.

Date	Site	Q (l/s)	Error	Northing	Easting	Map Sheet	MOEE	Site description
16-Aug-95	D-148	11.1	1.1	4859204	654736	30 M/14	26	Urfe Ck @ Rossland Rd.
23-Aug-95	D-148	2.2	0.4	4859204	654736	" "		" "
23-Aug-95	D-149	424	30	4859425	655460	30 M/14	27	Duffins Ck @ Rossland Rd.
24-Aug-95	D-149	441	34	4859425	655460	" "		" "
23-Aug-95	D-151	8.8		4858085	657839	30 M/14		Miller's Ck @ Highway 2
16-Aug-95	D-152	867	49	4857368	655769	30 M/14	5	Duffins Ck @ Highway 2
17-Aug-95	D-152	767	57	4857368	655769	" "		" "
24-Aug-95	D-152	613	47	4857368	655769	" "		" "
31-Aug-95	D-152	598	37	4857368	655769	" "		" "
16-Aug-95	D-153	288	18	4856976	653828	30 M/14	13	West Duffins Ck. @ Valley Farm Rd.
17-Aug-95	D-153	295	20	4856976	653828	" "		" "
24-Aug-95	D-153	229	17	4856976	653828	" "		" "
17-Aug-95	D-158	72	6.2	4868446	641854	30 M/14	61	Stouffville Ck. @ 19th ave.
17-Aug-95	D-159	20.9	1.9	4869919	640872	30 M/14	62	Stouffville Ck. Upstream of WPCP @ Burkholder St.
17-Aug-95	D-160	16.1	1.9	4872149	640013	30 M/14	12	Stouffville Ck. @ Bethesda srd.
18-Aug-95	D-164	0.2	0.09	4875388	645248	N/A		No Description Available
18-Aug-95	D-168	0.26	0.04	4875421	645546	31 D/3		Trib to West Duffins @ Secord Rd., 300m E of Conc.3
20-Aug-95	D-173	5.4	0.7	4872519	652774	30 M/14		Trib to Duffins Ck.@ Westney Rd. 1km N of Durham 5
20-Aug-95	D-174	0.7	0.03	4873022	652605	30 M/14		Trib to Duffins Ck.@ Westney Rd. 550m S of Ux-Pkg twnln
21-Aug-95	D-177	10.8	1.1	4871978	651207	30 M/14		Trib to Duffins Ck. @ s/l 14, 1km N of Durham 5
16-Aug-95	D-178	22.6	2	4870845	653332	30 M/14	68	Trib to Duffins Ck. @ Westney Rd.
21-Aug-95	D-178	22.4	2	4870845	653332	" "		" "
21-Aug-95	D-179	0.13	0.003	4869426	652896	N/A		No Description Available
22-Aug-95	D-180	0.51	0.04	4866751	653152	30 M/14		Trib. to Brougham Ck. @ s/l 14, 600m S of Durham 31
22-Aug-95	D-183	0.17	0.01	4864230	653045	N/A		No Description Available
18-Aug-95	D-198	35.7	3.2	4870253	646547	N/A		No Description Available
21-Aug-95	D-200	21.7	2.1	4871224	652321	N/A		No Description Available
20-Aug-95	D-202	0.77		4870615	654281	30 M/14		trib to Duffins Ck. @ s/l 8, 675m N of Conc. 8
22-Aug-95	D-203	0.7	0.2	4864295	655137	30 M/14		trib to Duffins Ck. @ Greenwood Rd, 675m N of Whitevale Rd.
16-Aug-95	D-206	4.5	0.7	4859731	649620	30 M/14		Trib to West Duffins Ck. E of golf course, upstream of Taunton Rd.
23-Aug-95	D-209	18.1	2.6	4856984	657128	30 M/14		Miller's, Ck.@ Jackwin Dr., W of Jallan Dr. (just N of 401)
20-Aug-95	D-211	15.4	2.1	4874017	653914	31 D/3		Trib to Duffins Ck.,1.6km W of Conc.6, on Ux-Pkg twnln (footpath)
20-Aug-95	D-212	0.11		4874018	653917	31 D/3		small trib to Duffins Ck.,1.61km W of Conc.6, on Ux-Pkg twnln (footpath)
20-Aug-95	D-213	6.3	0.9	4874060	654037	31 D/3		Trib to Duffins Ck.,1.7km W of Conc.6, on Ux-Pkg twnln (footpath)
21-Aug-95	D-215	7.6	0.9	4871732	649615	30 M/14		Michell Ck. @ Hoxton St. 225m W of Old Brock Rd.
22-Aug-95	D-218	25.6	2	4863865	654091	30 M/14		Brougham Ck., West branch confl. N.W. of Greenwood CA (1km upstream of Whitevale Rd.)
22-Aug-95	D-219	5.3	0.7	4863861	654118	30 M/14		Brougham Ck. East branch confl. N.W. of Greenwood CA (1km upstream of Whitevale Rd.)
18-Aug-95	D-221	3.7	0.7	4871450	646271	30 M/14		Wixon Ck. W. Branch 100m N. of Pick-Ux twnln
16-Aug-95	D-222	106	9	4872754	644347	30 M/14	36	West Duffins Ck. @ Webb Rd. Downstream of beaver pond (actually D-222)
18-Aug-95	D-222	111	9	4872754	644347	" "		" "
17-Aug-95	D-226	44.8	7.4	4869904	640904	30 M/14	11	Stouffville WPCP outflow
17-Aug-95	D-227	4.3	0.7	4869876	640963	N/A		No Description Available

Table B1: Duffins watershed low flow streamflow data.

Date	Site	Q (l/s)	Error	Northing	Easting	Map Sheet	MOEE	Site description
18-Aug-95	D-228	0.015	0.004	4873292	645553	N/A		No Description Available
30-Aug-95	D-239	33.2	3	4875306	646253	31 D/3		SE tributary to Secord's Pond, 100m upstream of pond
30-Aug-95	D-240	45.4	3.8	4875507	645949	31 D/3		NW tributary to Secord's pond
30-Aug-95	D-241	0.6	0.2	4875323	646184	31 D/3		small trib to Secord's Pond, near SE tributary
30-Aug-95	D-242	0.42		4875483	646014	N/A		No Description Available
Aug-01	D-001	13.16						Reesor @ Ux-Pkg Twnln
Aug-01	D-044	33.98						Reesor @ Durham 5, East of York/Durham Ln
Aug-01	D-046	10.41						Reesor @ Durham 5, N. of Stouffville Rd
Aug-01	D-048	10.59						Reesor @ Durham 5, & Bethesda Sdrd
Aug-01	D-053	24.46						Stouffville Ck @ Durham 30, S. of Durham 5
Aug-01	D-057	49.41						Reesor Ck @ 8th Conc. E. of York/Durham Ln
Aug-01	D-085	59.79						Reesor Ck @ 7th Conc. E. of York/Durham Ln
Aug-01	D-158	90.42						Stouffville Ck @ 10th Line, S. of 19th Ave.
Aug-01	D-159	13.43						Stouffville Ck @ Burkholder st. upstream of WPCP
Aug-01	D-160	No Flow						Stouffville Ck @ Bethesda Sdrd.

Note: **1995 measurements from Marc Hinton, Geological Survey of Canada.**
2001 measurements from Don Haley, TRCA

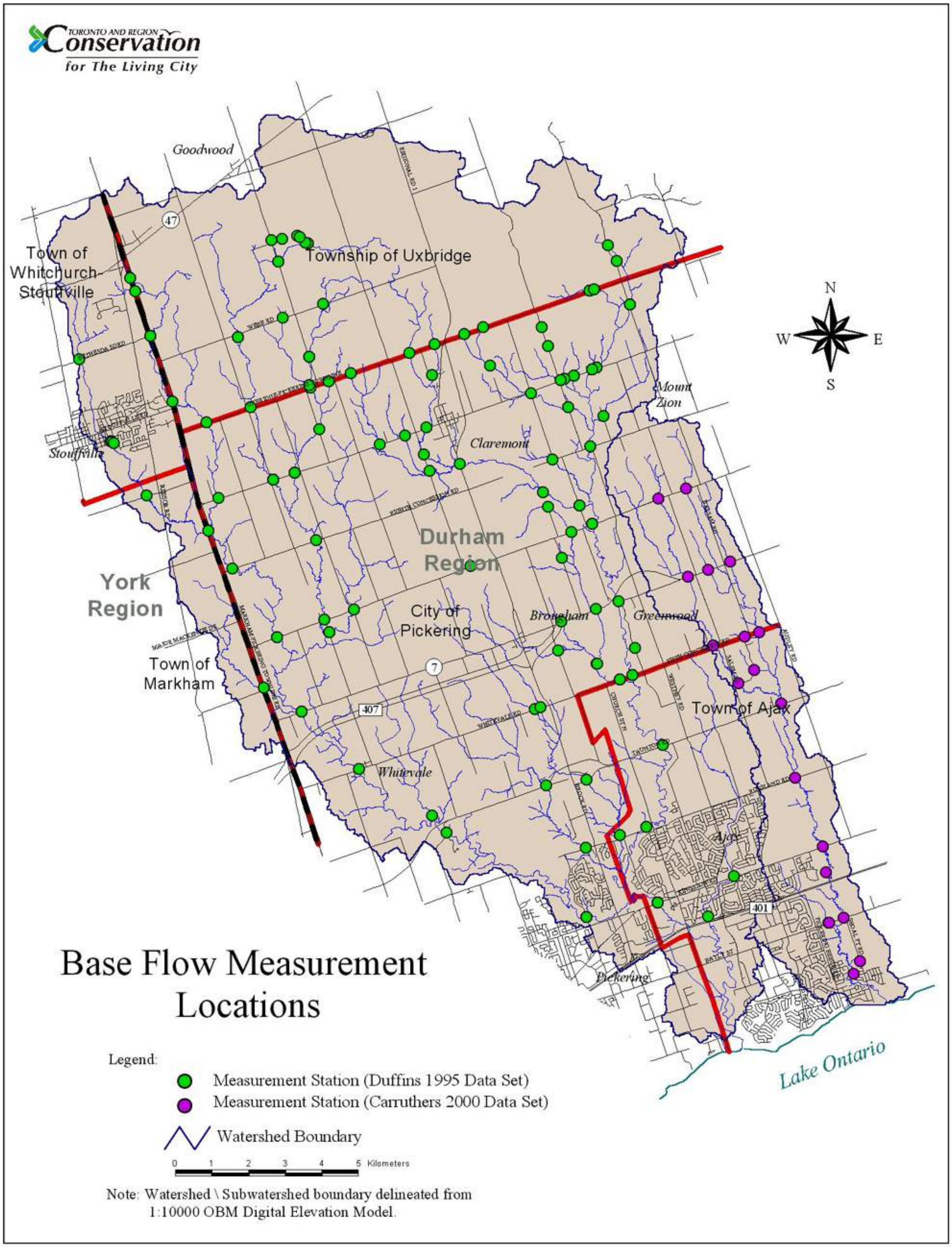


Figure B1: Duffins low flow streamflow survey measurement locations. Measurements conducted by the Geological Survey of Canada (Marc Hinton) and the TRCA (Don Haley).

Table C1: MOE/TRCA Groundwater Monitoring Network (October 2002)

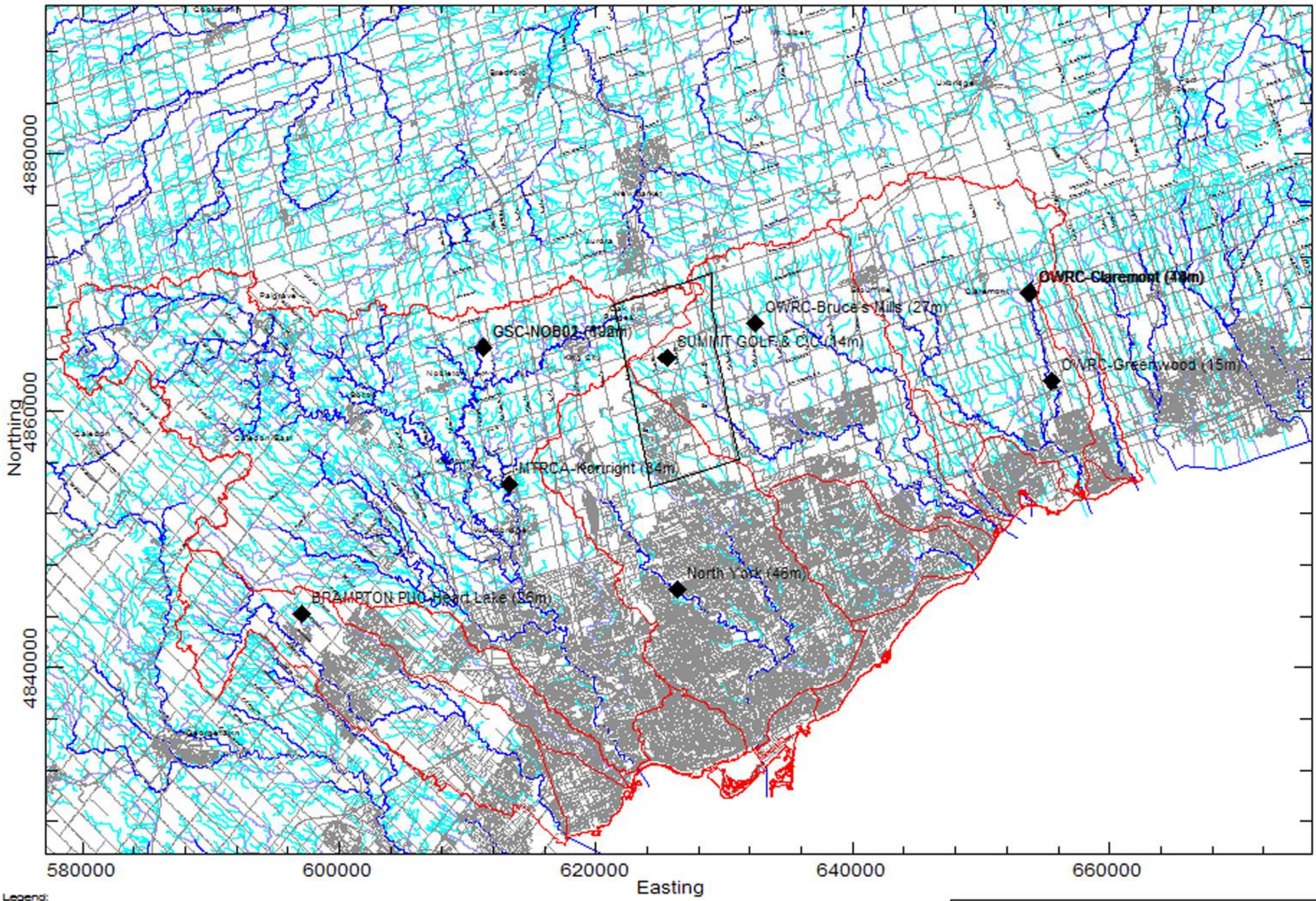
Well No.			Conservation Authority	GPS Location				Equipment Installed		Well Casing		
GA	MOE	CDMS		Datum	Easting	Northing	Elev (m) Approx	Date	Well Depth	ID (mm)	OD (mm)	Material
36	6910828	W0000006	Bruce's Mill (27m)	NAD83	632417	4866845	246	07-Jun-01	27.00	1.88	2.38	Steel
37	***4605547***	***W0000010***	***Claremont (74m)***	***NAD83***	***653692***	***4869173***	***221***	***07-Jun-01***	***74.04***	***1.88***	***2.38***	***Steel***
38	***4605546***	***W0000011***	***Claremont (48m)***	***NAD83***	***653692***	***4869173***	***221***	***07-Jun-01***	***47.75***	***1.97***	***2.36***	***Steel***
39	***4605544***	***W0000012***	***Claremont (13m)***	***NAD83***	***653761***	***4869187***	***185***	***07-Jun-01***	***13.55***	***1.97***	***2.36***	***Steel***
40	6925901	W0000017	North York (46m)	NAD83	626311	4845892	141	03-Jul-01	45.85	25.50		Steel
41	4901205	W0000021	Heart Lake (26m)	NAD83	597090	4844139	231	07-Jun-01	26.44	1.88	2.38	Steel
45	***4605087***	***W0000045***	***Greenwood (15m)***	***NAD83***	***655555***	***4862248***	***138***	***07-Jun-01***	***15.34***			***Steel***
59	TW2/95	W0000059	Summit G&CC (14m)	NAD83	625513	4864361	287	31-Jul-01	14.11	6.20	6.70	steel
60	GSC-NOB 01	W0000060	Nobleton (60m)	NAD83	611190	4864954	262	31-Jul-01	60.50	2.00	2.36	PVC
61	GSC-NOB 02	W0000061	Nobleton (192m)	NAD83	611192	4864947	268	31-Jul-01	192.63	2.00	2.36	PVC
75	6921815	W0000075	Kortright (34m)	NAD83	613237	4854287	206	09-Oct-01	34.34	2.00	2.50	PVC

Monitors situated within the Duffins watershed are in bold italics.

Table C2: Gerber/University of Toronto Groundwater Monitoring Location Details

Location	Piezo	Easting	Northing	GS (masl)	Scr-bot (masl)	Mid-scr (m asl)	Stickup (m)	Type	Screen Top (mbgs)	Screen Bottom (mbgs)	Unit
Site 1/94	**1/94-4**	649900	4857750	165.0	133.8	134.2	0.76	3/4"	30.49	31.17	NT
- near Clarke's	**1/94-2**	649900	4857752	165.0	142.9	143.7	0.85		20.53	22.05	IS
Hollow	**1/94-1**	649900	4857754	165.0	121.2	121.9	0.81		42.30	43.83	TF
	1/94-3	649900	4857756	165.0	154.7	155.4	0.76		8.79	10.32	HT
Greenwood C.A.	**OW308**	655500	4862055	125.0	121.3	121.3	1.00	6"		3.66	TF
	OW336	655498	4862055	125.0	110.7	111.1	0.90	2" steel	13.41	14.33	Sc
	OW337	655496	4862055	125.0	97.0	97.4	1.00	2" steel	27.13	28.05	BR
Claremont C.A.	**OW329**	653750	4869000	188.5	183.6	183.6	1.13	6"		4.88	IS
	OW330	653750	4869002	188.5	176.3	176.8	1.13	2" steel	11.28	12.20	NT
	OW331	653750	4869004	188.5	166.2	166.7	1.13	2" steel	21.34	22.26	TF
	OW332	653650	4868950	189.8	141.9	142.4	1.19	2" steel	46.95	47.87	TF
	OW333	653650	4868952	189.8	117.2	117.7	1.22	2" steel	71.65	72.56	BR
Site 2/94	**2/94-4**	648100	4868511	241.5	232.4	233.2	0.79		7.49	9.02	IS
-near Claremont	**2/94-3**	648100	4868507	241.5	227.7	228.5	0.77		12.20	13.72	IS
	2/94-1	648100	4868503	241.5	211.9	212.7	0.82		28.05	29.57	NT (sa)
	2/94-2	648100	4868499	241.5	178.0	178.8	0.75		61.89	63.41	TF
	2/94-5A	648094	4868499	241.5	203.7	204.0	0.85	3/4"	37.20	37.80	NT
	2/94-5B	648094	4868499	241.5	198.0	198.3	0.86	3/4"	42.86	43.47	NT
	2-75	648060	4868409	241.5	170.7	170.7	0.11	6"		70.73	TF
	1-75	648070	4868419	241.5	174.4	174.4	0.26	6"		67.07	TF
	OW406	648100	4868419	241.5	229.6	230.0	1.22	6"	10.98	11.89	IS
	4840	648100	4868396	241.5	180.2	180.2	0.70	6"		61.28	TF
	4841	648100	4868383	241.5	229.9	229.9	0.63	6"		11.59	IS
Site EE11	**1A**	651137	4859694	175.5	172.6	173.4	0.95		1.35	2.87	HT
	1B	651131	4859709	175.6	159.6	160.0	0.98		15.09	16.00	NT
	1C	651135	4859697	175.5	136.0	136.8	0.96		37.95	39.47	NT/TF
	1D	651141	4859703	175.5	129.3	130.0	1.06		44.71	46.23	TF
	1E	651141	4859700	175.5	118.4	119.2	1.03		55.52	57.08	Su
	1F	651134	4859701	175.5	104.7	105.5	1.07		69.19	70.71	BR
	1W	651137	4859701	175.5	134.8	139.1	0.88	6"	32.18	40.67	NT

Note:
HT = Halton Till
IS = Mackinaw Interstadial Unit
NT = Northern/Newmarket Till
TF = Thorncliffe Formation (Middle aquifer)
Su = Sunnybrook Diamict
Sc = Scarborough Formation (Lower aquifer)
BR = shale bedrock



Legend:
♦ TRCA/MOE monitoring wells

Scale in metres
0 10000 20000

Duffins Hydrogeology	
TRCA/MOE monitoring locations	
Date: 10/03/2003	Units: UTM NAD 83
Gerber Geosciences Inc.	Figure C1

Figure C2: MOE/TRCA Monitoring Network - Claremont (13) piezometer (data from TRCA).

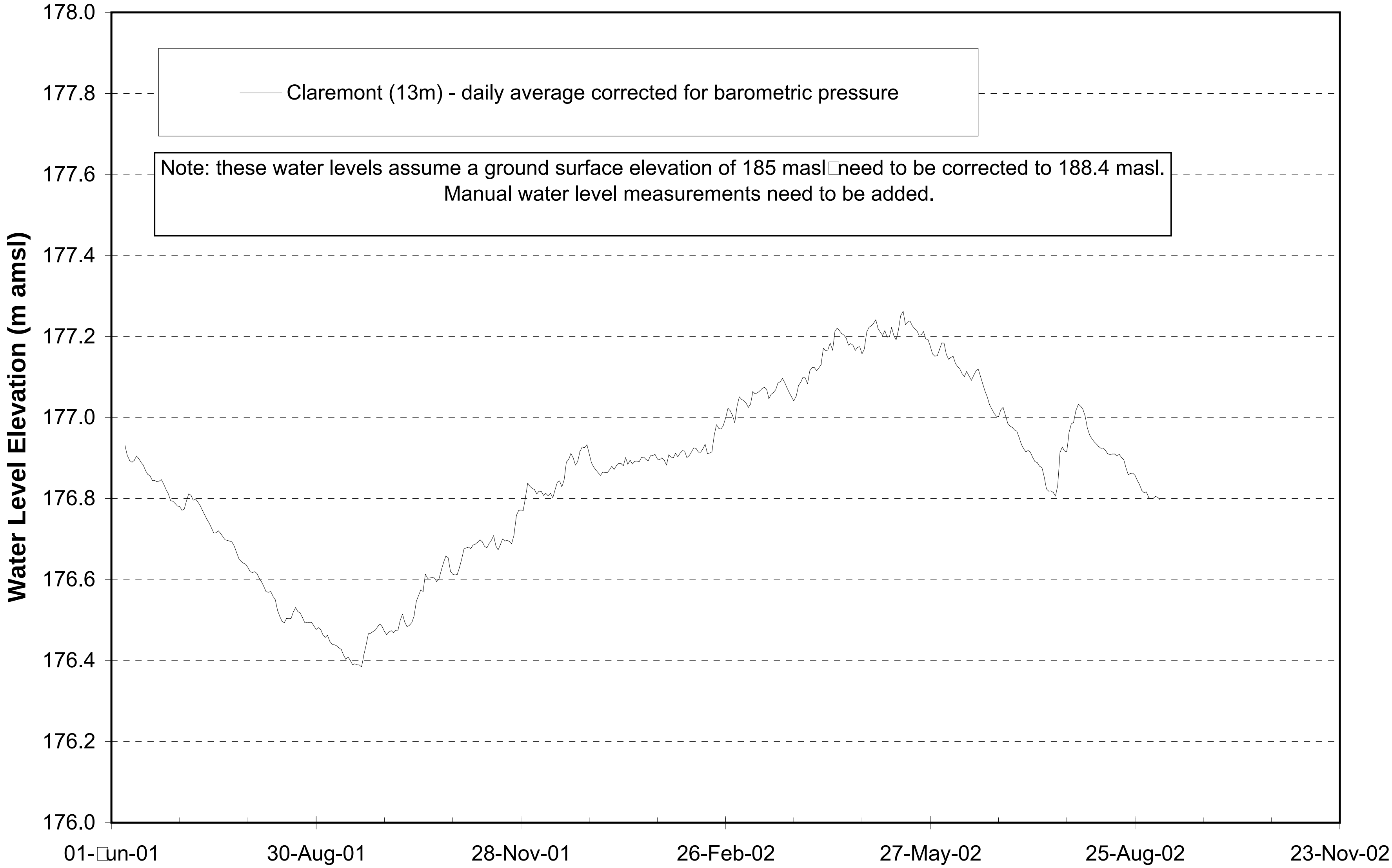


Figure C3: MOE/TRCA Monitoring Network - Claremont Wells (data from TRCA).

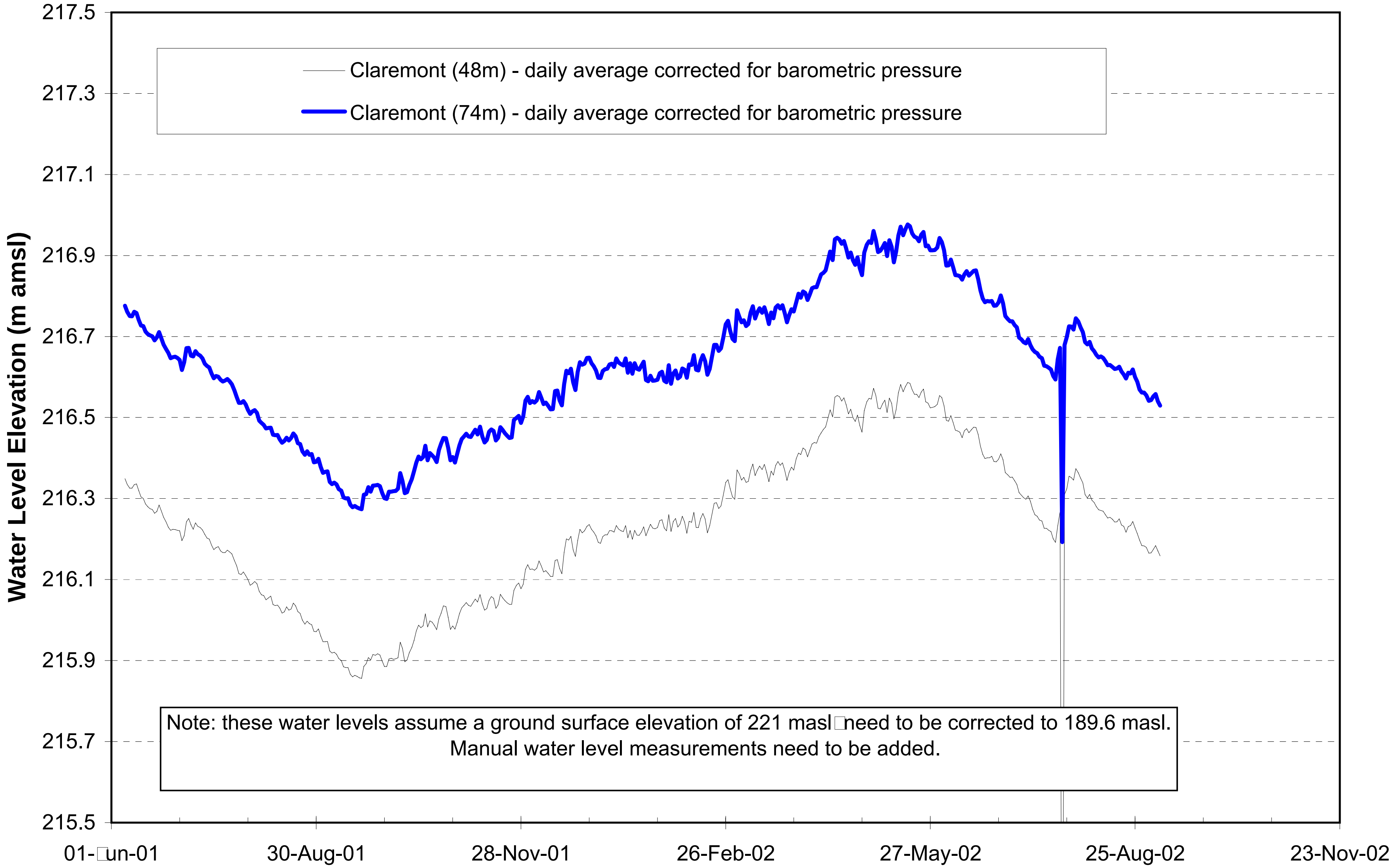


Figure C4: MOE/TRCA groundwater monitoring network - Greenwood well (data from TRCA).

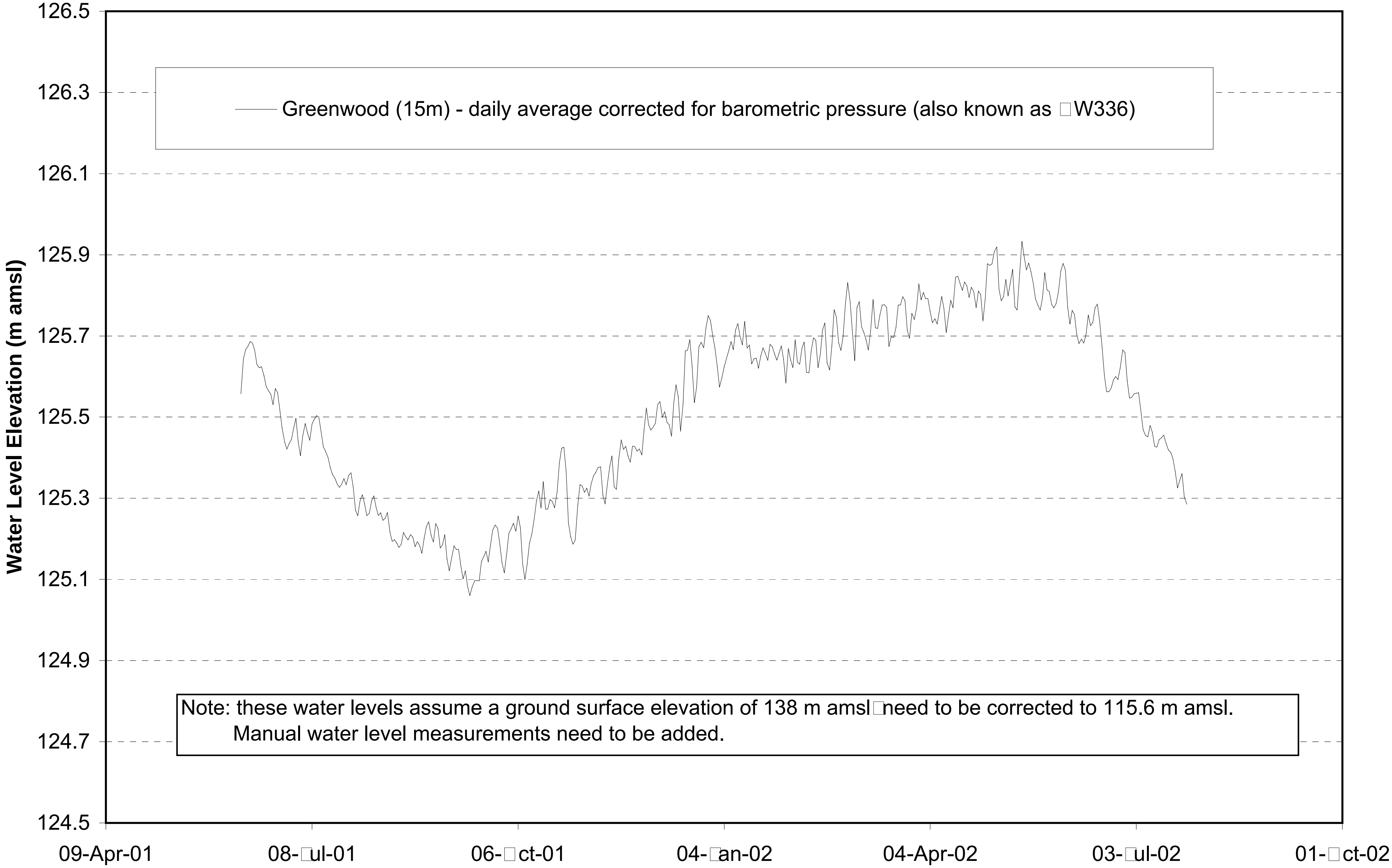


Figure C5: Site 1/94 piezometer water levels (see Figure 13 for location).

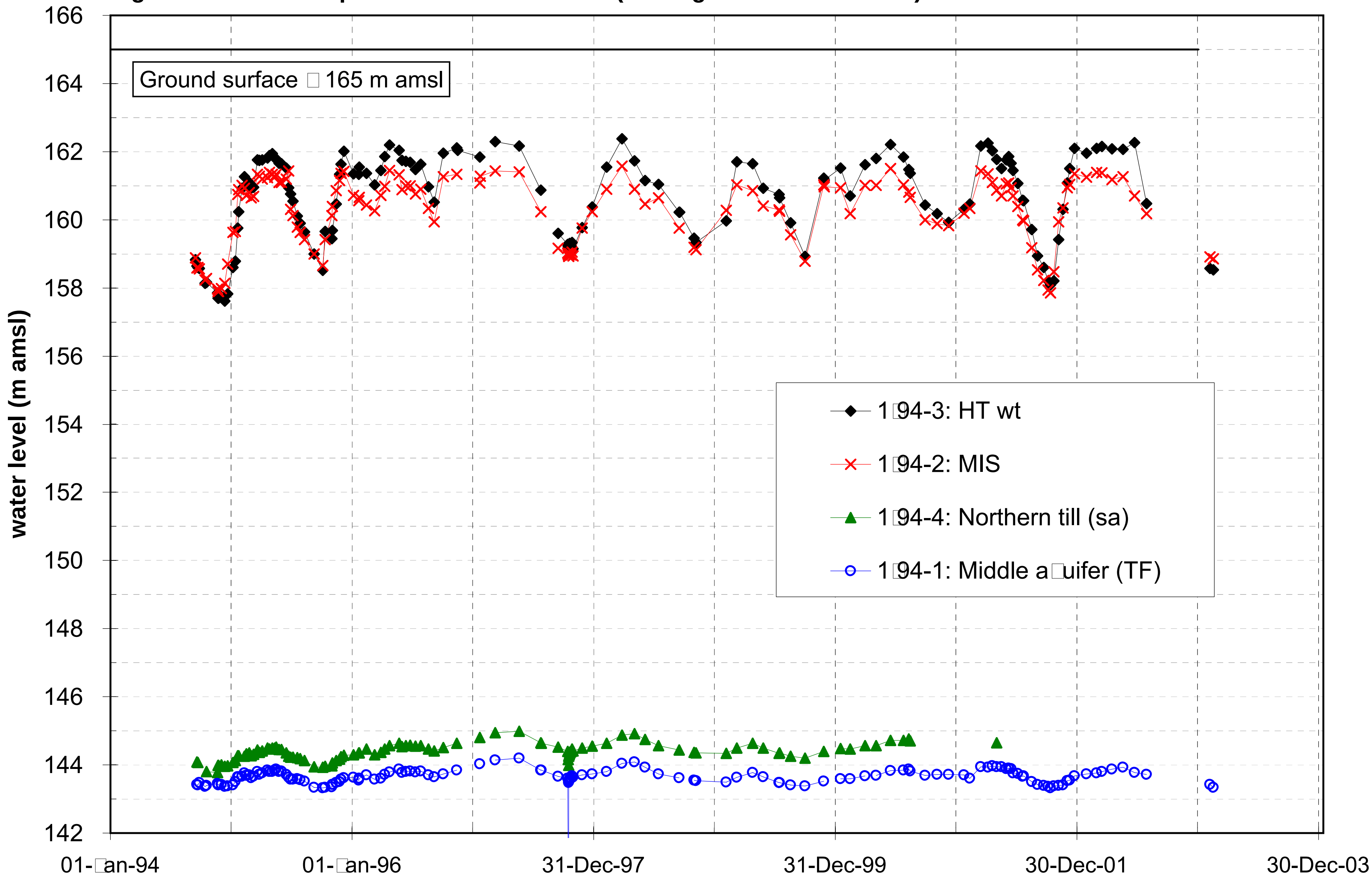


Figure C6: Site 2/94 piezometer water levels (see Figure 13 for location).

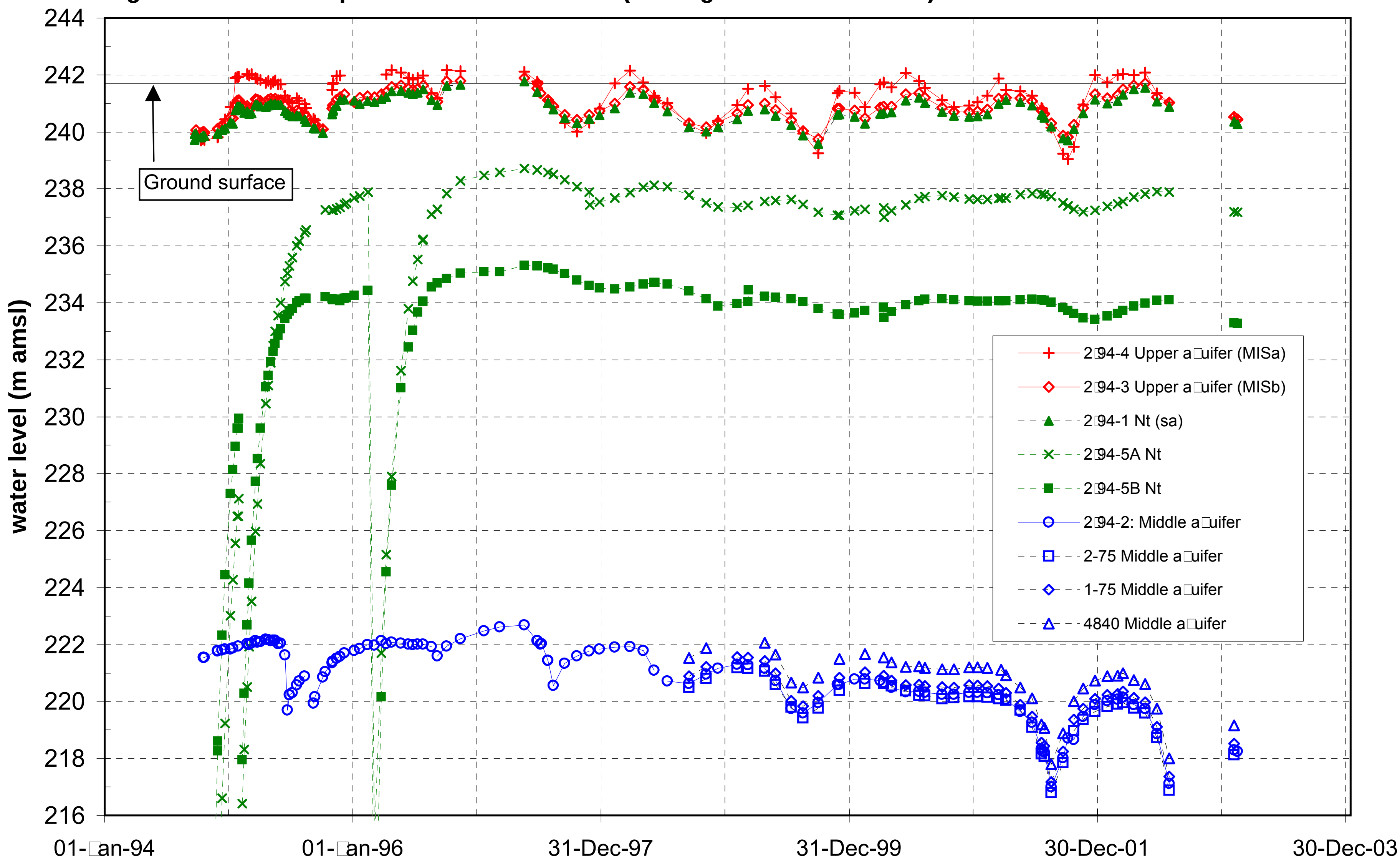
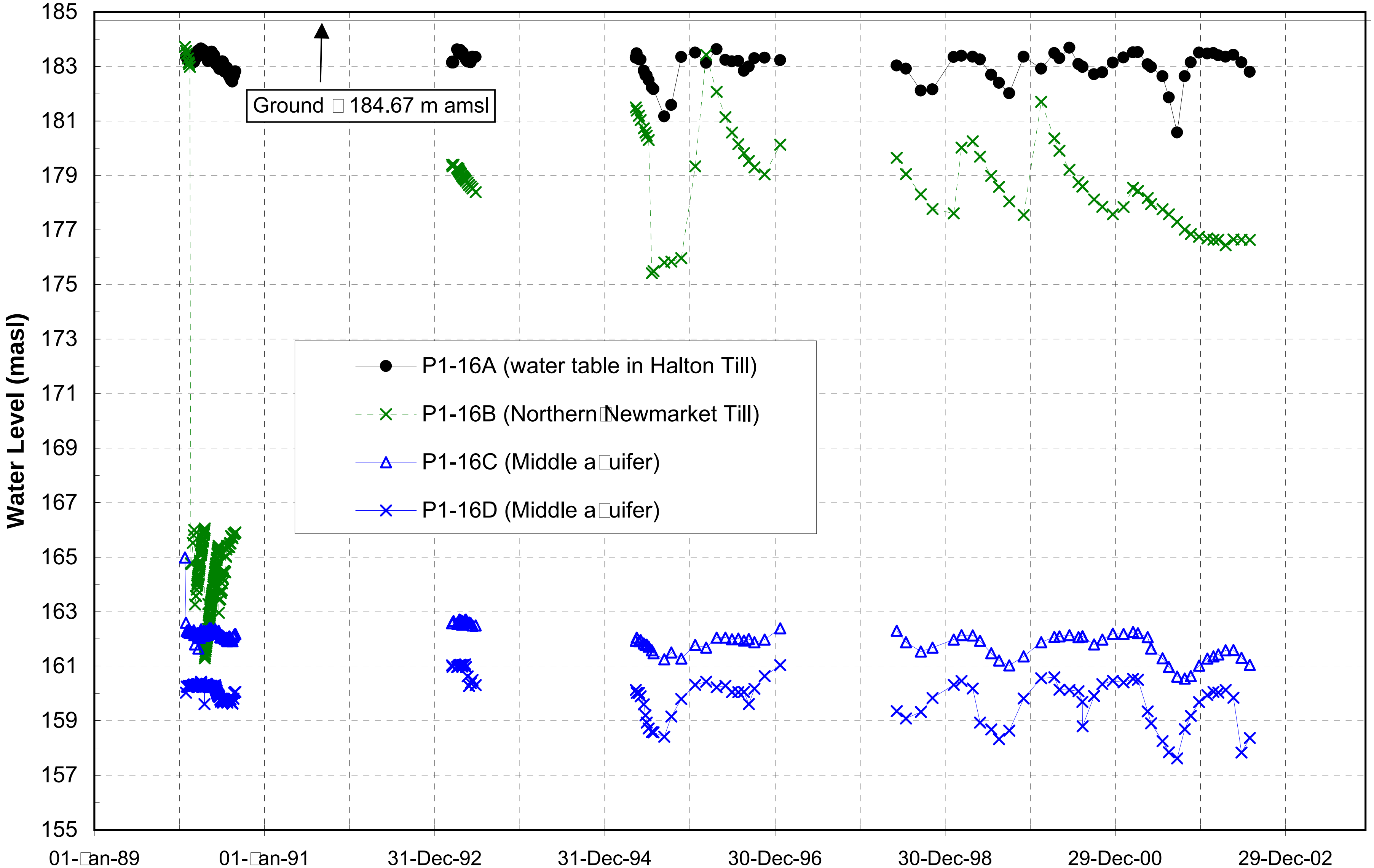


Figure C7: Site P1-16 groundwater monitoring (see Figure 13 for location).



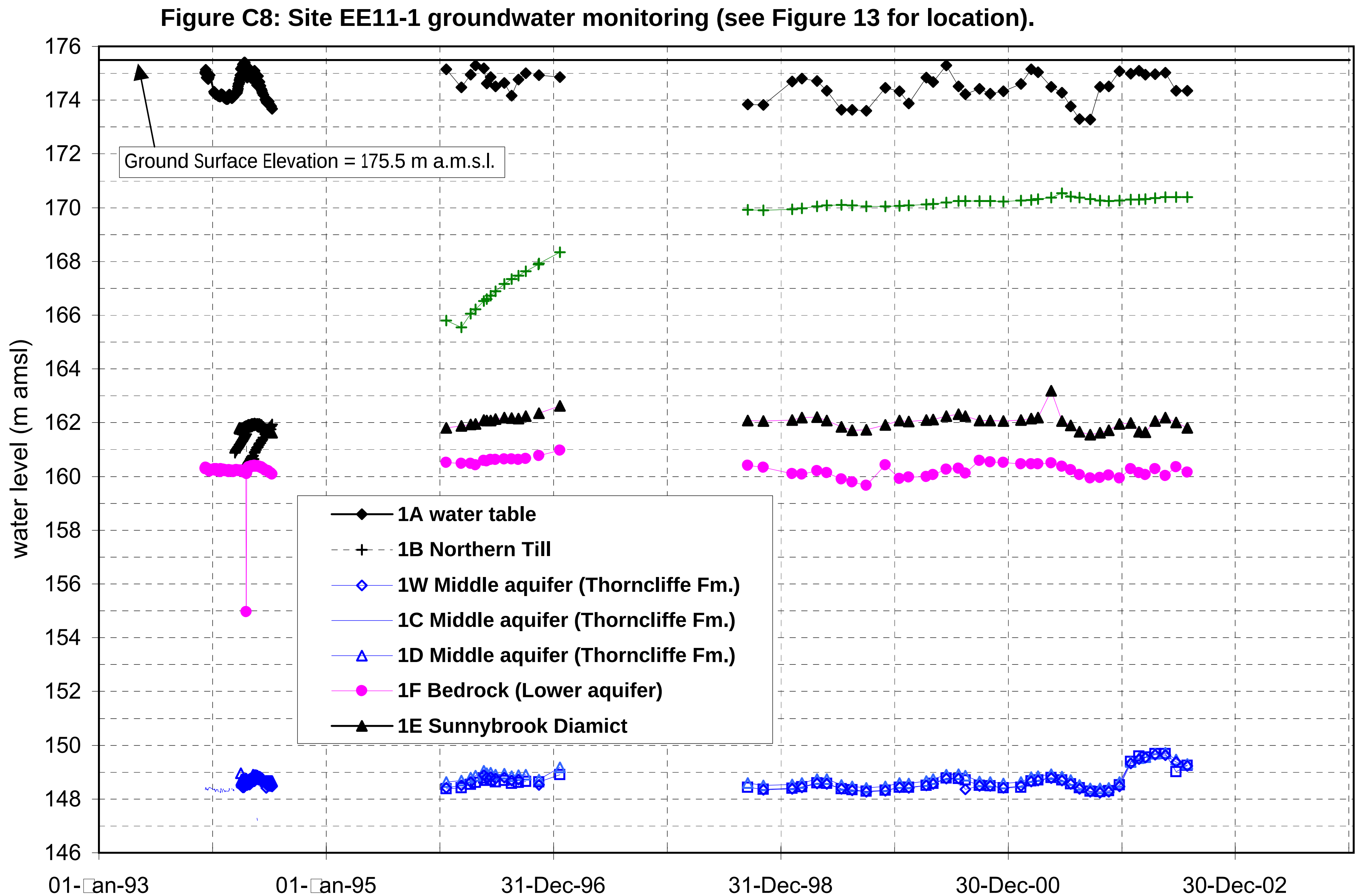


Figure C8: Site EE11-1 groundwater monitoring (see Figure 13 for location).
176
174
172
170
168
166
164
162
160
158
156
154
152
150
148
146
water level (m amsl)
Ground Surface Elevation = 175.5 m a.m.s.l.
1A water table
1B Northern Till
1W Middle aquifer (Thorncliffe Fm.)
1C Middle aquifer (Thorncliffe Fm.)
1D Middle aquifer (Thorncliffe Fm.)
1F Bedrock (Lower aquifer)
1E Sunnybrook Diamict
01-Jan-93
01-Jan-95
31-Dec-96
31-Dec-98
30-Dec-00
30-Dec-02

Figure C9: Claremont Conservation Area monitoring wells (see Figure 13 for location).

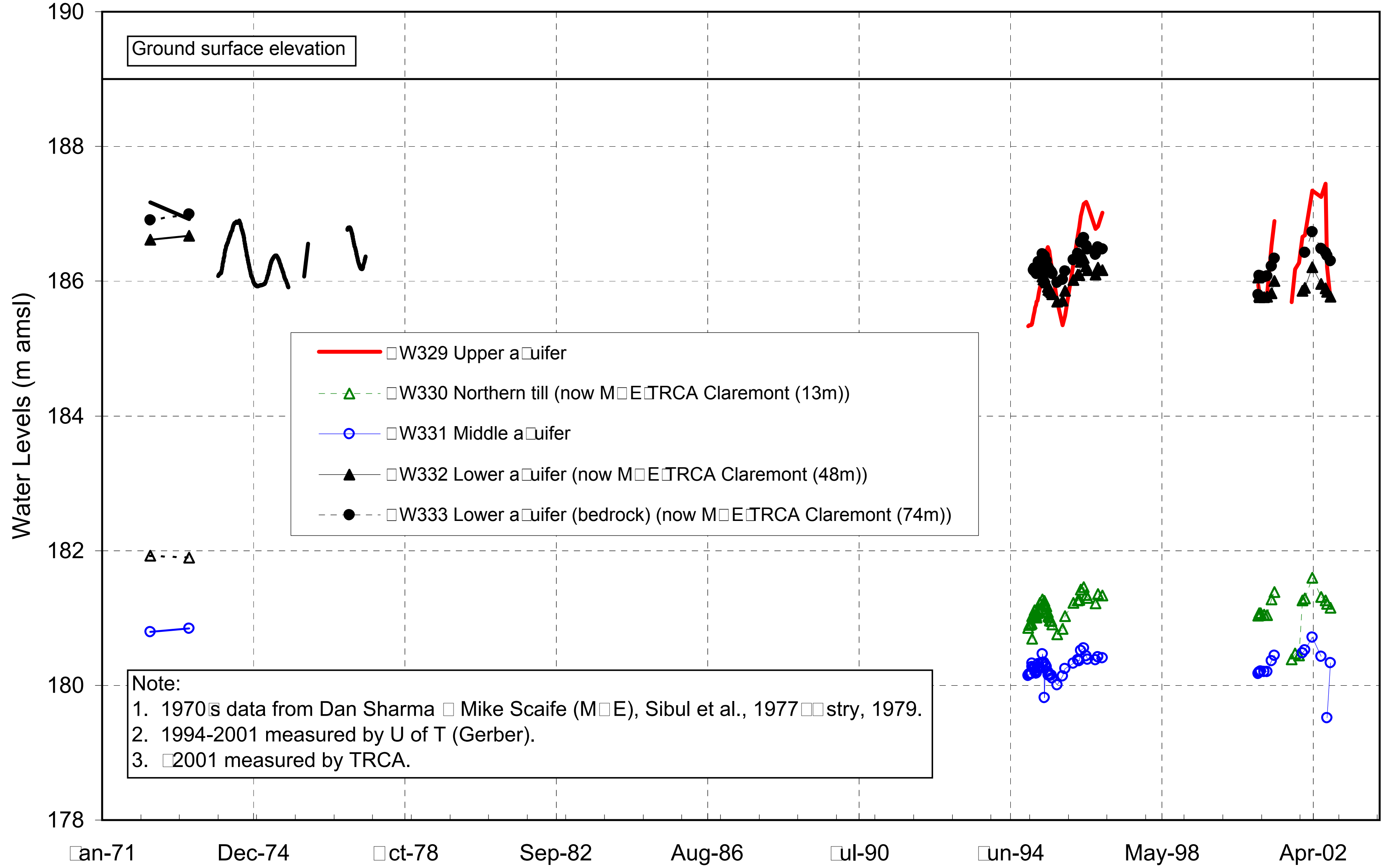


Figure C10: Greenwood Field Centre monitoring wells (see Figure 13 for location).

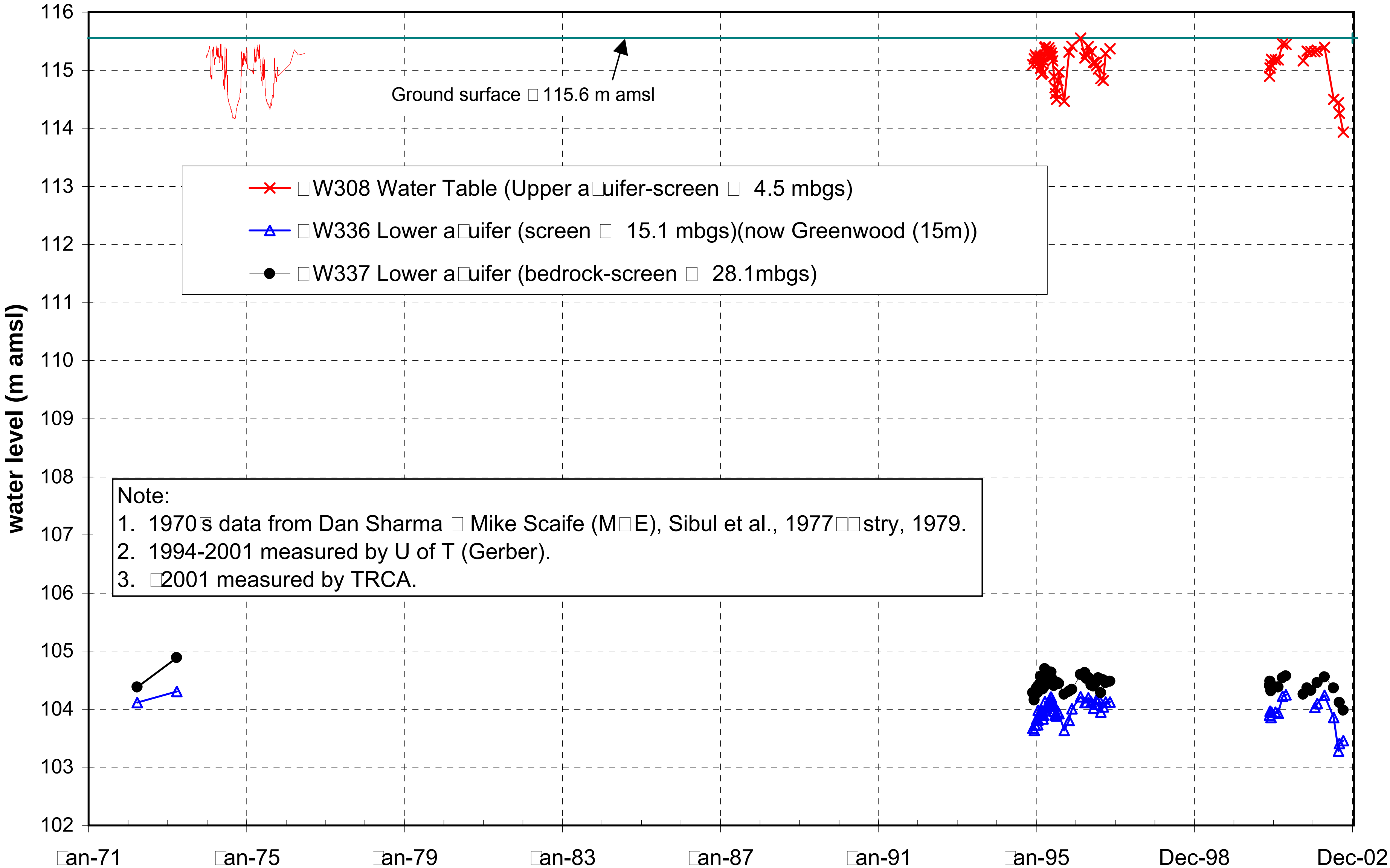


Table D1: MOE Permit to Take Water (PTTW) database for the Duffins Creek watershed (September, 2001).

	Municipality	Lot	Con	EASting	NORthing	GeneralPurpose	SpecificPurpose	days/yr	max L/d	Issued	Expiry	LakeRiverStreamName
SW	PICKERING	8	8	654386	4870760	Miscellaneous	Other - Miscellaneous	365	3,273,120	Apr-78	Mar-88	Duffin Creek
S	PICKERING	10	8	653654	4870516	Miscellaneous	Other - Miscellaneous			Mar-73	Mar-83	Duffin Creek
S	PICKERING	30	4	648668	4859938	Commercial	Golf Course Irrigation		1,022,850	Oct-64	Mar-94	West Duffin Creek
S	PICKERING	10	8	653654	4870516	Miscellaneous	Other - Miscellaneous			Oct-64	Mar-85	Tributary to Duffin Creek
S	WHITCHURCH-STOUFFVILLE	7	9	654182	4872671	Commercial	Golf Course Irrigation	180	431,870	Nov-64	Mar-89	Tributary of West Duffin Creek
S	PICKERING	10	8	653654	4870516	Miscellaneous	Other - Miscellaneous			Dec-64	Dec-74	Duffin Creek
GW	PICKERING	12	6	654160	4866652	Commercial	Golf Course Irrigation		226,845	May-76	Mar-81	Duffin Creek
S	PICKERING	13	1	657341	4856087	Commercial	Golf Course Irrigation		589,162	Jan-77	Mar-82	Duffin Creek
S	PICKERING	16	6	652838	4865684	Miscellaneous	Other - Miscellaneous			Jan-77	Mar-96	Intermittent Tributary to Duffin Creek
S	PICKERING	10	2	657757	4858738	Miscellaneous	Other - Miscellaneous			Dec-66	Dec-76	Tributary to Duffin Creek
S	PICKERING	12,13	4	654874	4862302	Miscellaneous	Other - Miscellaneous			Jul-67	Mar-87	Duffin Creek
G	PICKERING	4	5	658161	4865358	Miscellaneous	Other - Miscellaneous		195,478	Dec-67	Mar-87	
S	WHITCHURCH-STOUFFVILLE	2,3	9	656134	4873282	Miscellaneous	Other - Miscellaneous			Dec-77	Mar-87	West Duffin Creek
S	MARKHAM	30	10			Miscellaneous	Other - Miscellaneous			Apr-68	Mar-78	West Duffin Creek
S	WHITCHURCH-STOUFFVILLE	4	10			Miscellaneous	Other - Miscellaneous			Jun-69	Mar-79	Tributary of West Duffin Creek
S	PICKERING	13	6	653862	4866279	Miscellaneous	Other - Miscellaneous			Oct-69	Mar-79	Tributary of Duffin Creek
G	PICKERING	18	9	649871	4871207	Industrial	Other - Industrial	365	1,211,054	May-70	Mar-80	
S	MARKHAM	27	10			Commercial	Golf Course Irrigation		143,199	Dec-70	Mar-75	Duffin Creek
S	PICKERING	26	9	646752	4870081	Miscellaneous	Other - Miscellaneous			Jun-71	Mar-81	Tributary to West Duffin Creek
G	PICKERING	18	2	654603	4857774	Agricultural	Nursery	365	49,097	Feb-71	Mar-91	
S	PICKERING	15	5	653759	4863844	Industrial	Aggregate Washing		4,255,056	Dec-77	Mar-82	Duffin Creek
S	PICKERING	33,34	7	645240	4865464	Unknown Purpose	Unknown		550,066	May-88	Mar-98	Reesor Creek
S	PICKERING	22	3	651966	4859107	Industrial	Other - Industrial	365	2,725,200	Mar-97	Mar-07	West Duffin Creek
G	PICKERING	4	5	658161	4865358	Miscellaneous	Other - Miscellaneous	365	195,478	Jul-93	Mar-03	
Both	PICKERING	29,30	4	649038	4860012	Commercial	Golf Course Irrigation	120	1,671,832	Jan-95	Mar-05	West Duffin Creek
G	PICKERING	21	3	652779	4859311	Miscellaneous	Other - Miscellaneous	365	164,160	Oct-94	Mar-04	
G	PICKERING	21	3	652780	4859312	Miscellaneous	Other - Miscellaneous	365	197,280	Oct-94	Mar-04	
G	PICKERING	21	3	652781	4859313	Miscellaneous	Other - Miscellaneous	365	97,920	Oct-94	Mar-04	
G	PICKERING	21	3	652782	4859314	Miscellaneous	Other - Miscellaneous	365	66,240	Oct-94	Mar-04	
G	PICKERING	21	3	652783	4859315	Miscellaneous	Other - Miscellaneous	365	33,120	Oct-94	Mar-04	
S	MARKHAM	26,27	10			Commercial	Golf Course Irrigation	120	382,080	Aug-95	Aug-05	Duffin Creek
G	PICKERING	7	5	656942	4865026	Unknown Purpose	Unknown	154	981,936	Jul-96	Jan-00	
G	PICKERING					Dewatering	Other - Dewatering			Jun-99	Jul-99	
G	PICKERING	4	5	658161	4865358	Miscellaneous	Other - Miscellaneous			Dec-67	Mar-87	
B	PICKERING	29,30	4	649038	4860012	Commercial	Golf Course Irrigation	365	36,823	Jan-95	Mar-05	West Duffin Creek
S	UXBRIDGE	7	2	658880	4859179	Agricultural	Sod Farm		859,194	Aug-72	Mar-77	Duffin Creek
S	UXBRIDGE	6	2	659327	4859321	Miscellaneous	Other - Miscellaneous			Aug-65	Jul-75	Duffin Creek
S	UXBRIDGE	6	2	659328	4859322	Miscellaneous	Other - Miscellaneous			Nov-75	Mar-95	Duffin Creek
S	MARKHAM	7	10			Commercial	Golf Course Irrigation	120	143,199	May-75	Mar-92	West Duffin Creek
S	AJAX	16	2	655348	4857971	Commercial	Golf Course Irrigation	90	204,570	Jun-84	Mar-94	Duffin Creek
S	WHITCHURCH-STOUFFVILLE	32	9	644403	4869297	Water Supply	Other - Water Supply	20	340,500	Sep-96	Mar-06	Duffin Creek
B	PICKERING	29,30	4	649038	4860012	Commercial	Golf Course Irrigation	365	16,366	Jan-95	Mar-05	West Duffin Creek
S	WHITCHURCH-STOUFFVILLE	32	9	644403	4869297	Water Supply	Other - Water Supply	20	204,300	Sep-96	Mar-06	Duffin Creek

Note: data as directly received from MOE Central Region, September 15, 2001.

Table D2: Active Permits to Take Water: Duffins creek watershed (September, 2001).

PERMIT #	CLIENT NAME	LOT	CON	MUNICIPALITY	Max L/day	Source	Expiry	PURPOSE	SPECIFIC PURPOSE
87-P-3027	Eastern Power Developers Inc.	24	3	PICKERING	2,725,200	S	31-Mar-07	Industrial	Other - Industrial
92-P-3039	Thornbrook International Golf Course	7	3	UXBRIDGE	283,670	G	31-Mar-02	Commercial	Golf Course Irrigation
94-P-3056C	Whitevale Golf Club	29	4	PICKERING	1,638,000	G	31-Mar-05	Commercial	Golf Course Irrigation
94-P-3076	Metropolitan Toronto, Municipality of	21	3	PICKERING	164,160	G	31-Mar-04	Miscellaneous	Other - Miscellaneous
94-P-3076	Metropolitan Toronto, Municipality of	21	3	PICKERING	197,280	G	31-Mar-04	Miscellaneous	Other - Miscellaneous
94-P-3076	Metropolitan Toronto, Municipality of	21	3	PICKERING	97,920	G	31-Mar-04	Miscellaneous	Other - Miscellaneous
94-P-3076	Metropolitan Toronto, Municipality of	21	3	PICKERING	66,240	G	31-Mar-04	Miscellaneous	Other - Miscellaneous
94-P-3076	Metropolitan Toronto, Municipality of	21	3	PICKERING	33,120	G	31-Mar-04	Miscellaneous	Other - Miscellaneous
95-P-3004	Evelyn's Bushwood	27	10	MARKHAM	382,080	S	31-Aug-05	Commercial	Golf Course Irrigation
96-P-3030	L & M Gardens Limited	32	9	WHITCHURCH-STOUFFVILLE	340,500	S	31-Mar-06	Water Supply	Other - Water Supply
96-P-3030	L & M Gardens Limited	32	9	WHITCHURCH-STOUFFVILLE	204,300	S	31-Mar-06	Water Supply	Other - Water Supply
96-P-3040	Timber Ridge Artesian Spring Water	12	3	UXBRIDGE	392,774	G	31-May-07	Commercial	Bottled Water
97-P-3011	Prince Lee Acres Water Supply	14	4	UXBRIDGE	250,000	G	31-Mar-07	Commercial	Golf Course Irrigation
97-P-3026	Ducks Unlimited Canada	4	4	SCUGOG	160,000	S	31-Aug-08	Miscellaneous	Wildlife Conservation
97-P-3029	Ducks Unlimited Canada	6	4	UXBRIDGE	280,000	S	31-Aug-08	Miscellaneous	Wildlife Conservation
97-P-3029	Ducks Unlimited Canada	6	4	UXBRIDGE	300,000	S	31-Aug-08	Miscellaneous	Wildlife Conservation
98-P-3016	York, Regional Municipality of	35	10	WHITCHURCH-STOUFFVILLE	2,946,240	G	31-Mar-04	Water Supply	Municipal
98-P-3016	York, Regional Municipality of	35	10	WHITCHURCH-STOUFFVILLE	2,946,240	G	31-Mar-04	Water Supply	Municipal
98-P-3016	York, Regional Municipality of	35	10	WHITCHURCH-STOUFFVILLE	2,946,240	G	31-Mar-04	Water Supply	Municipal
98-P-3016	York, Regional Municipality of	35	10	WHITCHURCH-STOUFFVILLE	2,946,240	G	31-Mar-04	Water Supply	Municipal
98-P-3016	York, Regional Municipality of	35	10	WHITCHURCH-STOUFFVILLE	3,110,400	G	31-Mar-04	Water Supply	Municipal
99-P-3011	Granite Golf Inc.	9	1	UXBRIDGE	1,155,400	B	01-Oct-09	Commercial	Golf Course Irrigation
99-P-3011	Granite Golf Inc.	9	1	UXBRIDGE	2,200,000	B	01-Oct-09	Commercial	Golf Course Irrigation
TOTAL: 12 Active Permits				**Total**	**25,766,004**				

Source S surface water source
G groundwater source
both both surface and groundwater source

Note: Data as directly received from MOE Central Region, September 15, 2001.

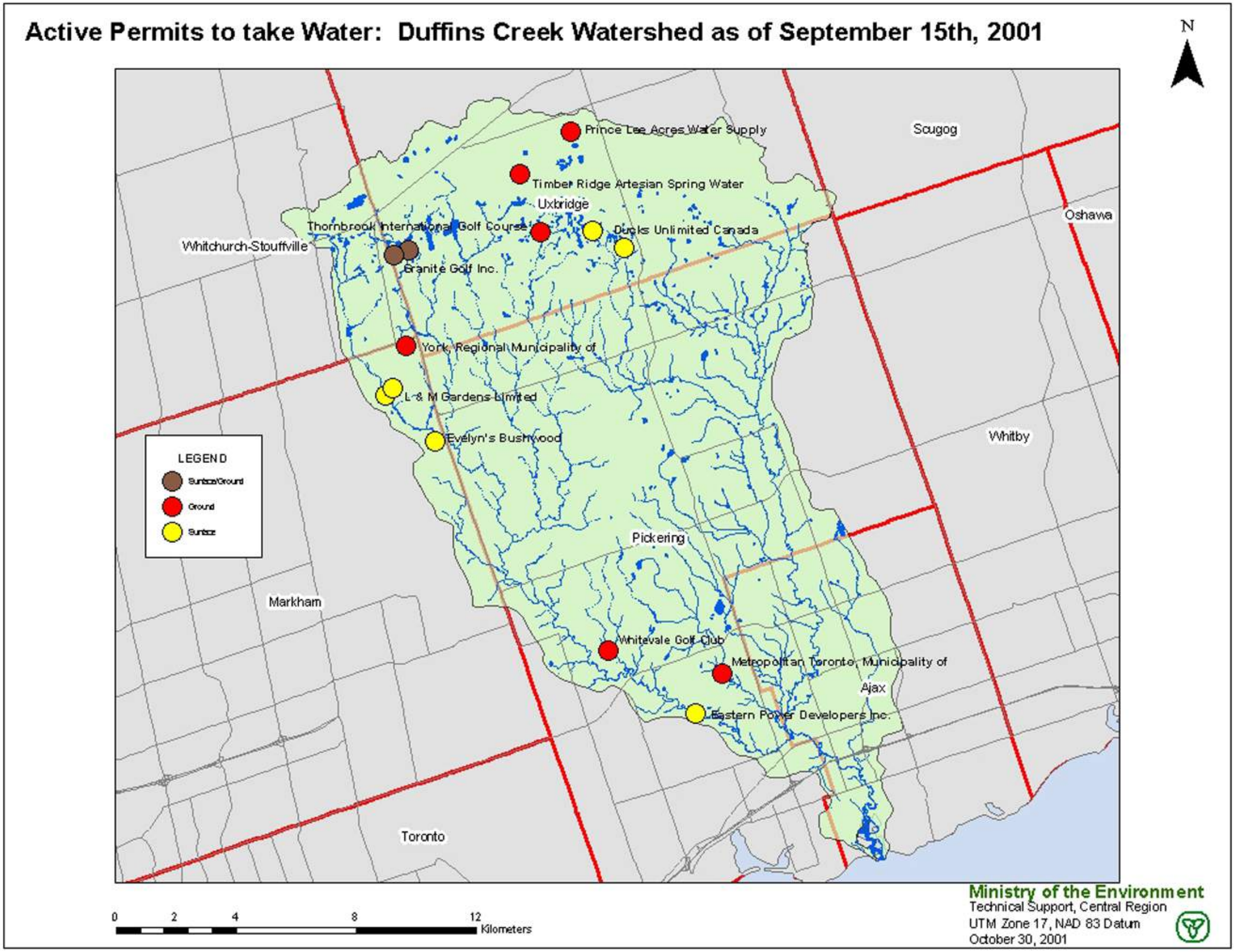


Figure D1: surface and ground water takings in PTTW database (figure directly from MOE, Central Region)

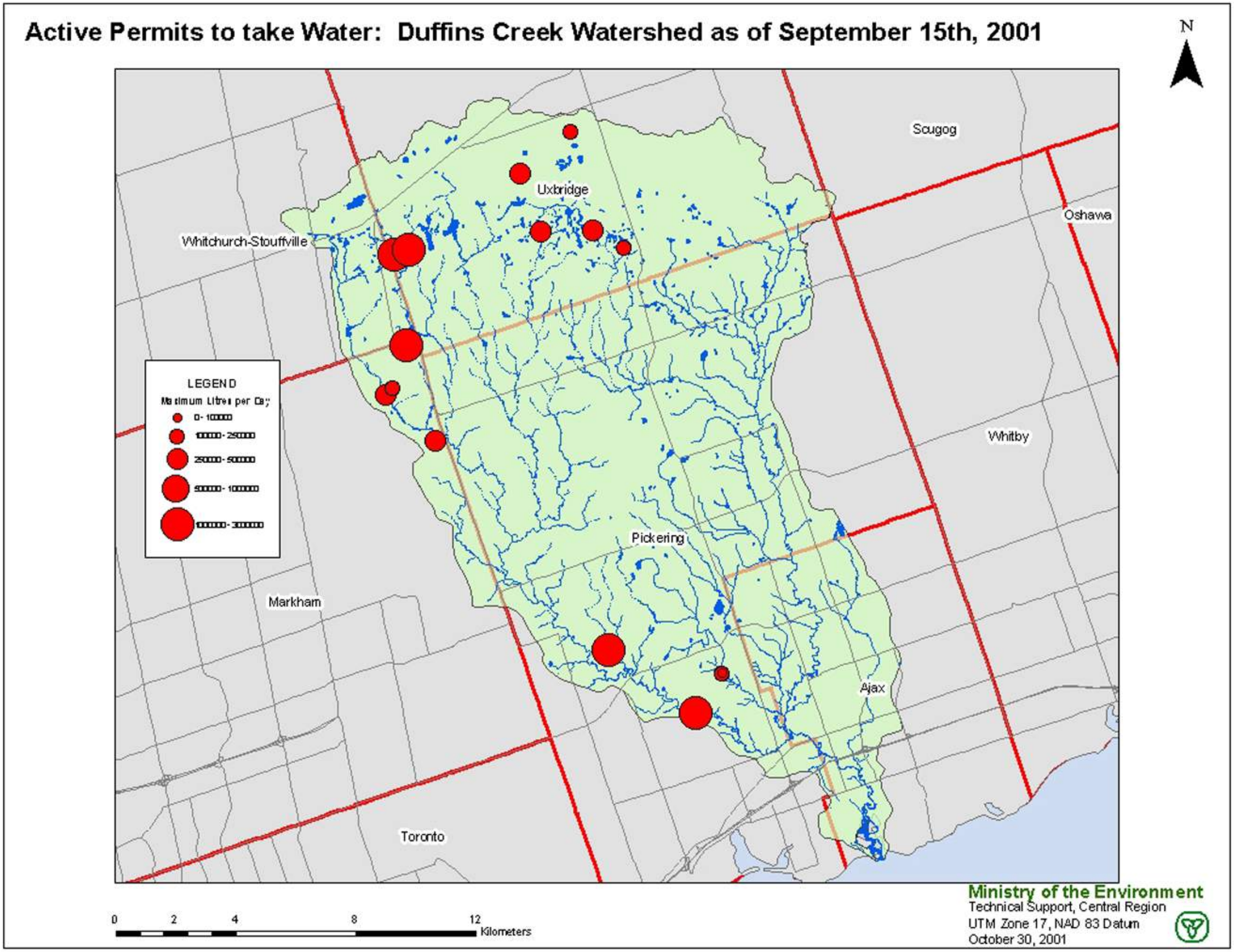


Figure D2: maximum takings in PTTW database (figure directly from MOE, Central Region).

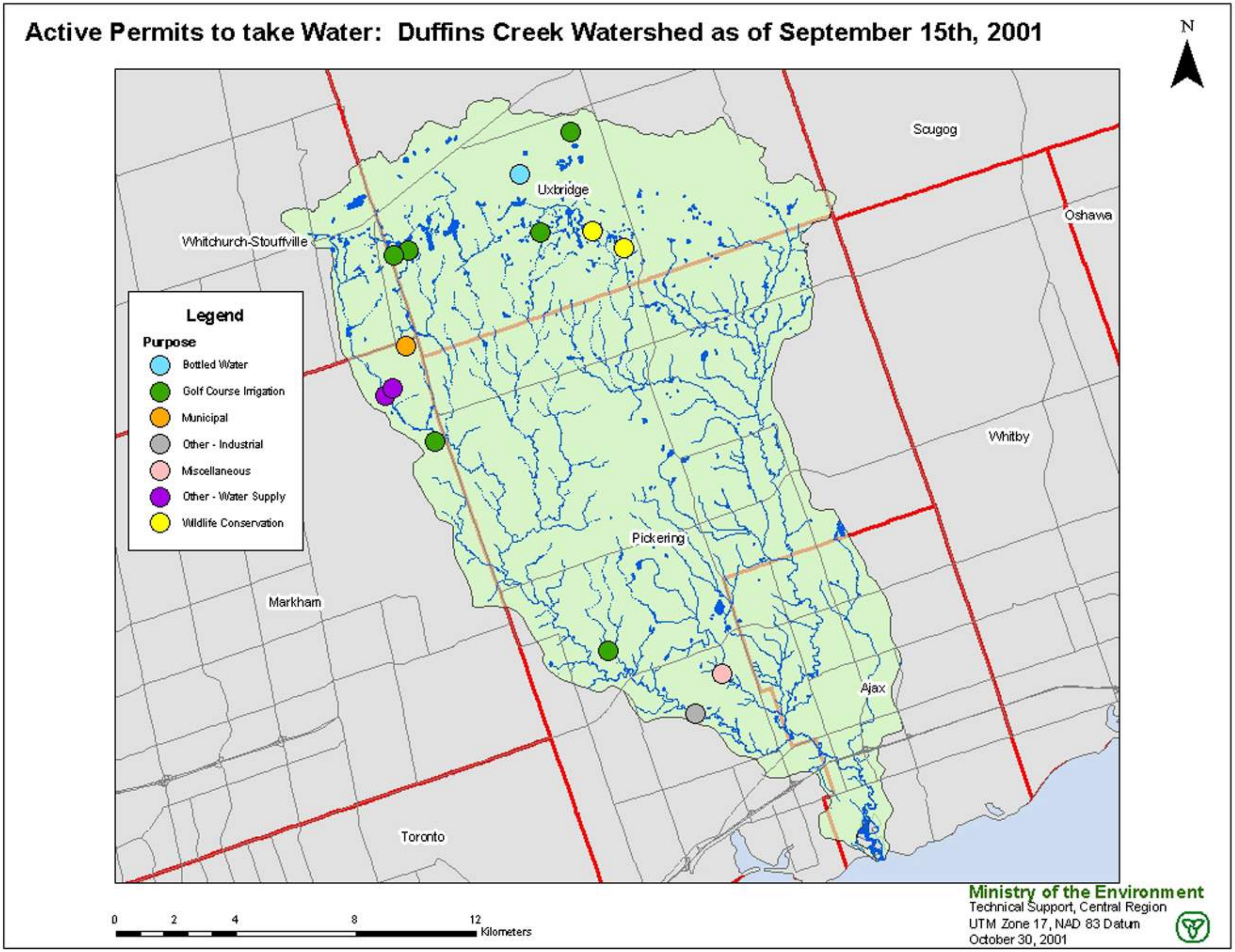


Figure D3: active permits by use in PTTW database (figure directly from MOE, Central Region).

Figure D4: Stouffville municipal annual groundwater pumping 1974-1990 (data provided by York Region)

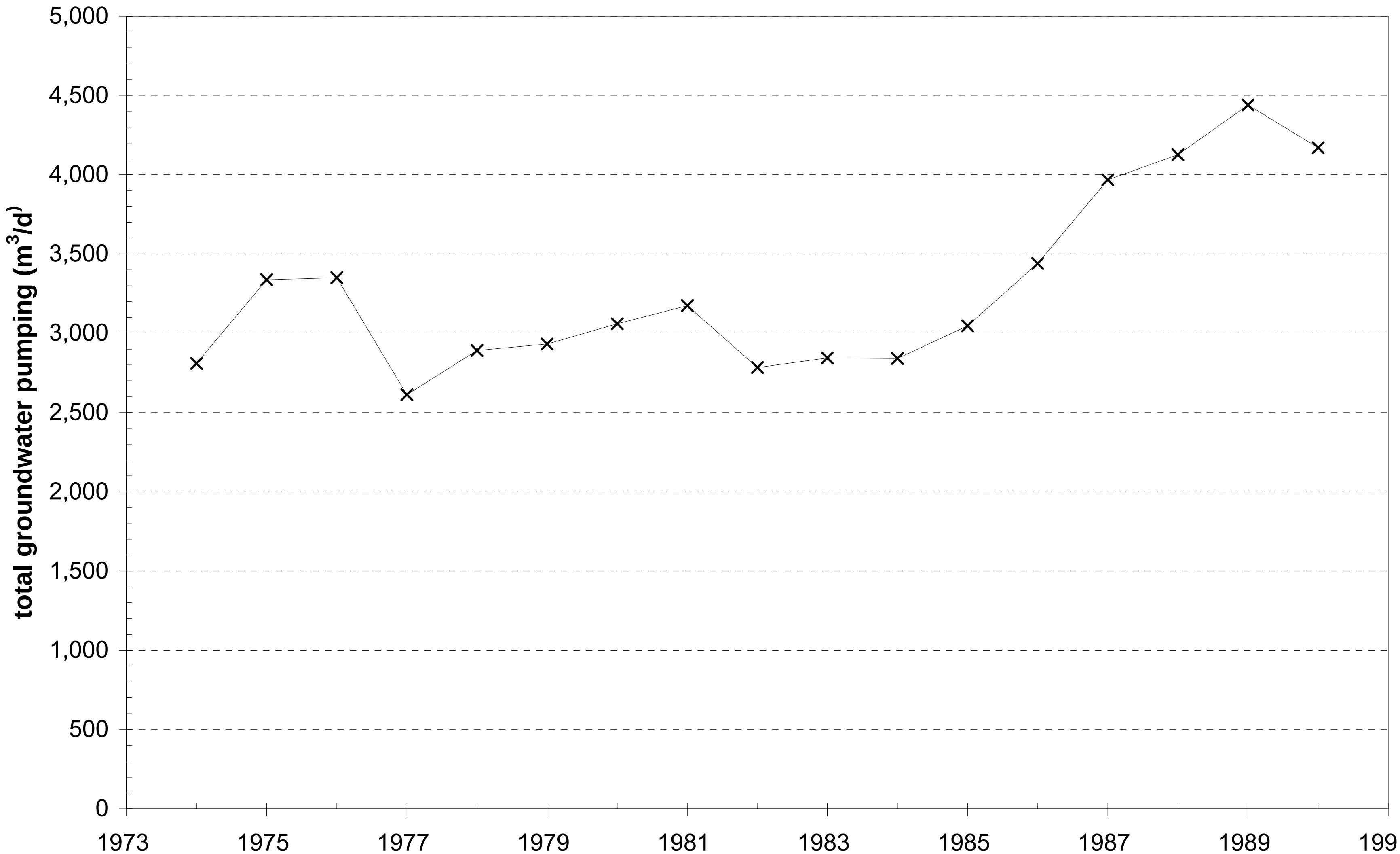


Figure D5: Stouffville groundwater pumping since 1990 (data from York Region)

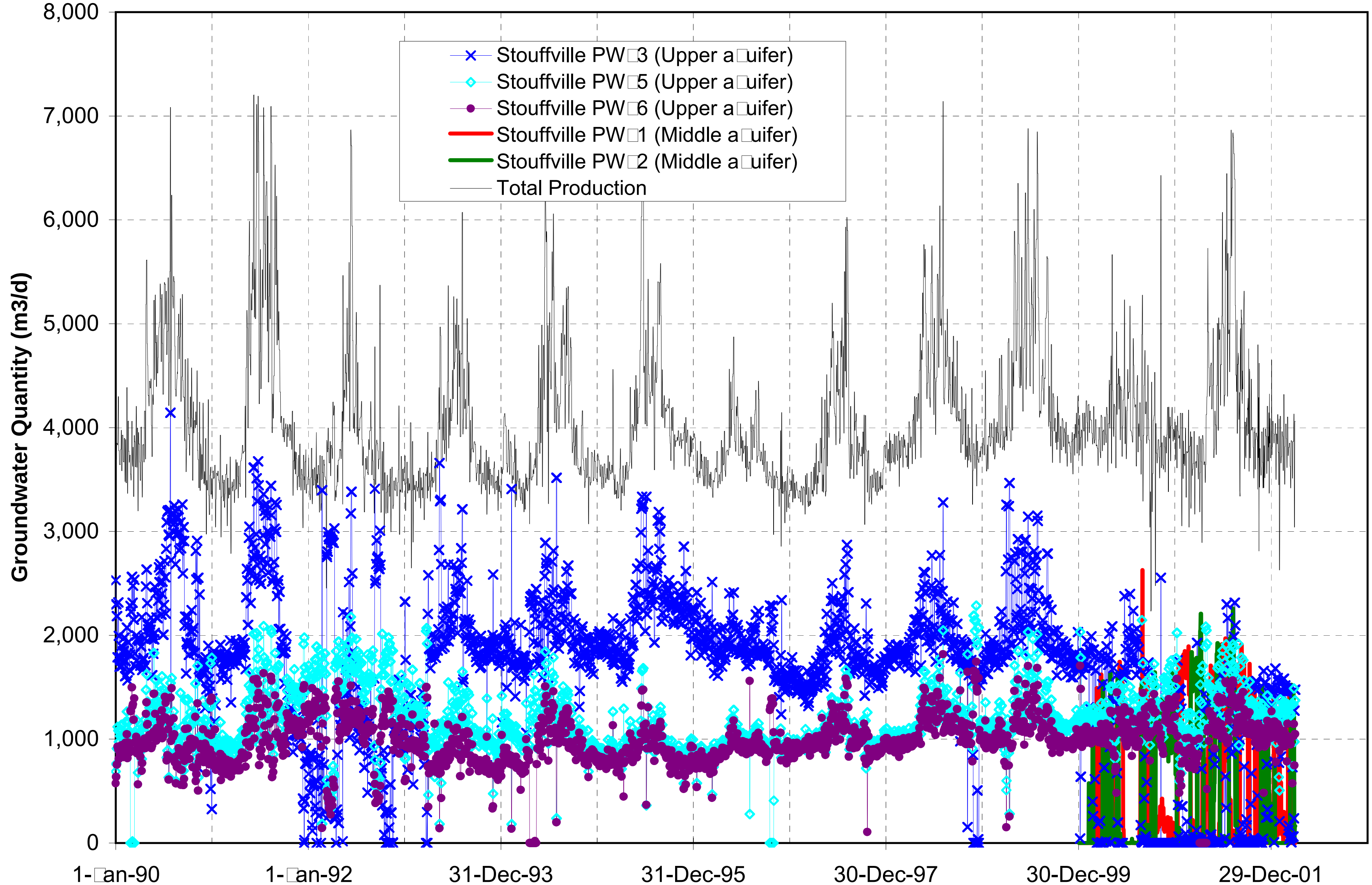


TABLE E1: Duffins watershed groundwater chemistry data summary - field measurements and major ions. Data from M.M. Dillon Limited, 1990: IWA, 1994 b,c,e; Gerber, unpublished).

			Date	Field Data			Laboratory Data								Cations				Anions				
Site Nest	Well No.	mid-scr mbgs		pH	Cond. uS/cm	Temp. °C	pH	Cond uS/cm	Alk. mg/L	Hard. mg/L	DOC mg/L	Cyanide mg/L	Phenols ug/L	TDS mg/L	Ca mg/L	Mg mg/L	Na mg/L	K mg/L	Cl mg/L	SO4 mg/L	CO3 mg/L	HCO3 mg/L	CBE %
P1-1	P1-1A	1.4	06/14/90	6.2		12.8	7.6		229					480	113	27.8	5.2	<2	18.5	68		279	11.1
	P1-1B	4.0	02/07/90	7.8		9.8	8		197						72	23.8	14.8	<2	10.4	82		240	2.1
	P1-1C	48.4	03/28/90	8.3		7.2	8.3		146						14.3	8.5	41	<2	3.6	<0.05		178	3.0
	P1-1C	48.4	06/28/90	8.4		10.5	8.4		140					200	12.3	7.6	40	<2	3.8	<0.6		171	1.0
P1-2	P1-2A	1.9	06/27/90	7.2		10.5	7.4		344					**640**	109	31.8	47.2	5	18.4	139		420	0.3
	P1-2B	11.1	02/08/90	8.4		8	8.4		162						15.3	21.4	30.9	<2	0.9	24.1		198	1.3
	P1-2B	11.1	07/26/90			8	8.2		164					200	20.1	22.7	32.4	3	0.8	23.2		200	7.0
	P1-2C	14.7	06/27/90	8.3		11.4	9.8		163					**630**	14.2	20.4	30.2	2	13.8	228.0			15.6
	P1-2C	14.7	06/27/90	9.9		11.4	9.8		162					**620**	15.5	29.6	29.6	2	13.2	230.0			6.3
P1-3	P1-3A	3.0	06/17/90	7.6		16.7	7.8		250					430	102	32.0	5.6	3	28	110		305	0.2
	P1-3B	12.6	02/07/90			10	7.5		241						79	32.4	6.2	2	15.7	74		294	0.9
	P1-3B	12.6	02/07/90	7.5		9.8	7.5		241						82	32.5	5.9	<2	15.5	74		294	1.6
	P1-3B	12.6	06/12/90			11.5	7.6		240					420	82	34.1	6.5	<2	17.8	40		293	7.9
	P1-3C	29.2	06/18/90	8.4		23	8.1		91					400	18.5	8.1	105	3	10.4	197		111	0.2
	P1-3C	29.2	06/28/90	9.1		11.9	8.3		91					470	16.0	8.4	101	2	10.3	193		111	1.6
P1-4	P1-4A	4.5	06/27/90	8.1		9.8	8.0		165					200	25.4	20.6	22.9	5	6.1	28.3		201	0.3
	P1-4B	40.7	06/27/90	7.5		10.2	7.6		133					290	18.9	3.39	80	4	28	70		162	1.1
	P1-4B	40.7	05/27/93				8.3		103					400	15.2	3.4	92.6	1.5	10.1	136		126	0.7
P1-5	P1-5A	4.1	06/17/90	8.6		17.4	7.5		179					**2550**	530	174.0	12.0	5	**1250**	76		218	1.2
	P1-5B	10.1	06/14/90	7.7		11.7	7.8		252					320	63	31.2	7.2	<2	4.0	27		307	2.6
	P1-5C	30.7	03/28/90	8.8		9.5	8.8		74					-	11.7	5.5	98	<2	6.8	179		90	0.9
P1-6	P1-6A	6.0	06/14/90	7.2		11.5	7.7		250					370	83	25.1	8.8	3	7.5	71		305	0.2
	P1-6B	16.0	02/08/90	7.5		8.5	7.5		244						74	25.4	6.3	<2	8.0	42.4		298	0.6
	P1-6B	16.0	06/11/90	7.4		10.7	7.6		250					330	75	25.7	6.1	<2	7.9	44.5		305	0.2
P1-7	P1-7A	4.6	06/28/90	7.8		10.6	8.2		210					480	51.4	38.7	30.8	5	6.5	140		256	0.6
	P1-7B	12.5	06/28/90	8.2		10	8.1		110					**570**	41.0	15.1	98	7	16.4	266		134	2.9
P1-8	P1-8A	5.6	06/12/90			10.7	7.8		240					300	41.7	34.7	23.4	4	3.81	34.2		293	3.7
	P1-8B	13.1	02/07/90	7.8		9.8	7.8		233						46	32.6	10.2	2	4.77	20.8		284	2.3
	P1-8B	13.1	06/12/90	7.6		12.2	7.7		230					280	46.5	34.1	9.7	2	5.2	20.7		281	3.9
P1-9	P1-9A	5.4	06/12/90	8.1		11.2	8.0		140					200	20.7	16.7	31.7	<2	2.73	39		171	1.3
	P1-9B	11.2	06/19/90	8.5		11.9	8.3		77					290	14.7	4.96	75	3	0.75	124		94	3.9
P1-10	P1-10A	17.7	06/14/90	7.4		11.1	7.7		232					260	44.2	33.8	13.7	2	4.0	21.5		283	4.0
P1-11	P1-11A	15.1	06/28/90	7.9		10.1	8.2		200					260	26.8	28.7	14.9	2	2.9	19.3		244	1.0
P1-12	P1-12A	6.1	06/28/90	7.7		9.4	7.9		250					390	61	16.0	9.2	5	6.7	32		305	9.0
	P1-12A	6.1	06/28/90			9.4	8.1		240					330	78	16.2	6.2	4	6.6	30.4		293	0.2
P1-13	P1-13A	14.5	06/17/90	7.2		21.7	8.0		239					250	58	27.0	8.3	2	3.3	31		292	0.1
P1-14	P1-14A	3.3	06/11/90	7.5		13.3	7.7		270					**620**	86	27.4	78	9	10.9	216		329	0.2
	P1-14B	13.4	06/28/90	8.1		10.7	8.1		130					**680**	47.9	20.0	125	9	12.6	366		159	4.3
	P1-14C	29.2	06/22/90	8.9		12.4	9.1		124					190	6.1	3.8	58	<2	6.1	21.4		151	0.9
P1-15	P1-15A	13.6	06/27/90	8.7		10.9	8.6		110					190	6.9	1.86	53	<2	1.4	29.9		134	1.0
P1-16	P1-16A	7.9	06/12/90	7.6		11.2	7.6		240					350	68	25.7	26.3	3	12.6	58		293	2.8
	P1-16A	7.9	05/18/93				7.8		226					280	62.6	28.1	14.7	1.7	10.4	64.8		276	0.4
	P1-16B	24.0	06/19/90	7.6		11.3	7.7		112					320	19.2	6.1	82	<2	15.4	116		137	0.6
	P1-16C	42.5	03/28/90	8.0			8.0		237						15.8	2.9	58.0	<2	15.5	3.6		289	19.3
	P1-16C	42.5	06/21/90	8.9		10.6	8.8		131					270	4.5	1.8	59.5	<2	15.5	7.4		160	4.0
	P1-16C	42.5	05/18/93				8.3		139					188	13.2	5.9	63.2	1.8	15.7	18.9		170	4.3
	P1-16C	42.5	05/18/93																				
	P1-16C	42.5	05/18/93																				
	P1-16D	57.0	07/05/90	7.8		10.7	7.9		209					230	31.6	13.5	51	2	17.7	6.5		255	1.5
P1-17	P1-17A	11.8	06/25/90	8.3		11.9	8.3		242					270	28.8	32.2	37.4	3	7.0	27.5		295	1.6
	P1-17B	16.3	06/14/90	7.6		10.6	8.2		160					200	17.8	20.7	34.9	<2	3.0	21.5		195	4.8
	P1-17C	29.1	06/19/90	8.6		10.1	8.4		101					260	8.1	4.15	88	<2	5.6	100		123	3.6
	P1-17C	29.1	05/27/93				8.6		127					344	9.5	3.6	101	1.1	4.7	108		155	2.7

TABLE E1: Duffins watershed groundwater chemistry data summary - field measurements and major ions. Data from M.M. Dillon Limited, 1990: IWA, 1994 b,c,e; Gerber, unpublished).

			Date	Field Data			Laboratory Data								Cations				Anions				
Site Nest	Well No.	mid-scr mbgs		pH	Cond. uS/cm	Temp. °C	pH	Cond uS/cm	Alk. mg/L	Hard. mg/L	DOC mg/L	Cyanide mg/L	Phenols ug/L	TDS mg/L	Ca mg/L	Mg mg/L	Na mg/L	K mg/L	Cl mg/L	SO4 mg/L	CO3 mg/L	HCO3 mg/L	CBE %
	P1-17C	29.1	05/27/93																			0	0.0
	P1-17D	52.1	06/25/90	8.3		10.2	8.1		136					180	8.5	3.6	50	<2	5.0	5.3		166	1.3
	P1-17E	75.6	07/05/90	8.8		10.8	8.4		174					180	36.6	18.4	21	4	13.9	9.6		212	3.1
P1-18	P1-18A	9.9	06/14/90	7.6		13.2	8.0		184					240	33.1	25.6	18.7	<2	1.8	24.4		224	3.8
	P1-18A	9.9	06/21/90	8.0		11.4	8.1		186					260	30.9	22.9	17.2	<2	2.0	24.7		227	1.4
	P1-18C	38.1	06/22/90	8.4		20.8	8.4		195					240	25.7	14.0	41	<2	4.6	3.0		238	1.6
	P1-18D	50.7	06/27/90	9.1		12.1	8.9		100					250	17.1	7.4	56	2	25.2	52.0		122	2.0
P1-19	P1-19A	8.4	06/20/90	7.3		10.5	7.7		315					570	68	64	28.4	3	3.9	162		384	1.0
	P1-19B	4.9	06/20/90	8.3		10.6	8.4		105					240	16.1	10.3	42.1	6	3.1	68		128	0.5
P1-20	P1-20A	9.1	06/17/90	7.7		15.6	8.0		229					380	85	30.5	6.0	<2	13.0	110		279	1.6
P1-21	P1-21A	29.6	06/19/90	8.1		14.5	7.7		110					250	16.0	5.7	65	2	24.0	46.0		134	3.9
	P1-21B	55.2	06/19/90	8.1		10.2	7.9		229					220	45.1	22.1	14	<2	1.3	<0.6		279	0.7
	P1-21B	55.2	05/18/93				8.0		224					152	42.7	20.6	14.3	1.5	1.7	0.4		273	0.6
	P1-21B	55.2	05/18/93																				
P1-22	P1-22A	49.4	06/26/90	8.6		10.9	8.1		197					270	23.5	14.0	37	<2	4.8	<0.6		240	2.0
	P1-22B	79.5	06/26/90	7.6		11.4	7.3		313					**4870**	441.0	120.0	1080	36	4060.0	23.5		382	20.6
P1-23	P1-23A	29.3	06/26/90	8.4		11	8.3		151					150	18.9	13.0	32	3	8.0	6.9		184	1.5
P1-25	P1-25A	14.4	06/14/90	8.6		12.3	8.2		157					170	16.2	18.2	38.6	<2	3.3	23.0		192	3.5
P1-26	P1-26A	14.9	06/17/90	7.9		16.4	7.9		235					350	50	41.2	16.8	3	47	35		287	0.5
	P1-26B	28.5	06/19/90	8.9		10.9	7.9		81					290	15.4	6.01	85	<2	18.6	130		99	1.1
	P1-26C	44.3	06/25/90	8.2		10.4	8.1		210					200	30.7	25.2	15	2	3.8	<0.6		256	0.1
P1-27	P1-27A	10.8	06/21/90	7.8		11.1	7.8		234					340	48.9	31.4	10.3	<2	12.5	34		285	2.4
	P1-27B	22.5	06/19/90	8.6		9.6	8.4		120					260	8.6	3.77	78	<2	3.0	78		146	0.3
	P1-27C	72.1	06/21/90	7.9		10.7	7.8		171					290	32.7	10.6	41	<2	15.1	18.1		209	0.6
P1-28	P1-28A	10.7	06/15/90	8.4		11.9	8.1		173					190	21.0	26.8	16.5	2	1.3	14.8		211	2.8
P1-29	P1-29A	10.7	06/15/90	7.9		12	7.9		220					240	32.8	35.7	15.0	2	4.7	25		268	2.2
	P1-29B	54.0	06/20/90	7.6		12.3	7.8		123					320	33.9	11.1	47	<2	21.0	69.0		150	1.8
P1-30	P1-30A	13.4	06/20/90	7.6		8.7	7.8		222					310	48.6	24.2	17.1	<2	4.4	24.2		271	0.9
	P1-30B	58.0	06/20/90	7.7		10.9	8.1		176					230	39.0	18.5	21	2	9.8	23.3		215	1.5
P1-32	P1-32A	3.4	07/05/90	7.6		14.7	7.8		257					320	74	20.0	16.9	4	1.5	39		314	1.5
	P1-32B	21.8	07/05/90	8.6		11.8	8.2		81					280	13.8	4.8	80	<2	9.8	122		99	1.4
	P1-32C	59.8	07/05/90	8.8		11.4	8.4		162					220	18.1	10.6	53	3	15.6	13.8		198	2.3
P1-34	P1-34A	4.3	06/25/90	7.5		10.5	7.5		247					**640**	122	31.9	35.1	5	139	65		301	0.7
	P1-34B	58.4	06/25/90	8.4		11.5	8.5		127					150	8.3	3.7	54	<2	17.3	1.9		155	0.0
P1-36	P1-36A	23.3	06/17/90	7.8		14.4	7.9		198					240	59.0	15.7	8.6	<2	3.4	34		242	1.6
EE4																							
EE4/1	EE4/1A	10.7	05/27/93	7.9			7.9	-	22					256	51.7	27.4	6.4	2.0	5.9	37.5	0	27.0	57.6
	EE4/1B	25.6	05/06/93	7.9			7.9	516	213					324	33.0	26.6	8.7	1.6	13.5	49.6	0	259.9	14.3
	EE4/1C	49.1	05/06/93	8.1			8.1	394	197					260	3.0	20.8	6.5	1.7	2.6	17.8	0	240.3	33.4
			05/06/93				-	-	-					-	-	-	-	-	-	-			
EE4/2	EE4/2A	7.6	05/05/93	7.6			7.6	613	337					328	118.0	6.5	3.8	0.6	2.8	13.4	0	411.1	3.6
	EE4/2B	24.0	05/05/93	7.9			7.9	562	219					376	78.5	23.6	3.9	1.3	8.6	69.6	0	267.2	0.1
EE4/3	EE4/3A	10.8	05/27/93	7.7			7.7	-	217					336	71.6	27.0	7.0	1.7	8.1	87.2	0	264.7	1.9
	EE4/3B	34.2	05/10/93	8.0			8.0	494	218					268	65.8	23.6	4.9	1.7	4.6	56.8	0	266.0	1.7
	EE4/3C	55.1	05/10/93	8.2			8.2	346	149					228	33.7	11.2	21.3	1.9	11.6	17.9	0	181.8	1.4
EE4/4	EE4/4B	34.9	05/04/93	7.8			7.8	486	208					288	64.7	24.0	10.1	1.5	8.8	54.2	0	253.8	1.3
	EE4/4C	59.2	05/04/93	7.9			7.9	624	218					444	75.4	30.0	7.9	2.0	62.2	44.5	0	266.0	3.0
EE4/5	EE4/5B	19.0	05/27/93	8.0			8.0	-	224					256	71.0	12.4	7.9	1.5	3.4	24.0	0	273.3	1.3
			05/27/93				-	-	-					-	-	-	-	-	-	-			
	EE4/5C	46.8	05/26/93	7.8			7.8	-	217					336	68.8	21.7	5.3	1.4	2.0	46.8	0	264.7	1.1
EE10																							

TABLE E1: Duffins watershed groundwater chemistry data summary - field measurements and major ions. Data from M.M. Dillon Limited, 1990: IWA, 1994 b,c,e; Gerber, unpublished).

			Date	Field Data			Laboratory Data								Cations				Anions				
Site Nest	Well No.	mid-scr mbgs		pH	Cond. uS/cm	Temp. °C	pH	Cond uS/cm	Alk. mg/L	Hard. mg/L	DOC mg/L	Cyanide mg/L	Phenols ug/L	TDS mg/L	Ca mg/L	Mg mg/L	Na mg/L	K mg/L	Cl mg/L	SO4 mg/L	CO3 mg/L	HCO3 mg/L	CBE %
EE10/1	EE10/1A	9.8	05/26/93	8.4			8.4	-	90					152	8.4	3.8	36.7	0.9	2.6	15.7	0	109.6	3.4
	EE10/1B	19.8	05/27/93	8.1			8.1	-	202					484	26.2	9.0	139.0	2.7	14.8	163.0	0	246.4	2.0
	EE10/1C	48.8	05/05/93	8.0			8.0	434	216					280	52.6	23.2	5.4	1.5	2.1	28.0	0	263.5	1.6
EE10/2	EE10/2A	10.7	05/18/93	8.0			8.0	-	205					208	40.1	28.5	13.5	2.0	5.7	39.5	0	250.1	1.0
	EE10/2B	19.8	05/27/93	8.1			8.1	-	121					368	23.4	7.7	89.4	1.8	7.4	143.0		147.6	1.2
	EE10/2B	19.8	05/27/93				-	-	-					-	-	-	-	-	-	-			
	EE10/2B	19.8	05/27/93				-	-	-					-	-	-	-	-	-	-			
	EE10/2C	36.7	05/27/93	8.1			8.1	-	193					196	42.5	18.2	12.3	1.3	1.9	16.9	0	235.5	0.9
EE10/3	EE10/3A	10.4	05/12/93	8.2			8.2	-	175					284	23.0	28.2	16.1	1.8	5.0	28.4	0	213.5	0.2
EE10/4	EE10/4B	36.0	05/18/93	7.8			7.8	-	208					292	59.1	18.4	57.6	2.6	41.8	49.7	0	253.8	4.9
	EE10/4C	57.9	05/13/93	7.9			7.9	-	162					256	34.2	15.5	15.1	1.1	1.5	18.5	0	197.6	0.0
EE10/5	EE10/5B	14.1	05/23/93	8.0			8.0	-	152					140	34.5	21.5	16.2	1.7	5.3	39.7	0	185.4	2.7
	EE10/5C	30.8	05/23/93	7.8			7.8	-	199					40	65.6	23.4	7.8	1.8	10.7	50.4	0	242.8	2.3
EE11																							
EE11/1	MW1A	3.0	19-Apr-94	7.3	1567	6.9	7.3	1550	345	564	4.3	< 0.002	16	**945**	206.0	53.0	114.0	0.5	234	81	2	343	16.9
	MW1A	3.0	21-Jul-94	6.4	1200	14.5	7.4	1500	252	NA	1.8	< 0.002	4	**1210**	213.0	39.2	72.9	1.8	319	40	< 1	307	6.9
	MW1B	16.2	19-Apr-94	8.2	391	10.1	8.1	385	99	81	1.8	< 0.002	13	230	22.2	19.0	46.2	1.7	22	50	1	98	18.1
	MW1B	16.2	21-Jul-94	7.8	400	17.3	8.2	464	120	NA	3.4	< 0.002	3	286	22.9	7.3	83.9	1.6	11	84	< 1	146	9.9
	MW1C	39.8	20-Apr-94	8.3	392	4.7	8.1	350	165	142	1.0	< 0.002	< 1	200	26.5	24.0	16.9	0.8	1	14	2	162	14.6
	MW1C-DU	39.8	20-Apr-94	8.3	392	4.7	8.1	350	162	143	< 0.3	< 0.002	1	200	39.4	23.3	14.3	1.2	1	14	< 1	226	6.0
	MW1C	39.8	21-Jul-94	7.0	305	14.5	8.1	360	185	NA	1.6	< 0.002	< 1	213	26.6	25.0	16.9	0.8	2	13	2	160	16.5
	MW1D	46.4	19-Apr-94	8.3	372	10.6	8.2	383	187	138	0.9	< 0.002	6	220	22.8	13.0	26.5	1.3	7	6	3	184	0.1
	MW1D	46.4	21-Jul-94	7.3	270	14.5	8.2	349	190	NA	3.6	< 0.002	2	195	28.0	23.6	23.5	1.6	5	3	< 1	232	4.7
	MW1E	57.3	19-Apr-94	8.2	374	10.4	8.1	390	207	153	0.4	< 0.002	6	220	31.3	28.0	19.3	1.7	6	6	3	204	12.4
	MW1E	57.3	21-Jul-94	7.5	315	15.6	8.1	367	196	NA	0.8	< 0.002	1	210	38.6	20.9	20.1	2.0	5	< 2	< 1	239	5.9
	MW1F	71.0	19-Apr-94	7.9	1095	10.9	7.9	1150	316	108	1.0	< 0.002	13	**640**	29.0	66.0	212.0	6.1	182	< 2	4	312	22.4
	MW1F	71.0	21-Jul-94	7.5	1050	19.2	8.1	1150	328	NA	2.8	< 0.002	1	**681**	36.9	10.1	244.0	7.7	198	< 2	< 1	400	5.2
EE11/2	MW2A	3.2	27-Apr-94	7.8	576	6.3	7.9	566	218	247	1.6	< 0.002	< 1	310	85.3	8.2	24.9	1.1	22	47	< 1	266	0.7
	MW2A	3.2	19-Jul-94	7.9	450	17.5	7.9	548	249	265	0.9	< 0.002	1	340	69.5	22.3	29.1	3.9	11	45	< 1	304	3.4
	MW2B	15.6	28-Apr-94	8.0	255	7.5	8.4	240	86	53	1.2	< 0.002	< 1	140	12.0	5.7	42.2	1.2	1	26	< 1	105	12.1
	MW2B	15.6	20-Jul-94	8.2	200	15.0	8.3	233	88	47	0.9	< 0.002	< 1	135	11.3	4.6	27.6	0.9	< 1	26	< 1	107	2.9
	MW2C	32.3	26-Apr-94	8.5	304	10.5	8.5	325	160	133	6.1	< 0.002	< 1	180	18.5	21.1	20.6	0.9	1	15	< 1	195	0.4
	MW2C	32.3	19-Jul-94	8.4	265	15.2	8.3	319	157	146	4.3	< 0.002	< 1	185	22.1	22.0	21.3	1.1	1	13	< 1	191	6.0
	MW2D	60.1	26-Apr-94	8.2	384	10.8	8.0	386	208	160	3.2	< 0.002	< 1	210	32.3	19.3	21.7	2.2	6	< 2	< 1	254	1.5
	MW2D	60.1	19-Jul-94	7.9	290	13.3	8.0	369	206	172	0.6	< 0.002	< 1	216	35.8	20.0	23.6	2.2	6	< 2	< 1	251	2.6
EE11/3	MW3A	8.2	26-Apr-94	8.0	464	7.6	8.1	465	169	220	2.7	< 0.002	1	270	47.6	24.6	12.7	1.5	9	66	< 1	206	0.1
	MW3A	8.2	19-Jul-94	7.9	330	12.3	7.9	412	162	222	0.7	< 0.002	2	256	47.9	24.9	12.4	1.4	8	60	< 1	197	3.2
	MW3B	15.9	02-May-94	8.4	451	10.4	8.2	419	121	74	2.2	< 0.002	< 1	245	17.9	7.0	63.5	1.2	5	79	< 1	147	0.9
	MW3B	15.9	20-Jul-94	8.1	490	22.7	8.1	516	150	101	2.7	< 0.002	2	332	25.1	9.2	63.8	1.4	4	110	< 1	183	5.7
	MW3C	23.0	26-Apr-94	8.3	314	9.3	8.3	319	158	138	1.7	< 0.002	2	175	22.4	20.0	17.3	0.9	2	10	< 1	193	1.5
	MW3C	23.0	19-Jul-94	8.2	245	13.0	8.2	317	160	148	1.7	< 0.002	< 1	180	25.2	20.6	18.2	1.0	3	12	< 1	195	3.3
	MW3D	50.6	26-Apr-94	8.0	379	9.3	8.1	384	203	171	4.8	< 0.002	1	205	33.3	21.3	16.4	1.8	6	< 2	< 1	247	0.5
	MW3D	50.6	19-Jul-94	8.0	285	11.5	8.0	371	200	188	0.8	< 0.002	1	216	38.9	22.0	1.1	1.8	5	< 2	< 1	244	3.7
	MW3E	57.9	26-Apr-94	7.7	395	8.4	8.2	397	198	152	1.9	< 0.002	< 1	215	31.9	17.6	28.3	2.3	7	4	< 1	241	1.1
	MW3E	57.9	19-Jul-94	8.1	305	12.8	8.1	378	197	167	0.8	< 0.002	4	222	35.6	19.0	25.3	2.2	7	< 2	< 1	240	4.2
EE11/4	MW4A	3.4	21-Apr-94	7.6	670	3.1	7.6	681	281	371	6.0	< 0.002	5	410	123.0	4.0	8.5	1.2	12	45	1	280	7.8
	MW4A	3.4	28-Apr-94		NA	NA	7.5	650	300	392	< 3	NA	NA	360	129.0	16.9	9.8	1.3	13	40	< 1	366	7.0
	MW4A	3.4	04-May-94		NA	NA	7.6	571	201	305	NA	NA	NA	340	100.0	13.5	6.8	1.1	10	33	< 1	245	12.5
	MW4A	3.4	15-Jul-94	7.0	500	16.4	7.5	537	294	351	1.8	< 0.002	2	365	117.0	14.3	8.5	1.4	7	28	< 1	358	5.5
	MW4B	15.9	21-Apr-94	8.8	210	8.8	8.7	225	103	34	< 0.3	< 0.002	< 1	130	7.5	5.0	38.2	0.7	2	9	1	102	11.9
	MW4B	15.9	27-Apr-94		NA	NA	8.7	228	100	34	0.5	NA	NA	130	7.8	3.4	37.4	0.6	3	10	< 1	122	0.5
	MW4B	15.9	15-Jul-94	8.7	165	11.8	8.6	224	106	64	1.5	< 0.002	< 1	145	18.2	4.4	42.1	1.2	3	10	< 1	129	13.1

TABLE E1: Duffins watershed groundwater chemistry data summary - field measurements and major ions. Data from M.M. Dillon Limited, 1990: IWA, 1994 b,c,e; Gerber, unpublished).

			Date	Field Data			Laboratory Data								Cations				Anions				
Site Nest	Well No.	mid-scr mbgs		pH	Cond. uS/cm	Temp. °C	pH	Cond uS/cm	Alk. mg/L	Hard. mg/L	DOC mg/L	Cyanide mg/L	Phenols ug/L	TDS mg/L	Ca mg/L	Mg mg/L	Na mg/L	K mg/L	Cl mg/L	SO4 mg/L	CO3 mg/L	HCO3 mg/L	CBE %
	MW4C	37.3	21-Apr-94	8.4	338	7.5	8.3	345	186	152	< 0.3	< 0.002	3	155	22.0	30.0	18.2	1.0	2	< 2	1	185	16.9
	MW4C	37.3	27-Apr-94		NA	NA	8.3	346	182	155	< 0.3	NA	NA	180	24.2	23.0	17.0	0.9	3	< 2	< 1	222	1.9
	MW4C	37.3	15-Jul-94	7.9	255	12.4	8.2	331	188	174	0.8	< 0.002	3	186	26.3	26.4	18.5	1.0	2	< 2	< 1	229	6.2
	MW4D	50.6	21-Apr-94	8.1	378	8.7	8.1	390	210	166	< 0.3	< 0.002	3	220	33.1	17.0	22.6	2.7	4	< 2	2	208	7.1
	MW4D-DU	50.6	21-Apr-94		378	NA	8.0	390	211	164	0.5	< 0.002	2	215	32.7	18.0	22.5	2.6	4	< 2	2	209	7.7
	MW4D	50.6	28-Apr-94		NA	NA	8.1	389	200	178	1.7	NA	NA	210	34.5	22.3	25.5	3.1	4	< 2	< 1	244	7.1
	MW4D-DU	50.6	28-Apr-94	8.1	NA	8.7	8.1	388	201	179	1.0	NA	NA	210	34.8	22.4	25.7	3.2	4	< 2	< 1	245	7.3
	MW4D	50.6	02-May-94		NA	NA	8.2	374	199	146	NA	NA	NA	170	29.9	17.4	18.4	1.7	4	< 2	< 1	243	4.2
	MW4D-DU	50.6	02-May-94		NA	NA	8.1	374	199	136	NA	NA	NA	200	28.0	16.1	16.4	1.5	4	< 2	< 1	243	8.2
	MW4D	50.6	15-Jul-94	7.8	320	11.2	8.1	371	200	180	1.3	< 0.002	< 1	215	37.0	21.3	24.3	2.7	4	< 2	< 1	244	6.9
	MW4D-DU	50.6	15-Jul-94		NA	NA	8.0	374	201	178	0.4	< 0.002	< 1	214	36.2	21.3	23.2	2.8	4	< 2	< 1	245	5.8
EE11/5	MW5A	4.6	22-Apr-94	7.6	657	6.9	7.8	672	205	333	0.8	< 0.002	1	400	119.0	15.0	6.1	0.6	90	34	1	204	6.0
	MW5A	4.6	15-Jul-94	7.4	700	19.2	7.7	785	240	488	1.6	< 0.002	< 1	571	172.0	14.1	8.0	1.2	100	72	< 1	293	5.2
	MW5B	12.3	26-Apr-94	7.9	364	9.3	8.2	360	191	148	2.6	< 0.002	2	195	20.1	23.8	21.8	2.6	5	< 2	< 1	233	0.3
	MW5B	12.3	15-Jul-94	7.9	270	13.1	8.1	344	186	164	0.7	< 0.002	4	194	23.3	25.8	22.8	2.9	< 1	< 2	< 1	227	7.8
	MW5C	21.1	22-Apr-94	8.0	374	9.0	8.1	385	204	166	0.4	< 0.002	3	210	26.9	18.0	19.9	1.6	< 1	5	2	202	3.9
	MW5C	21.1	15-Jul-94	7.9	300	15.7	8.1	369	197	200	2.4	< 0.002	4	214	36.6	26.3	20.6	2.1	6	< 2	< 1	240	9.2
EE11/6	MW6A	3.7	20-Apr-94	8.3	628	5.6	8.1	619	176	265	< 0.3	< 0.002	3	345	48.7	11.0	15.3	2.9	68	27	2	174	13.6
	MW6A	3.7	19-Jul-94	7.9	500	15.8	7.9	599	193	310	0.3	< 0.002	< 1	354	56.6	41.1	16.4	3.3	74	28	< 1	235	3.6
	MW6B	21.9	02-May-94	8.2	545	11.1	8.2	532	113	102	0.7	< 0.002	< 1	320	27.7	7.9	75.6	2.0	25	111	< 1	138	0.9
	MW6B	21.9	19-Jul-94		NA	NA	8.2	658	124	103	4.0	< 0.002	< 1	430	26.0	9.2	114.0	2.0	14	180	< 1	151	3.3
	MW6C	45.5	20-Apr-94	8.5	330	8.3	8.2	351	176	153	1.0	< 0.002	3	210	30.1	30.0	33.0	1.8	6	8	3	173	25.8
	MW6C	45.5	16-Jul-94	8.3	270	14.5	8.2	331	189	146	1.4	< 0.002	< 1	224	22.8	21.6	30.7	1.6	6	7	< 1	230	2.5
EE11/7	MW7A	4.0	20-Apr-94	7.9	608	4.1	7.6	602	246	295	< 0.3	< 0.002	4	375	83.6	29.0	6.0	2.0	3	70	2	244	10.3
	MW7A	4.0	16-Jul-94	7.4	475	13.6	7.5	619	278	378	1.2	< 0.002	< 1	413	112.0	24.0	5.9	1.8	3	50	< 1	339	8.1
	MW7B	42.2	20-Apr-94	8.3	429	6.8	8.3	422	194	210	13.5	< 0.002	7	415	54.0	390.0	30.4	2.6	8	30	2	192	80.0
	MW7B	42.2	16-Jul-94	7.9	315	13.1	7.9	425	190	287	13.3	< 0.002	4	335	74.8	24.3	30.2	2.6	7	36	< 1	232	19.9
	MW7C	18.1	20-Apr-94	8.2	416	7.9	7.9	431	183	199	0.6	< 0.002	4	260	49.6	36.0	9.9	2.2	6	30	2	181	21.9
	MW7C	18.1	16-Jul-94	7.8	300	10.2	7.9	421	193	226	1.1	< 0.002	< 1	259	53.1	22.6	10.7	2.6	6	24	< 1	235	5.4
EE11/8	MW8A	7.6	03-May-94	7.8	560	12.4	7.7	562	229	289	1.4	< 0.002	< 1	315	99.2	10.1	12.9	1.6	31	25	< 1	279	3.3
	MW8A	7.6	18-Jul-94	7.5	415	11.5	7.8	528	228	249	1.3	< 0.002	< 1	320	86.0	8.4	9.0	1.4	25	26	< 1	278	3.5
	MW8B	20.3	03-May-94	8.4	555	13.7	8.1	542	104	116	2.6	< 0.002	2	330	30.4	9.8	75.2	1.8	16	137	< 1	127	2.5
	MW8B	20.3	20-Jul-94	8.1	550	20.8	8.1	611	121	117	2.8	< 0.002	< 1	411	30.6	9.8	76.6	1.6	7	200	< 1	147	8.5
	MW8C	33.1	04-May-94	8.2	416	16.7	8.1	395	156	132	< 0.3	< 0.002	1	220	33.6	11.7	35.4	2.4	13	34	< 1	190	0.5
	MW8C-DU	33.1	04-May-94		NA	NA	8.2	395	156	131	1.5	< 0.002	< 1	220	33.2	11.6	35.4	2.4	13	34	< 1	190	0.3
	MW8C	33.1	14-Jul-94	8.0	280	13.3	8.2	341	138	114	1.1	< 0.002	2	219	28.2	10.7	36.1	1.9	6	33	< 1	168	3.9
	MW8D-DU	60.5	19-Jul-94		NA	NA	8.1	367	201	192	2.4	< 0.002	< 1	210	35.5	24.2	14.8	1.5	< 1	8	< 1	247	2.6
	MW8D	60.5	03-May-94	8.1	385	14.1	8.1	376	203	188	1.1	< 0.002	< 1	200	37.2	24.5	13.2	1.4	2	5	< 1	238	4.9
	MW8D	60.5	19-Jul-94	8.0	265	13.3	8.1	365	195	194	2.4	< 0.002	< 1	214	36.6	24.5	12.6	1.4	2	6	< 1	245	2.6
EE11/9	MW9A	3.7	29-Apr-94	7.7	733	7.3	8.0	724	169	373	2.4	< 0.002	1	430	68.8	48.8	7.7	6.0	< 1	< 2	< 1	< 1	
	MW9A	3.7	03-May-94		NA	NA	7.8	687	280	382	NA	NA	NA	410	73.8	48.1	7.9	5.8	22	87	< 1	341	0.7
	MW9A	3.7	15-Jul-94	7.4	550	15.4	7.8	679	284	NA	1.4	< 0.002	< 1	468	NA	NA	NA	NA	20	85	< 1	346	
	MW9A	3.7	16-Jul-94		NA	NA	NA	NA	NA	420	NA	< 0.002	NA	NA	81.3	52.6	11.9	8.4	NA	NA	NA	NA	
	MW9B	10.2	29-Apr-94	8.0	426	9.5	8.3	426	192	189	1.6	< 0.002	1	220	15.5	36.5	18.9	2.1	1	39	< 1	234	0.4
	MW9B	10.2	03-May-94		NA	NA	8.2	415	197	197	NA	NA	NA	190	16.3	37.9	20.3	2.1	2	34	< 1	240	1.8
	MW9B	10.2	15-Jul-94	7.9	305	11.6	8.2	416	190	216	0.7	< 0.002	4	235	18.8	41.0	23.1	2.2	2	36	< 1	232	7.6
	MW9C	51.6	29-Apr-94	7.9	328	10.9	8.3	333	156	129	0.8	< 0.002	1	190	23.9	16.8	20.3	1.2	< 1	19	< 1	190	0.3
	MW9C	51.6	03-May-94		NA	NA	8.2	321	156	134	NA	NA	NA	160	24.8	17.4	21.3	1.0	< 1	17	< 1	190	2.2
	MW9C	51.6	16-Jul-94	8.1	245	12.9	8.2	294	156	142	1.2	< 0.002	< 1	191	27.0	18.2	24.3	1.6	< 1	17	< 1	190	6.4
EE11/10	MW10A	4.1	22-Apr-94	7.4	782	6.1	7.6	783	392	427	0.9	< 0.002	2	420	116.0	49.0	4.5	2.9	44	4	1	391	13.1
	MW10A	4.1	15-Jul-94	7.1	600	13.8	7.4	795	438	539	1.3	< 0.002	< 1	489	150.0	39.9	4.9	3.5	3	42	< 1	534	6.5
	MW10A	4.1	20-Jul-94		NA	NA	7.3	799	431	NA	NA	NA	NA	496	NA	NA	NA	NA	3	40	< 1	525	
EE11/11	MW11A	20.2	19-Jul-94	7.9	369	6.7	8.1	336	168	174	2.3	< 0.002	2	200	37.6	18.9	17.1	2.3	3	17	< 1	199	6.6

TABLE E1: Duffins watershed groundwater chemistry data summary - field measurements and major ions. Data from M.M. Dillon Limited, 1990: IWA, 1994 b,c,e; Gerber, unpublished).

			Date	Field Data			Laboratory Data							Cations					Anions				
Site	Well	mid-scr		pH	Cond.	Temp.	pH	Cond	Alk.	Hard.	DOC	Cyanide	Phenols	TDS	Ca	Mg	Na	K	Cl	SO4	CO3	HCO3	CBE
Nest	No.	mbgs			uS/cm	°C		uS/cm	mg/L	mg/L	mg/L	mg/L	ug/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	%
	MW11A	20.2	28-Apr-94	8.1	260	12.6	8.1	355	163	172	0.6	< 0.002	1	200	38.5	18.9	11.5	1.5	2	14	< 1	205	4.0
	MW11B	44.0	28-Apr-94	8.4	308	6.6	8.4	313	141	116	0.6	< 0.002	2	170	17.6	17.4	33.1	1.1	2	16	< 1	172	8.1
	MW11B	44.0	19-Jul-94	8.4	235	11.5	8.3	296	147	114	1.5	< 0.002	< 1	171	18.0	16.7	25.5	0.8	2	13	< 1	179	2.1
EE11/12	MW12A	4.3	22-Apr-94	8.0	443	5.7	8.1	438	184	223	0.9	< 0.002	1	240	61.1	30.0	4.9	3.4	43	2	2	182	15.3
	MW12A	4.3	15-Jul-94		NA	NA	8.0	435	191	257	1.2	< 0.002	< 1	277	73.1	18.1	6.0	4.0	2	44	< 1	233	6.9
	MW12B	11.7	22-Apr-94	7.8	390	6.9	8.1	391	165	184	0.6	< 0.002	1	240	46.9	11.0	9.5	1.2	32	5	2	163	0.3
	MW12B		15-Jul-94	7.5	290	10.4	7.9	375	166	208	0.7	< 0.002	2	231	54.1	17.6	9.3	1.2	< 1	33	< 1	202	6.8
	MW12C	29.0	29-Apr-94	9.1	542	14.7	9.0	478	116	38	1.7	< 0.002	1	350	12.4	160.0	103.0	1.0	14	36	< 1	141	68.2
	MW12C		04-May-94		NA	NA	9.1	499	142	375	NA	NA	NA	**850**	84.3	39.9	121.0	8.9	38	126	< 1	173	33.1
	MW12C		20-Jul-94	9.2	380	18.6	9.1	422	243	523	2.1	< 0.002	< 1	**1010**	183.0	16.0	88.3	3.2	15	76	< 1	296	35.4
	MW12D	42.2	26-Apr-94	8.3	305	17.3	8.5	304	161	95	2.5	< 0.002	2	160	16.0	13.3	29.8	1.0	3	< 2	< 1	196	1.5
	MW12D		15-Jul-94	8.1	215	10.9	8.3	291	151	116	0.7	< 0.002	< 1	179	20.2	15.9	30.3	1.0	3	< 2	< 1	184	8.3
EE11/13	MW13A	5.8	21-Apr-94		NA	NA	7.5	1870	241	584	< 0.3	< 0.002	3	**1120**	209.0	2.0	143.0	1.2	450	32	1	240	1.4
	MW13A		26-Apr-94	7.2	1763	6.8	7.6	1940	236	585	1.3	NA	NA	**1160**	211.0	14.1	144.0	1.1	441	35	< 1	288	0.3
	MW13A-DUP		04-May-94	9.1	2011	9.1	7.6	1870	242	587	< 0.3	< 0.002	< 1	**1160**	211.0	14.5	149.0	1.2	440	34	< 1	295	0.8
	MW13A		15-Jul-94	7.4	1000	10.4	7.7	1510	230	379	2.7	< 0.002	< 1	**946**	138.0	8.4	193.0	1.2	323	48	< 1	280	4.2
	MW13A		20-Jul-94		NA	NA	7.8	1510	237	NA	NA	NA	NA	**935**	NA	NA	NA	NA	323	49	< 1	289	
	MW13B	21.7	21-Apr-94	8.4	352	6.9	8.3	358	185	127	< 0.3	< 0.002	3	205	18.7	15.0	33.7	1.6	4	5	2	183	6.0
	MW13B		26-Apr-94		NA	NA	8.4	352	183	124	5.9	NA	NA	190	18.2	19.1	29.6	1.5	4	4	< 1	223	0.7
	MW13B		15-Jul-94	8.2	270	12.5	8.3	337	178	129	1.9	< 0.002	< 1	204	20.5	19.0	34.5	1.5	3	3	< 1	217	5.4
	MW13B-DUP		15-Jul-94		NA	NA	8.3	334	178	129	1.8	< 0.002	< 1	201	20.6	18.9	35.0	1.5	3	4	< 1	217	5.3
	MW13B		20-Jul-94		NA	NA	8.3	334	184	NA	NA	NA	NA	187	NA	NA	NA	NA	4	3	< 1	224	
	MW13B-DUP		20-Jul-94		NA	NA	8.3	334	182	NA	NA	NA	NA	187	NA	NA	NA	NA	3	4	< 1	222	
EE11/14	MW14A	4.6	21-Apr-94	7.6	517	6.6	7.6	517	271	278	0.5	< 0.002	3	300	102.0	96.0	3.6	0.7	3	8	2	269	47.4
	MW14A		26-Apr-94		NA	NA	7.6	501	262	267	2.3	NA	NA	280	99.0	4.9	3.7	0.6	3	10	< 1	319	0.1
	MW14A		15-Jul-94	7.3	375	11.9	7.4	579	261	322	< 0.3	< 0.002	< 1	385	119.0	6.1	4.0	0.6	4	61	< 1	318	0.3
	MW14B	27.7	21-Apr-94	7.9	365	9.9	8.2	368	191	148	< 0.3	< 0.002	4	200	21.6	18.0	23.2	1.1	4	< 2	2	189	5.0
	MW14B		26-Apr-94		NA	NA	8.2	365	191	148	3.1	NA	NA	190	21.5	22.8	22.9	1.0	5	< 2	< 1	233	0.2
	MW14B		15-Jul-94	7.9	275	11.9	8.2	355	192	171	1.0	< 0.002	2	202	26.8	25.3	25.9	1.2	5	< 2	< 1	234	7.0
EE11/15	MW15A	10.1	22-Apr-94	7.5	588	4.7	7.9	506	199	246	0.7	< 0.002	< 1	300	86.2	6.0	3.1	0.8	25	27	1	197	4.5
	MW15A		16-Jul-94	7.6	390	11.9	7.7	484	194	297	2.2	< 0.002	< 1	320	105.0	8.4	3.3	1.1	30	19	< 1	236	8.8
	MW15B	27.0	21-Apr-94	7.9	426	10.7	7.9	440	216	213	0.4	< 0.002	2	250	57.3	23.0	15.5	1.3	7	16	1	215	14.7
	MW15B		27-Apr-94		NA	NA	8.0	438	209	214	1.3	NA	NA	240	57.6	17.1	14.8	1.1	7	16	< 1	255	2.6
	MW15B		16-Jul-94	7.8	330	13	7.8	423	214	229	1.1	< 0.002	< 1	246	61.9	18.0	16.3	1.3	6	15	< 1	261	5.5
EE11/16	MW16A	13.0	21-Apr-94	8.4	355	8.0	8.2	350	166	133	0.7	< 0.002	< 1	190	21.3	12.0	26.5	0.6	3	18	2	164	0.7
	MW16A		27-Apr-94		NA	NA	8.2	359	161	133	1.3	NA	NA	200	21.6	19.3	25.5	0.5	3	20	< 1	196	0.8
	MW16A		16-Jul-94	8.2	230	11.9	8.2	326	161	130	0.9	< 0.002	< 1	187	21.7	18.4	29.7	0.7	3	14	< 1	196	4.2
	MW16B	18.3	21-Apr-94	8.4	331	9.0	8.4	335	167	122	< 0.3	< 0.002	2	190	20.0	10.0	28.7	0.8	3	10	2	165	1.0
	MW16B		27-Apr-94		NA	NA	8.2	356	161	96	3.0	NA	NA	200	17.2	12.8	40.1	0.6	4	18	< 1	196	0.3
	MW16B		16-Jul-94	8.2	230	12.2	8.2	340	164	1580	1.9	< 0.002	< 1	263	554.0	47.2	41.0	2.2	4	12	< 1	200	80.3
EE11/17	MW17A	2.3	21-Apr-94	7.0	1644	4.5	7.0	1710	481	992	1.3	< 0.002	3	**1240**		15.0	9.6	1.2	150	240	1	480	82.1
	MW17A		27-Apr-94		NA	NA	7.1	1710	436	945	3.5	NA	NA	**1090**	342	22.1	9.5	0.9	137	242	< 1	531	4.6
	MW17A		14-Jul-94		NA	NA	NA	NA	NA	NA	2.9	NA	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	
	MW17A		16-Jul-94		NA	NA	NA	NA	NA	NA	NA	< 0.002	NA	NA									
	MW17B	12.0	22-Apr-94	9.0	189	7.3	8.9	209	87	22	0.5	< 0.002	2	120	5.6	4.0	39.9	0.4	1	13	6	81	15.4
	MW17B		14-Jul-94	9.0	150	11.7	8.8	197	89	25	1.0	NA	< 1	120	6.2	2.3	40.4	0.4	1	11	< 1	108	5.5
	MW17C	32.8	21-Apr-94	8.4	284	11.3	8.5	295	138	72	4.0	< 0.002	< 1	180	12.1	13.0	38.3	0.8	8	14	1	137	9.6
	MW17C		28-Apr-94		NA	NA	8.6	300	131	76	5.3	NA	NA	160	12.8	10.8	47.0	1.0	3	16	< 1	160	8.5
	MW17C		14-Jul-94	8.5	190	10.8	8.4	260	136	82	2.2	< 0.002	3	161	13.5	11.8	32.0	0.8	1	8	< 1	166	2.4
EE11/18	MW18A	4.6	28-Apr-94	7.5	512	5.9	7.8	520	211	302	2.2	< 0.002	< 1	300	71.6	29.9	5.8	3.4	2	57	< 1	257	7.8
	MW18A		20-Jul-94	7.6	420	14.0	7.7	511	228	258	1.2	< 0.002	< 1	316	65.2	23.2	4.1	2.6	1	71	< 1	278	5.7
	MW18B	14.9	28-Apr-94	8.4	235	10.5	8.6	242	93	61	0.5	< 0.002	< 1	130	10.2	8.7	38.0	1.1	2	26	< 1	113	8.5
	MW18B		20-Jul-94	8.8	NA	10.3	8.5	230	101	48	0.7	< 0.002	9	136	8.3	6.5	24.4	0.8	2	18	< 1	123	9.3

TABLE E1: Duffins watershed groundwater chemistry data summary - field measurements and major ions. Data from M.M. Dillon Limited, 1990: IWA, 1994 b,c,e; Gerber, unpublished).

Site Nest	Well No.	mid-scr mbgs	Date	Field Data pH	Cond. uS/cm	Temp. °C	Laboratory Data pH	Cond uS/cm	Alk. mg/L	Hard. mg/L	DOC mg/L	Cyanide mg/L	Phenols ug/L	TDS mg/L	Cations Ca mg/L	Mg mg/L	Na mg/L	K mg/L	Anions Cl mg/L	SO4 mg/L	CO3 mg/L	HCO3 mg/L	CBE %
	MW18C	28.1	25-Apr-94	7.8	563	10.8	8.0	587	238	254	1.9	< 0.002	1	340	53.6	29.1	25.0	2.0	2	76	< 1	290	1.6
	MW18C		14-Jul-94	7.7	480	12.7	8.0	567	244	290	1.0	< 0.002	7	354	58.4	35.0	26.4	1.9	2	85	< 1	297	2.2
	MW18D	49.4	04-May-94	8.1	331	12.2	8.3	325	169	123	0.7	< 0.002	1	170	18.0	19.0	27.9	1.4	4	9	< 1	206	0.6
	MW18D		14-Jul-94	8.3	230	11.9	8.3	316	166	138	1.3	< 0.002	3	191	19.5	21.6	24.4	1.4	2	4	< 1	202	5.4
EE11/19	MW19A	17.7	02-May-94	8.5	782	12.8	8.4	768	335	518	< 3	< 0.002	< 1	**1260**	143	39.0	159	22.7	41	187	< 1	408	20.6
	MW19A		20-Jul-94	8.0	750	17.8	8.1	958	182	178	3.2	< 0.002	2	**888**	60.0	6.9	40.0	1.5	18	320	< 1	222	33.9
	MW19B	17.8	02-May-94	8.3	471	13.8	8.2	454	124	77	15.0	< 0.002	14	270	30.5	0.3	50.9	1.6	18	80	< 1	151	10.0
	MW19C	45.6	28-Apr-94	8.5	346	11.2	8.6	338	159	74	0.6	< 0.002	1	190	13.1	10.1	55.8	2.9	7	6	< 1	194	6.4
	MW19C		20-Jul-94	8.3	230	12.5	8.3	306	163	76	1.4	< 0.002	< 1	188	13.7	10.2	29.0	2.0	5	4	< 1	199	10.3
EE11/20	MW20A	10.2	28-Apr-94	7.6	581	6.9	8.0	602	218	280	< 0.3	< 0.002	1	350	73.1	23.8	37.5	2.5	9	82	< 1	266	7.1
	MW20A		19-Jul-94	7.8	450	12.6	7.8	551	231	277	0.8	< 0.002	1	355	72.9	23.1	21.6	1.6	9	77	< 1	282	0.3
	MW20B	16.7	28-Apr-94	8.1	415	6.7	8.2	421	174	198	< 0.3	< 0.002	1	240	34.6	27.1	28.6	1.6	3	36	< 1	212	9.6
	MW20B		19-Jul-94	8.1	310	12.8	8.0	405	184	175	0.8	< 0.002	< 1	240	31.2	23.6	27.2	1.2	3	37	< 1	224	2.0
	MW20C	58.4	28-Apr-94	8.0	368	11.1	8.3	359	162	141	1.3	< 0.002	< 1	200	25.6	18.8	37.4	1.6	1	20	< 1	197	9.9
	MW20C		19-Jul-94	8.2	300	17.4	8.1	342	169	147	0.9	< 0.002	< 1	200	28.2	18.6	23.2	1.2	< 1	18	< 1	206	2.9
EE11/21	MW21A	15.1	03-May-94	8.1	516	13.2	8.0	488	95	89	1.0	< 0.002	1	280	23.3	7.4	72.8	1.7	19	113	< 1	116	1.9
	MW21A		20-Jul-94	8.2	500	17.4	8.1	635	96	91	4.2	< 0.002	7	425	22.5	8.5	88.8	1.5	13	180	< 1	117	2.6
	MW21B	26.5	03-May-94	7.6	299	10.3	8.4	300	116	57	< 0.3	< 0.002	1	160	13.0	6.0	46.3	1.4	2	35	< 1	141	1.5
	MW21B		20-Jul-94	8.5	210	13	8.4	270	114	49	2.9	< 0.002	8	173	11.4	4.9	33.6	0.9	1	31	< 1	139	9.2
	MW21C	52.3	03-May-94	7.9	426	12.0	7.9	406	214	224	0.4	< 0.002	< 1	210	50.8	23.5	8.0	1.2	1	16	< 1	261	2.2
	MW21C		20-Jul-94	7.5	305	11.4	7.9	380	211	184	0.8	< 0.002	< 1	234	41.7	19.3	7.6	1.0	< 1	17	< 1	257	6.3
EE11/GT1	MWGT-1	23.9	02-May-94	8.6	294	10.9	8.4	284	144	98	4.3	< 0.002	< 1	150	15.3	14.6	21.0	0.6	6	8	< 1	176	5.1
	MWGT-1		14-Jul-94	8.5	210	13.6	8.4	285	139	113	0.9	< 0.002	< 1	164	17.9	16.7	24.5	0.7	< 1	11	< 1	169	5.5
EE11/GT2	MWGT-2	26.5	25-Apr-94	8.6	310	9.8	8.6	312	150	68	6.0	< 0.002	2	170	12.4	8.9	42.2	0.8	5	6	< 1	183	0.8
	MWGT-2		14-Jul-94	8.6	252	14.1	8.5	303	163	170	1.7	NA	< 1	219	49.0	11.6	49.4	1.0	5	5	< 1	199	22.8
1/94	1/94-1	43.1	24-Jan-95	7.8	309	8.8								238	34.1	9.4	10.2	1.7	2.7	30.3	0	301	31.1
	1/94-2	21.5	24-Jan-95	8.0	298	8.5								296	25.7	9.5	16.4	2.4	2.6	31.0	0	420	45.6
	1/94-3	9.7	24-Jan-95	7.7	325									**1422**	709.2	21.7	6.6	2.3	12.4	73.3	0	1192	27.3
	1/94-4	30.8	24-Jan-95	9.6	325	6.5								**1328**	453.0	16.4	115.3	5.4	15.7	22.3	256.2	1393	1.9
2/94	2/94-1	28.8	30-Jan-95	8.4	152	8.1								130	11.4	5.7	39.1	1.5	0.6	11.4	66	122	9.4
	2/94-2	62.7	31-Jan-95		215	8								197	29.9	13.1	26.8	1.8	1	2.9	0	242	3.5
	2/94-3	13.0	30-Jan-95	7.6	262	8								232	46.9	17.4	20.6	1.2	1.2	21	0	248	1.8
	2/94-5A	37.5	30-Jan-95	7.0	1500	5.5								**1423**	10.4	3.0	580.2	57.2	347.9	439.9	504	0	0.2
	2/94-5B	43.2	30-Jan-95	8.3	680	7.1								603	11.7	3.0	227.8	26.6	95.3	203.8	0	87	15.5

CBE **Charge balance error.**

TABLE E2: Duffins watershed groundwater chemistry data summary - minor ions and trace metals. Data from M.M. Dillon Limited, 1990; IWA, 1994 b,c,e; Gerber, unpublished).

			Date	Minor Ions							Trace Metals																
Site Nest	Well No.	mid-scr mbgs		B ug/L	PO4 mg/L	NO3 mg/L	NO2 mg/L	F mg/L	Br mg/L	I mg/L	Al µg/L	V µg/L	Cr µg/L	Mn µg/L	Fe µg/L	Co µg/L	Ni µg/L	Cu µg/L	Zn µg/L	Ba µg/L	Sr µg/L	Cd µg/L	Pb µg/L	As µg/L	Sb µg/L	Mo µg/L	P mg/L
P1-1	P1-1A	1.4	06/14/90	-	<0.05	**20.2**	<0.01	<0.2	<0.05	<0.5	-			<0.01	<0.01					0.050	0.235						<0.05
	P1-1B	4.0	02/07/90	0.02	<0.05	**1.26**	0.02	<0.2	<0.05	-	<0.1			<0.01	<0.01					0.060	0.261						<0.05
	P1-1C	48.4	03/28/90	0.1	0.2	<0.01	<0.02	0.49	0.07	<0.5	0.3			0.01	0.36					0.090	0.210						0.05
	P1-1C	48.4	06/28/90	-	0.23	<0.05	<0.01	0.5	0.06	<0.2	-			0.01	0.53					0.059	0.193						0.07
P1-2	P1-2A	1.9	06/27/90	-	<0.05	**8.9**	<0.01	<0.3	0.15	<0.2				0.04	0.02					0.053	0.332						<0.05
	P1-2B	11.1	02/08/90	0.08	<0.05	<0.01	<0.02	<0.2	<0.05	-	<0.1			<0.01	0.07					0.070	0.530						<0.05
	P1-2B	11.1	07/26/90	0.09	<0.05	0.06	<0.01	0.4	<0.05	-	<0.1			<0.01	0.14					0.063	0.495						<0.05
	P1-2C	14.7	06/27/90			0.43	0.6	1.1																			
	P1-2C	14.7	06/27/90			0.44	0.6	1.1																			
P1-3	P1-3A	3.0	06/17/90	-	<0.05	2.3	<0.01	<0.2	0.05	<0.5				<0.01	0.01					0.055	0.338						<0.05
	P1-3B	12.6	02/07/90	0.02	<0.05	<0.01	<0.02	0.1	<0.05	-	<0.1			0.04	0.51					0.050	0.233						<0.05
	P1-3B	12.6	02/07/90	0.01	<0.05	<0.01	<0.02	<0.2	<0.05	-	<0.1			0.04	0.61					0.040	0.214						<0.05
	P1-3B	12.6	06/12/90	-	<0.05	<0.05	<0.01	<0.2	<0.05	<0.5				0.04	0.58					0.045	0.225						<0.05
	P1-3C	29.2	06/18/90	-	1.2	0.29	<0.01	0.8	0.16	0.5	-			0.01	0.64					0.038	0.456						0.43
	P1-3C	29.2	06/28/90	-	1.1	0.27	<0.01	0.9	0.21	0.6	-			<0.01	0.06					0.026	0.406						0.37
P1-4	P1-4A	4.5	06/27/90	-	<0.05	<0.05	<0.01	0.6	0.1	<0.2				0.02	0.03					0.054	0.438						<0.05
	P1-4B	40.7	06/27/90	-	0.29	<0.05	<0.05	1.3	1.8	0.7	-			0.02	0.08					0.009	0.150						0.97
	P1-4B	40.7	05/27/93	-	<0.1	<0.02	<0.02	0.6	0.58	0.07				0.009	0.49					0.037	0.240						-
P1-5	P1-5A	4.1	06/17/90	-	<0.05	0.22	<0.5	<0.1	1.3	<0.5				0.05	0.02					0.435	1.220						<0.05
	P1-5B	10.1	06/14/90	-	<0.05	<0.05	<0.01	0.2	<0.05	<0.5				0.01	0.39					0.131	0.277						<0.05
	P1-5C	30.7	03/28/90	-	0.34	<0.01	<0.02	0.97	0.16	<0.5	0.3			<0.01	0.32					0.040	0.274						0.1
P1-6	P1-6A	6.0	06/14/90	-	<0.05	<0.05	<0.01	<0.2	<0.05	<0.5				0.03	0.02					0.066	0.233						<0.05
	P1-6B	16.0	02/08/90	0.01	<0.05	<0.01	<0.02	<0.2	<0.05	-				0.05	0.25					0.060	0.274						<0.05
	P1-6B	16.0	06/11/90	-	<0.05	0.17	<0.01	<0.2	<0.05	<0.5				0.05	0.4					0.058	0.270						<0.05
P1-7	P1-7A	4.6	06/28/90	-	0.14	0.41	<0.01	0.4	0.14	<0.2				<0.01	0.02					0.093	0.744						0.05
	P1-7B	12.5	06/28/90	-	<0.05	0.11	<0.01	0.6	0.36	<0.2	-			<0.01	0.02					0.036	0.617						<0.05
P1-8	P1-8A	5.6	06/12/90	-	<0.05	<0.05	<0.01	0.3	<0.05	<0.5				0.04	0.09					0.095	0.438						<0.05
	P1-8B	13.1	02/07/90	0.02	<0.05	<0.01	<0.02	0.2	<0.05	-				<0.01	0.43					0.120	0.402						<0.05
	P1-8B	13.1	06/12/90	-	<0.05	<0.05	<0.01	0.3	<0.05	<0.5				<0.01	0.46					0.139	0.440						<0.05
P1-9	P1-9A	5.4	06/12/90	-	<0.05	<0.05	<0.01	0.4	0.07	<0.5				0.02	0.03					0.047	0.350						<0.05
	P1-9B	11.2	06/19/90	-	<0.05	0.11	<0.01	3.5	0.08	<0.5				<0.01	0.18					0.018	0.229						<0.05
P1-10	P1-10A	17.7	06/14/90	-	<0.05	<0.05	<0.01	0.3	<0.05	<0.5				0.02	0.56					0.111	0.530						<0.05
P1-11	P1-11A	15.1	06/28/90	-	<0.05	<0.05	<0.01	0.3	<0.05	<0.2				0.01	0.18					0.083	0.449						<0.05
P1-12	P1-12A	6.1	06/28/90	-	<0.05	4.5	0.02	<0.2	<0.05	<0.2				0.03	0.1					0.066	0.363						<0.05
	P1-12A	6.1	06/28/90	-	<0.05	3.6	0.04	0.4	0.06	<0.2				0.03	0.14					0.061	0.301						<0.05
P1-13	P1-13A	14.5	06/17/90	-	<0.05	<0.05	<0.01	0.3	<0.05	<0.5				0.01	0.15					0.118	0.368						<0.05
P1-14	P1-14A	3.3	06/11/90	-	<0.05	0.67	<0.01	0.3	0.18	<0.5				0.04	0.02					0.043	0.650						<0.05
	P1-14B	13.4	06/28/90	-	<0.05	1.25	0.04	0.7	0.16	<0.2	-			0.02	0.02					0.058	0.766						<0.05
	P1-14C	29.2	06/22/90	-	1.2	<0.05	0.01	0.6	0.06	<0.2				<0.01	0.04					0.014	0.119						0.42
P1-15	P1-15A	13.6	06/27/90	-	0.14	<0.05	<0.01	0.7	0.07	<0.2				<0.01	0.12					0.013	0.075						<0.05
P1-16	P1-16A	7.9	06/12/90	-	<0.05	0.92	<0.01	0.3	<0.05	<0.5				0.02	0.11					0.083	0.292						<0.05
	P1-16A	7.9	05/18/93	-	<0.1	0.06	<0.02	0.11	<0.05	0.001				0.016	<0.01					0.091	0.290						-
	P1-16B	24.0	06/19/90	-	11	0.06	<0.01	1	0.12	<0.5	-			<0.01	0.51					0.032	0.285						2.59
	P1-16C	42.5	03/28/90	-	0.6	<0.01	<0.02	0.86	0.37	<0.50				0.060	3.76					0.080	0.100						
	P1-16C	42.5	06/21/90	-	0.7	<0.05	<0.01	0.9	0.68	0.200				<0.010	0.14					0.015	0.079						0.23
	P1-16C	42.5	05/18/93		0.3	<0.02	<0.02	0.54	0.25	0.130				0.016	0.62					0.046	0.180						
	P1-16C	42.5	05/18/93																								
	P1-16C	42.5	05/18/93																								
	P1-16D	57.0	07/05/90	-	0.2	<0.05	<0.01	0.6	0.2	<0.2				0.04	0.04					0.090	0.350						0.07
P1-17	P1-17A	11.8	06/25/90	-	1.9	<0.05	<0.01	0.3	0.06	<0.2				<0.01	0.02					0.103	0.291						0.75
	P1-17B	16.3	06/14/90	-	0.22	<0.05	<0.01	0.4	0.05	<0.5				<0.01	0.03					0.070	0.414						<0.05
	P1-17C	29.1	06/19/90	-	7.2	0.46	<0.01	0.9	0.05	<0.5	-			<0.01	0.11					0.019	0.168						2.14
	P1-17C	29.1	05/27/93		21.0	0.28	<0.02	0.6	0.06	0.018				0.002	0.36					0.028	0.230						
	P1-17C	29.1	05/27/93																								
	P1-17D	52.1	06/25/90	-	1.8	<0.05	<0.01	0.7	0.06	<0.2				0.01	0.19					0.015	0.133						0.56

TABLE E2: Duffins watershed groundwater chemistry data summary - minor ions and trace metals. Data from M.M. Dillon Limited, 1990; IWA, 1994 b,c,e; Gerber, unpublished).

			Date	Minor Ions							Trace Metals																
Site Nest	Well No.	mid-scr mbgs		B ug/L	PO4 mg/L	NO3 mg/L	NO2 mg/L	F mg/L	Br mg/L	I mg/L	Al µg/L	V µg/L	Cr µg/L	Mn µg/L	Fe µg/L	Co µg/L	Ni µg/L	Cu µg/L	Zn µg/L	Ba µg/L	Sr µg/L	Cd µg/L	Pb µg/L	As µg/L	Sb µg/L	Mo µg/L	P mg/L
	P1-17E	75.6	07/05/90	-	<0.05	<0.05	<0.01	0.5	0.08	<0.2				0.33	0.02					0.121	0.316						<0.05
P1-18	P1-18A	9.9	06/14/90	-	<0.05	<0.05	<0.01	0.3	0.06	<0.5				0.01	0.03					0.103	0.431						<0.05
	P1-18A	9.9	06/21/90	-	<0.05	<0.05	<0.01	0.3	<0.05	<0.5				0.01	0.08					0.087	0.373						<0.05
	P1-18C	38.1	06/22/90	-	6.5	<0.05	<0.01	0.5	0.06	<0.2				0.04	0.31					0.042	0.430						1.91
	P1-18D	50.7	06/27/90	-	6.0	0.13	0.1	1.7	0.27	<0.2				<0.01	0.05					0.017	0.142						2.5
P1-19	P1-19A	8.4	06/20/90	-	0.8	0.24	<0.01	0.5	<0.05	<0.5				0.02	0.04					0.034	0.660						0.3
	P1-19B	4.9	06/20/90	-	<0.05	<0.05	<0.01	0.6	0.09	<0.5				<0.01	0.02					0.027	0.231						<0.05
P1-20	P1-20A	9.1	06/17/90	-	<0.05	<0.05	<0.01	<0.2	<0.05	<0.5				0.02	0.05					0.056	0.249						<0.05
P1-21	P1-21A	29.6	06/19/90	-	4.5	0.23	<0.01	1	0.11	<0.5				0.01	0.77					0.029	0.173						2.38
	P1-21B	55.2	06/19/90	-	0.60	<0.05	<0.01	0.2	0.06	<0.5				0.05	0.31					0.090	0.381						0.26
	P1-21B	55.2	05/18/93		<0.01	<0.02	<0.02	0.14	<0.05	0.003				0.059	0.098					0.094	0.390						
	P1-21B	55.2	05/18/93																								
P1-22	P1-22A	49.4	06/26/90	-	0.40	<0.05	<0.01	0.4	0.07	<0.5				0.02	0.78					0.095	0.329						0.16
	P1-22B	79.5	06/26/90	-	7.0	<2.5	<2	<1	30.5	0.4				0.47	0.04					3.320	11.400						2.96
P1-23	P1-23A	29.3	06/26/90	-	<0.05	<0.05	<0.01	0.7	0.06	0.8				<0.01	0.02					0.055	0.323						<0.05
P1-25	P1-25A	14.4	06/14/90	-	<0.05	<0.05	0.01	0.4	0.06	<0.5				<0.01	0.01					0.057	0.361						<0.05
P1-26	P1-26A	14.9	06/17/90	-	<0.05	<0.05	<0.05	0.2	0.05	<0.5				<0.01	0.01					0.126	0.640						<0.05
	P1-26B	28.5	06/19/90	-	3.8	0.12	<0.01	1	0.06	<0.5				<0.01	0.11					0.019	0.285						1.21
	P1-26C	44.3	06/25/90	-	0.45	<0.05	<0.01	0.3	0.05	<0.2				0.02	0.1					0.111	0.483						0.18
P1-27	P1-27A	10.8	06/21/90	-	<0.05	<0.05	<0.01	0.3	0.05	<0.5				0.02	0.38					0.110	0.386						<0.05
	P1-27B	22.5	06/19/90	-	0.06	<0.05	<0.01	0.8	0.05	<0.5				<0.01	0.07					0.022	0.132						<0.05
	P1-27C	72.1	06/21/90	-	2.3	<0.05	0.02	0.5	0.1	<0.5				0.04	0.58					0.050	0.268						0.69
P1-28	P1-28A	10.7	06/15/90	-	<0.05	<0.05	<0.01	0.4	0.05	<0.5				<0.01	0.04					0.088	0.430						<0.05
P1-29	P1-29A	10.7	06/15/90	-	0.40	<0.05	<0.01	0.4	<0.05	<0.5				0.04	0.22					0.118	0.550						0.25
	P1-29B	54.0	06/20/90	-	<0.05	0.24	0.11	0.9	<0.05	<0.5				0.34	0.02					0.037							0.314
P1-30	P1-30A	13.4	06/20/90	-	<0.05	<0.05	<0.01	0.4	<0.05	<0.5				0.03	0.75					0.095	0.331						<0.05
	P1-30B	58.0	06/20/90	-	0.11	<0.05	<0.01	0.6	<0.05	<0.5				0.04	0.25					0.088	0.342						0.12
P1-32	P1-32A	3.4	07/05/90	-	<0.05	0.24	<0.01	<0.2	0.06	<0.2				<0.01	0.1					0.069	0.227						<0.05
	P1-32B	21.8	07/05/90	-	0.16	0.05	<0.01	0.9	0.13	<0.2				<0.01	0.02					0.021	0.226						0.05
	P1-32C	59.8	07/05/90	-	1	0.24	0.01	1	0.12	<0.2				<0.01	0.02					0.061	0.320						0.4
P1-34	P1-34A	4.3	06/25/90	-	<0.05	**6.1**	<0.05	0.2	0.08	<0.2				0.01	0.02					0.155	0.490						<0.05
	P1-34B	58.4	06/25/90	-	0.06	<0.05	<0.01	0.5	0.23	<0.2				<0.01	0.04					0.015	0.136						<0.05
P1-36	P1-36A	23.3	06/17/90	-	<0.05	<0.05	<0.01	<0.2	<0.05	<0.5				0.02	0.16					0.111	0.310						<0.05
EE4																											
EE4/1	EE4/1A	10.7	05/27/93	29	<0.1	<0.02	<0.02	0.20	<0.05	3	250	<2	2	13	60	<1	<2	<2	11	180	390	<0.5	0.1	<2	4	2	
	EE4/1B	25.6	05/06/93	25	<0.1	0.02	<0.02	0.16	<0.05	3	18	<2	<2	9	<10	<1	<2	<2	3	130	390	<0.5	<0.1	3	9	<2	
	EE4/1C	49.1	05/06/93	10	<0.1	<0.02	<0.02	0.20	<0.05	1	66	<2	<2	21	74	<1	<2	<2	5	120	200	<0.5	0.1	<2	3	<2	
EE4/2	EE4/2A	7.6	05/05/93	7	<0.1	0.13	<0.02	<0.1	<0.05	<1	17	<2	<2	11	40	<1	<2	<2	10	21	200	<0.5	<0.1	<2	2	<2	
	EE4/2B	24.0	05/05/93	7	<0.1	**4.54**	<0.02	<0.1	<0.05	1	54	<2	<2	16	50	<1	<2	<2	21	62	220	<0.5	<0.1	<2	2	<2	
EE4/3	EE4/3A	10.8	05/27/93	10	<0.1	<0.02	<0.02	0.10	<0.05	<1	52	<2	2	20	<10	1	2	<2	8	85	270	<0.5	<0.1	<2	3	2	
	EE4/3B	34.2	05/10/93	9	<0.1	<0.02	<0.02	0.11	0.05	1	33	<2	<2	17	300	<1	<2	<2	3	190	230	<0.5	<0.1	<2	11	<2	
	EE4/3C	55.1	05/10/93	35	<0.1	<0.02	<0.02	0.52	0.12	3	18	<2	<2	93	<10	<1	4	<2	24	72	280	<0.5	0.6	<2	2	5	
EE4/4	EE4/4B	34.9	05/04/93	14	<0.1	<0.02	<0.02	0.10	<0.05	2	56	<2	<2	24	230	<1	<2	<2	14	140	250	<0.5	0.1	<2	2	2	
	EE4/4C	59.2	05/04/93	15	<0.1	0.02	<0.20	<0.10	<0.05	3	<5	<2	<2	30	700	<1	<2	<2	15	170	340	<0.5	0.1	<2	2	<2	
EE4/5	EE4/5B	19.0	05/27/93	15	1.4	0.20	<0.02	0.10	<0.05	2	31	2	2	28	<10	1	5	5	28	46	320	<0.5	0.3	<2	6	<2	
	EE4/5C	46.8	05/26/93	11	<0.1	0.04	<0.02	<0.10	<0.05	<1	8	<2	<2	32	97	1	2	<2	<2	91	230	<0.5	<0.1	<2	3	<2	
EE10																											
EE10/1	EE10/1A	9.8	05/26/93	200	<0.1	<0.02	<0.02	0.60	<0.05	5	**160**	<2	<2	3	78	<1	<2	<2	12	27	210	<0.5	0.2	3	3	3	
	EE10/1B	19.8	05/27/93	250	23.0	0.02	<0.02	0.40	0.09	28	**140**	7	2	16	37	1	5	4	19	63	580	<0.5	0.4	13	9	29	
	EE10/1C	48.8	05/05/93	14	<0.1	<0.02	<0.02	<0.1	<0.05	1	82	<2	<2	30	1200	<1	<2	<2	16	110	250	<0.5	0.1	<2	<2	<2	
EE10/2	EE10/2A	10.7	05/18/93	39	<0.1	<0.02	<0.02	0.18	<0.05	3	32	<2	<2	10	<10	<1	<2	<2	11	120	520	<0.5	<0.1	<2	2	2	
	EE10/2B	19.8	05/27/93	250	5.1	0.12	<0.02	0.50	0.08	27	**170**	8	2	8	69	<1	6	4	36	47	550	<0.5	0.6	7	7	25	
	EE10/2C	36.7	05/27/93	31	<0.1	<0.02	<0.02	0.20	<0.05	2	15	<2	<2	15	<10	<1	<2	<2	11	85	320	<0.5	<0.1	3	7	2	

TABLE E2: Duffins watershed groundwater chemistry data summary - minor ions and trace metals. Data from M.M. Dillon Limited, 1990; IWA, 1994 b,c,e; Gerber, unpublished).

			Date	Minor Ions							Trace Metals																
Site Nest	**Well No.**	**mid-scr mbgs**		**B ug/L**	**PO4 mg/L**	**NO3 mg/L**	**NO2 mg/L**	**F mg/L**	**Br mg/L**	**I mg/L**	**Al µg/L**	**V µg/L**	**Cr µg/L**	**Mn µg/L**	**Fe µg/L**	**Co µg/L**	**Ni µg/L**	**Cu µg/L**	**Zn µg/L**	**Ba µg/L**	**Sr µg/L**	**Cd µg/L**	**Pb µg/L**	**As µg/L**	**Sb µg/L**	**Mo µg/L**	**P mg/L**
EE10/3	EE10/3A	10.4	05/12/93	45	<0.1	<0.02	<0.02	0.29	<0.05	2	42	<2	<2	9	39	<1	<2	<2	11	110	700	<0.5	0.1	2	5	<2	
EE10/4	EE10/4B	36.0	05/18/93	78	3.2	**3.40**	0.34	0.26	0.05	9	26	4	<2	30	<10	<1	2	<2	<2	71	1000	<0.5	0.1	6	6	2	
	EE10/4C	57.9	05/13/93	32	<0.1	<0.02	<0.02	0.18	<0.05	2	61	<2	<2	16	31	<1	<2	<2	<2	52	330	<0.5	0.1	5	2	<2	
EE10/5	EE10/5B		05/23/93	53	<0.1	<0.02	<0.02	0.21	<0.05	1	120	<2	<2	8	62	<1	<2	<2	25	110	500	<0.5	0.1	2	3	<2	
	EE10/5C	30.8	05/23/93	15	<0.1	<0.02	<0.02	<0.10	<0.05	<1	77	<2	<2	10	27	<1	2	2	6	63	330	<0.5	<0.1	<2	23	<2	
EE11																											
EE11/1	MW1A	3.0	19-Apr-94	34	< 0.01		< 0.01	0.1	0.18	0.005	7	< 2	3	53	< 10	1	3	2	3	72	420	3.3	0.2	< 2	3	< 2	
	MW1A	3.0	21-Jul-94	7	< 0.01		< 0.01	0.1	0.10	NA	10	2	< 2	39	30	< 0.4	< 2	2	4	210	550	< 0.2	0.2	2	4	< 2	
	MW1B	16.2	19-Apr-94	120	< 0.01		< 0.01	0.9	0.50	0.120	**170**	6	2	19	120	< 1	9	8	2	61	350	1.6	0.2	< 2	8	10	
	MW1B	16.2	21-Jul-94	170	< 0.01		< 0.01	0.8	0.16	NA	13	2	< 2	12	< 10	< 0.4	6	4	< 2	66	430	< 0.2	0.7	< 2	8	24	
	MW1C	39.8	20-Apr-94	41	0.36		< 0.01	< 0.1	0.08	0.005	16	< 2	< 2	24	30	< 1	< 2	< 2	3	140	420	< 0.2	< 0.1	5	< 2	3	
	MW1C-DUP	39.8	20-Apr-94	42	0.17		< 0.01	< 0.1	0.10	NA	20	< 2	< 2	25	30	< 1	< 2	170	90	140	420	< 0.2	28.0	5	< 2	3	
	MW1C	39.8	21-Jul-94	43	0.36		< 0.01	< 0.1	0.06	NA	87	< 2	< 2	28	110	< 0.4	3	< 2	3	180	490	< 0.2	0.3	7	3	2	
	MW1D	46.4	19-Apr-94	69	< 0.01		< 0.01	0.1	0.24	< 0.005	63	< 2	< 2	13	47	< 1	< 2	35	18	220	600	0.2	7.5	4	4	3	
	MW1D	46.4	21-Jul-94	100	0.02		0.01	0.1	0.20	NA	23	< 2	< 2	10	20	< 0.4	< 2	< 2	< 2	260	680	< 0.2	0.3	7	4	2	
	MW1E	57.3	19-Apr-94	61	0.07		< 0.01	0.3	0.30	0.040	50	< 2	< 2	28	120	< 1	< 2	< 2	2	130	470	0.2	< 0.1	< 2	2	< 2	
	MW1E	57.3	21-Jul-94	64	0.05		< 0.01	0.1	0.13	NA	50	< 2	9	27	100	< 0.4	< 2	< 2	< 2	140	480	< 0.2	< 0.1	< 2	2	< 2	
	MW1F	71.0	19-Apr-94	1300	0.07		< 0.01	1.1	1.20	0.070	**240**	2	< 2	66	360	< 1	< 2	< 2	3	500	690	0.8	0.1	< 2	< 2	< 2	
	MW1F	71.0	21-Jul-94	1500	0.08		< 0.01	0.7	2.40	NA	30	4	< 2	63	30	< 0.4	< 2	< 2	5	560	730	< 0.2	0.1	2	7	< 2	
EE11/2	MW2A	3.2	27-Apr-94	10	< 0.01		< 0.01	0.1	0.03	NA	17	< 2	2	< 2	20	< 1	< 2	< 2	4	46	170	85.3	0.1	< 2	4	10	
	MW2A	3.2	19-Jul-94	35	< 0.01		< 0.01	< 0.1	0.83	NA	9	< 2	< 2	22	10	< 0.4	< 2	4	2	71	310	< 0.2	< 0.1	< 2	7	10	
	MW2B	15.6	28-Apr-94	160	0.42		< 0.01	0.7	0.03	< 0.005	25	6	< 2	< 2	30	< 1	2	3	9	39	310	12.0	0.3	2	5	3	
	MW2B	15.6	20-Jul-94	150	0.31		< 0.01	0.6	0.20	NA	**690**	4	2	11	630	1	< 2	4	5	47	320	< 0.2	0.4	2	4	3	
	MW2C	32.3	26-Apr-94	56	< 0.01		< 0.01	0.2	0.03	< 0.005	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
	MW2C	32.3	19-Jul-94	56	0.03		< 0.01	< 0.1	0.10	NA	48	2	< 2	10	50	< 0.4	< 2	< 2	< 2	200	460	< 0.2	< 0.1	2	12	3	
	MW2D	60.1	26-Apr-94	70	< 0.01		< 0.01	0.1	0.08	0.005	15	< 2	2	19	150	< 1	< 2	< 2	5	180	480	32.3	0.1	< 2	2	< 2	
	MW2D	60.1	19-Jul-94	75	0.05		< 0.01	0.5	0.13	NA	9	< 2	< 2	22	620	< 0.4	< 2	2	< 2	200	490	< 0.2	< 0.1	< 2	2	< 2	
EE11/3	MW3A	8.2	26-Apr-94	23	< 0.01		< 0.01	0.1	0.03	NA	23	< 2	2	7	25	< 1	2	< 2	5	160	440	47.6	0.2	< 2	4	2	
	MW3A	8.2	19-Jul-94	27	< 0.01		< 0.01	< 0.1	0.07	NA	10	< 2	< 2	4	< 10	< 0.4	< 2	2	3	160	460	< 0.2	0.1	< 2	3	< 2	
	MW3B	15.9	02-May-94	200	< 0.01		< 0.01	0.9	0.06	0.010	66	2	< 2	6	55	< 1	5	5	9	64	490	17.9	0.6	< 2	7	32	
	MW3B	15.9	20-Jul-94	190	< 0.01		< 0.01	0.2	0.21	NA	20	< 2	< 2	13	13	< 0.4	8	4	3	88	670	< 0.2	0.2	< 2	5	28	
	MW3C	23.0	26-Apr-94	47	< 0.01		< 0.01	0.1	0.03	< 0.005	41	< 2	2	8	45	< 1	2	< 2	9	95	< 5	22.4	0.2	< 2	2	< 2	
	MW3C	23.0	19-Jul-94	43	0.05		< 0.01	< 0.1	0.10	NA	50	< 2	< 2	9	50	< 0.4	< 2	< 2	6	87	520	< 0.2	< 0.1	< 2	2	2	
	MW3D	50.6	26-Apr-94	57	< 0.01		< 0.01	< 0.1	0.07	0.005	40	< 2	< 2	8	60	< 1	< 2	< 2	5	150	440	33.3	0.2	< 2	2	< 2	
	MW3D	50.6	19-Jul-94	60	0.06		< 0.01	< 0.1	0.10	NA	67	< 2	< 2	10	270	< 0.4	< 2	< 2	2	140	430	< 0.2	< 0.1	< 2	2	< 2	
	MW3E	57.9	26-Apr-94	68	< 0.01		< 0.01	0.1	0.08	0.005	**180**	< 2	< 2	18	160	< 1	< 2	< 2	8	180	420	31.9	0.3	2	2	2	
	MW3E	57.9	19-Jul-94	83	0.06		< 0.01	0.5	0.08	NA	30	< 2	< 2	16	90	< 0.4	< 2	< 2	< 2	170	410	< 0.2	< 0.1	< 2	5	< 2	
EE11/4	MW4A	3.4	21-Apr-94	5	< 0.01		< 0.01	0.4	0.08	NA	7	< 2	2	4	38	< 1	2	< 2	2	55	230	< 0.2	0.1	< 2	3	< 2	
	MW4A	3.4	28-Apr-94	6	< 0.01		< 0.01	< 0.1	0.05	NA	42	< 2	2	< 2	55	< 1	2	< 2	8	49	220	129.0	0.3	< 2	5	< 2	
	MW4A	3.4	04-May-94	8	< 0.01		< 0.01	0.1	0.03	< 0.005	17	< 2	< 2	< 2	25	< 1	< 2	< 2	5	53	220	100.0	0.1	< 2	5	< 2	
	MW4A	3.4	15-Jul-94	11	< 0.01		< 0.01	< 0.1	0.09	NA	< 5	< 2	2	2	15	< 0.4	< 2	2	3	56	200	< 0.2	< 0.1	< 2	2	< 2	
	MW4B	15.9	21-Apr-94	120	0.02		< 0.01	0.7	0.08	< 0.005	**460**	< 2	2	5	320	< 1	< 2	< 2	< 2	22	190	< 0.2	0.2	2	3	2	
	MW4B	15.9	27-Apr-94	120	< 0.01		< 0.01	0.3	0.03	< 0.005	73	< 2	2	< 2	50	< 1	< 2	< 2	6	21	200	7.8	0.2	2	3	2	
	MW4B	15.9	15-Jul-94	130	0.03		< 0.01	0.3	0.07	NA	**650**	2	< 2	20	640	< 0.4	< 2	2	3	32	200	< 0.2	0.7	2	2	2	
	MW4C	37.3	21-Apr-94	64	0.06		< 0.01	0.4	0.08	< 0.005	160	< 2	< 2	30	130	< 1	< 2	< 2	< 2	110	600	< 0.2	0.2	< 2	3	< 2	
	MW4C	37.3	27-Apr-94	61	< 0.01		< 0.01	0.2	0.05	< 0.005	100	< 2	< 2	26	100	< 1	< 2	< 2	5	120	600	24.2	0.2	< 2	2	< 2	
	MW4C	37.3	15-Jul-94	67	0.04		< 0.01	< 0.1	0.08	NA	11	< 2	< 2	25	42	< 0.4	3	< 2	4	110	68	< 0.2	< 0.1	< 2	2	< 2	
	MW4D	50.6	21-Apr-94	88	0.05		< 0.01	0.4	0.05	0.005	6	< 2	< 2	17	260	< 1	< 2	< 2	2	210	510	< 0.2	0.2	< 2	< 2	< 2	
	MW4D-DUP	50.6	21-Apr-94	88	0.05		< 0.01	0.3	0.07	0.005	5	< 2	< 2	18	260	< 1	< 2	< 2	2	210	500	< 0.2	0.1	< 2	< 2	< 2	
	MW4D	50.6	28-Apr-94	83	0.05		< 0.01	0.2	0.07	< 0.005	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
	MW4D-DUP	50.6	28-Apr-94	80	0.05		< 0.01	0.2	0.07	< 0.005	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
	MW4D	50.6	02-May-94	80	< 0.01		< 0.01	0.2	0.07	< 0.005	15	< 2	< 2	16	95	< 1	< 2	< 2	5	200	510	29.9	0.2	< 2	< 2	< 2	
	MW4D-DUP	50.6	02-May-94	76	< 0.01		< 0.01	0.1	0.07	< 0.005	13	< 2	< 2	16	150	< 1	< 2	< 2	5	200	490	28.0	0.2	< 2	< 2	< 2	
	MW4D	50.6	15-Jul-94	92	0.03		< 0.01	< 0.1	0.08	NA	< 5	< 2	< 2	15	170	< 0.4	< 2	< 2	4	210	540	< 0.2	< 0.1	< 2	2	< 2	

TABLE E2: Duffins watershed groundwater chemistry data summary - minor ions and trace metals. Data from M.M. Dillon Limited, 1990; IWA, 1994 b,c,e; Gerber, unpublished).

Site	Well	mid-scr	Date	Minor Ions							Trace Metals																
				B	PO4	NO3	NO2	F	Br	I	Al	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ba	Sr	Cd	Pb	As	Sb	Mo	P
Nest	No.	mbgs		ug/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L
	MW4D-DUP	50.6	15-Jul-94	82	0.03		< 0.01	< 0.1	0.09	NA	14	< 2	< 2	15	190	< 0.4	5	< 2	7	200	520	< 0.2	< 0.1	< 2	2	< 2	
EE11/5	MW5A	4.6	22-Apr-94	11	< 0.01		< 0.01	< 0.1	0.25	NA	85	< 2	< 2	15	100	< 1	2	2	2	34	280	< 0.2	0.2	< 2	2	< 2	
	MW5A	4.6	15-Jul-94	28	< 0.01		< 0.01	0.2	0.37	NA	**360**	< 2	2	38	610	< 0.4	< 2	3	35	93	710	< 0.2	0.7	< 2	11	< 2	
	MW5B	12.3	26-Apr-94	110	< 0.01		< 0.01	0.3	0.08	0.005	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
	MW5B	12.3	15-Jul-94	150	< 0.01		< 0.01	0.3	0.15	NA	50	< 2	< 2	12	66	< 0.4	< 2	2	30	110	960	< 0.2	0.1	< 2	3	3	
	MW5C	21.1	22-Apr-94	77	< 0.01		< 0.01	0.2	0.10	< 0.005	**110**	< 2	< 2	18	290	< 1	< 2	< 2	< 2	120	610	< 0.2	0.2	< 2	< 2	< 2	
	MW5C	21.1	15-Jul-94	110	0.05		< 0.01	0.2	0.32	NA	**230**	< 2	< 2	41	690	< 0.4	< 2	< 2	9	180	700	< 0.2	0.4	< 2	5	< 2	
EE11/6	MW6A	3.7	20-Apr-94	28	< 0.01		< 0.01	0.1	0.08	< 0.005	< 5	< 2	< 2	11	< 10	< 1	2	< 2	< 2	110	520	< 0.2	< 0.1	< 2	3	5	
	MW6A	3.7	19-Jul-94	40	< 0.01		< 0.01	0.2	0.28	NA	7	< 2	< 2	12	10	< 0.4	< 2	2	< 2	110	550	< 0.2	< 0.1	< 2	5	6	
	MW6B	21.9	02-May-94	120	< 0.01		< 0.01	1.5	0.10	0.040	64	< 2	< 2	21	28	< 1	5	5	9	39	330	27.7	4.6	< 2	5	45	
	MW6B	21.9	19-Jul-94	150	0.01		< 0.01	0.6	0.23	NA	10	< 2	< 2	20	10	< 0.4	10	2	< 2	38	400	0.2	0.1	< 2	5	69	
	MW6C	45.5	20-Apr-94	63	< 0.01		< 0.01	0.1	0.46	0.010	**1700**	3	3	30	1500	1	2	4	7	170	520	< 0.2	0.6	2	5	4	
	MW6C	45.5	16-Jul-94	66	0.06		< 0.01	0.2	0.13	NA	**270**	< 2	< 2	10	290	< 0.4	< 2	2	6	160	530	< 0.2	0.3	2	4	3	
EE11/7	MW7A	4.0	20-Apr-94	11	< 0.01		< 0.01	< 0.1	0.07	0.005	15	< 2	< 2	29	< 10	1	2	< 2	3	53	260	< 0.2	< 0.1	< 2	3	3	
	MW7A	4.0	16-Jul-94	9	< 0.01		< 0.01	< 0.1	0.12	NA	< 5	< 2	< 2	10	16	< 0.4	< 2	< 2	6	59	240	< 0.2	< 0.1	< 2	2	2	
	MW7B	42.2	20-Apr-94	43	< 0.01		< 0.01	< 0.1	0.15	0.005	**15000**	25	18	390	16000	8	22	21	54	300	560	0.2	17.0	5	2	8	
	MW7B	42.2	16-Jul-94	26	0.03		< 0.01	0.2	0.15	NA	**1500**	3	3	86	2600	1	5	3	19	210	440	< 0.2	4.9	< 2	2	4	
	MW7C	18.1	20-Apr-94	37	< 0.01		< 0.01	< 0.1	0.08	0.005	95	< 2	< 2	36	120	< 1	3	< 2	2	210	450	< 0.2	< 0.1	< 2	2	3	
	MW7C	18.1	16-Jul-94	41	< 0.01		< 0.01	0.2	0.12	NA	64	< 2	< 2	16	65	< 0.4	< 2	2	5	220	450	< 0.2	0.1	< 2	3	< 2	
EE11/8	MW8A	7.6	03-May-94	19	< 0.01		< 0.01	< 0.1	0.03	NA	33	< 2	< 2	< 2	26	< 1	< 2	< 2	5	24	260	99.2	0.2	< 2	5	< 2	
	MW8A	7.6	18-Jul-94	17	< 0.01		< 0.01	0.2	0.03	NA	< 5	< 2	< 2	2	< 10	< 0.4	< 2	2	3	23	270	< 0.2	< 0.1	< 2	2	< 2	
	MW8B	20.3	03-May-94	720	< 0.01		< 0.01	0.8	0.09	0.010	20	< 2	< 2	21	25	< 1	5	8	9	80	740	30.4	0.3	< 2	8	26	
	MW8B	20.3	20-Jul-94	680	0.07		< 0.01	0.3	0.23	NA	80	< 2	< 2	74	71	< 0.4	5	5	3	77	870	< 0.2	0.2	< 2	5	46	
	MW8C	33.1	04-May-94	81	< 0.01		< 0.01	0.7	0.07	< 0.005	40	< 2	< 2	96	55	< 1	3	< 2	5	39	350	33.6	0.2	< 2	6	7	
	MW8C-DUP	33.1	04-May-94	85	< 0.01		< 0.01	0.8	0.06	< 0.005	52	< 2	< 2	100	65	< 1	3	< 2	5	41	370	33.2	0.2	< 2	4	8	
	MW8C	33.1	14-Jul-94	83	< 0.01		< 0.01	0.6	0.10	NA	10	< 2	< 2	55	18	< 0.4	< 2	< 2	3	36	290	< 0.2	0.1	< 2	3	7	
	MW8D-DUP	60.5	19-Jul-94	49	< 0.01		< 0.01	< 0.1	0.05	< 0.005	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
	MW8D	60.5	03-May-94	43	0.01		< 0.01	< 0.1	0.18	NA	20	< 2	< 2	17	20	< 0.4	< 2	< 2	< 2	260	450	< 0.2	< 0.1	< 2	5	2	
	MW8D	60.5	19-Jul-94	43	0.01		< 0.01	< 0.1	0.15	NA	20	< 2	< 2	18	20	< 0.4	< 2	< 2	2	260	450	< 0.2	< 0.1	< 2	5	< 2	
EE11/9	MW9A	3.7	29-Apr-94	23	< 0.01		< 0.01	0.2	0.05	NA	16	< 2	< 2	< 2	150	< 1	3	< 2	4	46	430	68.8	0.2	< 2	5	17	
	MW9A	3.7	03-May-94	25	< 0.01		< 0.01	0.2	0.06	< 0.005	15	6	< 2	4	120	< 1	3	< 2	3	56	450	73.8	0.2	< 2	5	16	
	MW9A	3.7	15-Jul-94	NA	< 0.01		0.02	0.3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
	MW9A	3.7	16-Jul-94	37	NA		NA	NA	0.33	NA	< 5	< 2	< 2	31	140	< 0.4	2	< 2	29	57	480	< 0.2	< 0.1	< 2	7	27	
	MW9B	10.2	29-Apr-94	45	< 0.01		< 0.01	0.4	0.03	< 0.005	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
	MW9B	10.2	03-May-94	47	< 0.01		< 0.01	0.4	0.03	< 0.005	51	< 2	< 2	3	60	< 1	< 2	< 2	5	130	920	16.3	0.2	< 2	3	5	
	MW9B	10.2	15-Jul-94	86	< 0.01		< 0.01	0.4	0.06	NA	38	< 2	< 2	6	47	< 0.4	< 2	2	2	230	1900	< 0.2	0.1	< 2	4	14	
	MW9C	51.6	29-Apr-94	53	< 0.01		< 0.01	0.3	0.05	< 0.005	**230**	< 2	< 2	17	220	< 1	< 2	< 2	5	170	370	23.9	0.4	4	4	4	
	MW9C	51.6	03-May-94	55	< 0.01		< 0.01	0.2	0.03	< 0.005	85	< 2	< 2	18	80	< 1	< 2	< 2	5	160	360	24.8	0.2	5	3	3	
	MW9C	51.6	16-Jul-94	58	0.02		< 0.01	0.1	0.12	NA	32	< 2	< 2	15	27	< 0.4	< 2	< 2	< 2	160	320	< 0.2	0.1	5	3	4	
EE11/10	MW10A	4.1	22-Apr-94	15	< 0.01		< 0.01	< 0.1	0.03	NA	< 5	< 2	< 2	49	890	1	3	< 2	5	84	380	< 0.2	< 0.1	< 2	3	2	
	MW10A	4.1	15-Jul-94	19	< 0.01		< 0.01	< 0.1	0.20	NA	44	< 2	2	48	340	1	4	2	12	100	430	< 0.2	0.3	< 2	3	3	
	MW10A	4.1	20-Jul-94	NA	< 0.01		< 0.01	< 0.1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
EE11/11	MW11A	20.2	19-Jul-94	56	< 0.01		< 0.01	0.2	0.02	< 0.005	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
	MW11A	20.2	28-Apr-94	42	< 0.01		< 0.01	< 0.1	0.05	NA	40	< 2	< 2	48	50	< 0.4	< 2	< 2	2	90	430	< 0.2	0.1	< 2	< 2	< 2	
	MW11B	44.0	28-Apr-94	110	< 0.01		< 0.01	0.2	0.03	< 0.005	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
	MW11B	44.0	19-Jul-94	100	0.02		< 0.01	< 0.1	0.12	NA	31	< 2	< 2	12	35	< 0.4	< 2	< 2	< 2	140	440	< 0.2	0.1	3	2	5	
EE11/12	MW12A	4.3	22-Apr-94	23	< 0.01		< 0.01	0.1	0.05	NA	20	< 2	< 2	30	28	< 1	3	< 2	2	52	210	< 0.2	0.1	< 2	2	23	
	MW12A	4.3	15-Jul-94	26	< 0.01		< 0.01	0.2	0.35	NA	15	< 2	< 2	29	19	< 0.4	6	2	11	51	230	< 0.2	0.1	< 2	5	24	
	MW12B	11.7	22-Apr-94	86	< 0.01		< 0.01	0.1	0.06	< 0.005	40	< 2	< 2	11	39	< 1	2	< 2	2	100	280	< 0.2	< 0.1	< 2	3	2	
	MW12B		15-Jul-94	42	< 0.01		< 0.01	0.2	0.07	NA	13	< 2	< 2	9	49	< 0.4	4	< 2	3	110	280	< 0.2	< 0.1	< 2	5	2	
	MW12C	29.0	29-Apr-94	160	< 0.01		< 0.01	0.9	0.31	0.010	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
	MW12C		04-May-94	360	< 0.01		< 0.01	1.2	0.13	0.010	**31000**	15	25	350	18000	5	21	26	370	430	470	84.3	66.0	15	< 2	28	
	MW12C		20-Jul-94	440	0.21		0.02	0.3	0.24	NA	**33000**	28	34	420	18000	10	44	70	200	380	710	0.5	54.0	13	< 2	10	
	MW12D	42.2	26-Apr-94	90	< 0.01		< 0.01	0.2	0.08	NA	50	2	2	7	40	< 1	2	2	5	110	420	16.0	0.2	4	8	5	
	MW12D		15-Jul-94	81	0.06		< 0.01	0.2	0.17	NA	180	< 2	< 2	15	210	< 0.4	< 2	4	55	98	43	< 0.2	0.7	3	4	4	

TABLE E2: Duffins watershed groundwater chemistry data summary - minor ions and trace metals. Data from M.M. Dillon Limited, 1990; IWA, 1994 b,c,e; Gerber, unpublished).

			Date	Minor Ions							Trace Metals																
Site	Well	mid-scr		B	PO4	NO3	NO2	F	Br	I	Al	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ba	Sr	Cd	Pb	As	Sb	Mo	P
Nest	No.	mbgs		ug/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L
EE11/13	MW13A	5.8	21-Apr-94	28	< 0.01		< 0.01	0.5	0.06	NA	< 5	< 2	2	2	50	< 1	6	2	3	66	450	< 0.2	0.1	< 2	3	< 2	
	MW13A		26-Apr-94	27	< 0.01		< 0.01	< 0.1	0.05	NA	15	4	2	< 2	40	< 1	4	< 2	35	65	460	211.0	0.2	3	4	< 2	
	MW13A-DUP		04-May-94	31	< 0.01		< 0.01	0.1	0.06	NA	15	3	< 2	< 2	40	< 1	3	< 2	5	71	500	211.0	0.1	2	4	< 2	
	MW13A		15-Jul-94	21	< 0.01		< 0.01	< 0.1	0.18	NA	12	< 2	< 2	2	< 10	< 0.4	< 2	4	3	47	270	< 0.2	0.1	< 2	2	< 2	
	MW13A		20-Jul-94	NA	< 0.01		< 0.01	< 0.1	NA	NA																	
	MW13B	21.7	21-Apr-94	430	0.05		< 0.01	0.8	0.04	NA	32	< 2	< 2	15	30	< 1	< 2	< 2	< 2	92	490	< 0.2	0.1	2	3	3	
	MW13B		26-Apr-94	360	< 0.01		< 0.01	0.2	0.05	NA	31	6	2	10	35	< 1	< 2	< 2	3	93	540	18.2	0.2	2	4	3	
	MW13B		15-Jul-94	260	0.06		< 0.01	0.1	0.09	NA	27	< 2	< 2	13	40	< 0.4	< 2	< 2	< 2	83	480	< 0.2	0.1	2	< 2	3	
	MW13B-DUP		15-Jul-94	270	0.06		< 0.01	0.1	0.10	NA	34	< 2	2	13	40	< 0.4	< 2	< 2	< 2	88	520	< 0.2	0.1	2	< 2	4	
	MW13B		20-Jul-94	NA	0.05		< 0.01	< 0.1	NA	NA																	
	MW13B-DUP		20-Jul-94	NA	0.05		< 0.01	< 0.1	NA	NA																	
EE11/14	MW14A	4.6	21-Apr-94	9	< 0.01		< 0.01	0.1	0.04	NA	< 5	< 2	2	96	45	1	4	< 2	< 2	13	180	< 0.2	< 0.1	< 2	4	< 2	
	MW14A		26-Apr-94	5	< 0.01		< 0.01	< 0.1	0.04	NA	20	< 2	2	< 2	25	< 1	2	< 2	5	11	160	99.0	0.1	< 2	4	< 2	
	MW14A		15-Jul-94	10	< 0.01		< 0.01	0.1	0.07	NA	12	44	< 2	26	17	< 0.4	12	24	16	13	1900	< 0.2	0.1	< 2	2	< 2	
	MW14B	27.7	21-Apr-94	100	0.04		< 0.01	0.3	0.12	NA	**170**	< 2	2	18	240	< 1	< 2	< 2	< 2	99	660	< 0.2	0.1	2	< 2	< 2	
	MW14B		26-Apr-94	93	< 0.01		< 0.01	0.2	0.07	NA	19	< 2	< 2	15	45	< 1	< 2	< 2	6	82	660	21.5	0.2	2	3	< 2	
	MW14B		15-Jul-94	92	0.04		< 0.01	0.1	0.10	NA	88	< 2	23	16	220	< 0.4	2	< 2	3	90	680	< 0.2	0.1	2	< 2	< 2	
EE11/15	MW15A	10.1	22-Apr-94	16	< 0.01		< 0.01	< 0.1	0.16	NA	22	< 2	2	6	39	< 1	< 2	< 2	< 2	13	160	< 0.2	< 0.1	< 2	4	< 2	
	MW15A		16-Jul-94	19	< 0.01		< 0.01	< 0.1	0.17	NA	9	< 2	< 2	3	17	< 0.4	< 2	2	2	12	150	< 0.2	< 0.1	< 2	4	< 2	
	MW15B	27.0	21-Apr-94	56	< 0.01		< 0.01	0.1	0.03	NA	45	< 2	2	23	46	< 1	< 2	< 2	< 2	140	420	< 0.2	< 0.1	< 2	5	< 2	
	MW15B		27-Apr-94	56	< 0.01		< 0.01	0.1	0.07	NA	18	< 2	2	< 2	15	< 1	2	< 2	7	110	400	57.6	0.3	< 2	8	< 2	
	MW15B		16-Jul-94	54	< 0.01		< 0.01	< 0.1	0.13	NA	8	< 2	< 2	22	26	< 0.4	< 2	< 2	2	120	410	< 0.2	< 0.1	< 2	3	< 2	
EE11/16	MW16A	13.0	21-Apr-94	92	0.03		< 0.01	0.3	0.02	NA	15	< 2	2	12	30	< 1	< 2	< 2	< 2	90	490	< 0.2	< 0.1	3	2	3	
	MW16A		27-Apr-94	95	< 0.01		< 0.01	0.2	0.05	NA	16	< 2	< 2	5	40	< 1	2	< 2	4	98	530	21.6	0.1	3	3	3	
	MW16A		16-Jul-94	93	0.03		< 0.01	0.1	0.06	NA	13	< 2	< 2	10	18	< 0.4	< 2	< 2	2	82	430	< 0.2	< 0.1	3	3	4	
	MW16B	18.3	21-Apr-94	87	0.02		< 0.01	0.3	0.05	NA	40	< 2	2	10	40	< 1	< 2	< 2	< 2	150	410	< 0.2	< 0.1	2	3	2	
	MW16B		27-Apr-94	100	< 0.01		< 0.01	0.2	0.06	NA	72	< 2	2	3	30	< 1	< 2	< 2	6	100	410	17.2	0.2	3	4	4	
	MW16B		16-Jul-94	120	0.01		< 0.01	0.2	0.19	NA	**16000**	45	34	1100	24000	17	37	39	85	440	1100	0.2	30.0	7	< 2	2	
EE11/17	MW17A	2.3	21-Apr-94		< 0.01		< 0.01	< 0.1	0.07	NA	< 5	< 2	2	15	56	< 1	3	< 2	5	93	600	< 0.2	0.1	< 2	3	< 2	
	MW17A		27-Apr-94	16	< 0.01		**0.80**	0.2	0.18	NA	17	2	< 2	< 2	50	< 1	5	< 2	7	86	720	342.0	1.3	2	8	< 2	
	MW17A		14-Jul-94	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
	MW17A		16-Jul-94																								
	MW17B	12.0	22-Apr-94	130	< 0.01		< 0.01	0.6	0.06	NA	**180**	4	2	4	150	< 1	< 2	2	< 2	11	110	< 0.2	0.1	4	2	3	
	MW17B		14-Jul-94	130	0.10		< 0.01	0.7	0.10	NA	62	2	< 2	2	56	< 0.4	< 2	3	3	10	100	< 0.2	0.1	4	2	3	
	MW17C	32.8	21-Apr-94	80	0.04		< 0.01	0.4	0.04	NA	**330**	< 2	2	13	280	< 1	< 2	< 2	< 2	99	320	< 0.2	0.4	2	4	8	
	MW17C		28-Apr-94	83	< 0.01		< 0.01	0.3	0.04	NA	59	2	< 2	6	52	< 1	< 2	2	5	120	320	12.8	0.3	2	8	9	
	MW17C		14-Jul-94	80	0.03		< 0.01	0.1	0.19	NA	73	< 2	< 2	10	83	< 0.4	< 2	< 2	< 2	99	330	< 0.2	0.2	2	5	4	
EE11/18	MW18A	4.6	28-Apr-94	10	< 0.01		< 0.01	0.1	0.02	NA	22	< 2	< 2	< 2	25	< 1	2	< 2	5	55	220	71.6	0.2	< 2	5	8	
	MW18A		20-Jul-94	13	< 0.01		< 0.01	< 0.1	0.06	NA	11	< 2	< 2	8	12	< 0.4	< 2	< 2	2	70	220	< 0.2	0.1	< 2	2	9	
	MW18B	14.9	28-Apr-94	130	< 0.01		< 0.01	0.5	0.02	< 0.005	26	< 2	< 2	< 2	20	< 1	< 2	< 2	5	58	400	10.2	0.2	2	2	2	
	MW18B		20-Jul-94	130	< 0.01		< 0.01	0.6	0.06	NA	47	< 2	< 2	2	34	< 0.4	< 2	< 2	< 2	53	400	< 0.2	0.2	3	2	3	
	MW18C	28.1	25-Apr-94	78	< 0.01		< 0.01	0.2	0.03	0.030	16	NA	NA	NA	NA	NA	NA	NA	NA	87	NA	NA	NA	< 2	9	NA	
	MW18C		14-Jul-94	79	< 0.01		< 0.01	0.1	0.10	NA	7	< 2	2	11	< 10	< 0.4	3	5	6	100	450	0.3	0.1	< 2	2	6	
	MW18D	49.4	04-May-94	81	< 0.01		< 0.01	0.4	0.10	0.005	70	2	< 2	11	70	< 1	< 2	2	8	160	510	18.0	0.2	3	7	4	
	MW18D		14-Jul-94	65	0.03		< 0.01	0.1	0.33	NA	66	< 2	3	12	76	< 0.4	< 2	2	2	140	480	0.3	0.1	2	5	3	
EE11/19	MW19A	17.7	02-May-94	160	< 0.01		< 0.01	1.0	0.24	NA	**34000**	33	29	590	24000	9	80	110	250	950	1700	1.2	46.0	13	<2	57	
	MW19A		20-Jul-94	230	0.04		< 0.01	0.5	0.25	NA	**34000**	33	29	590	24000	9	80	110	250	950	1700	1.2	46.0	13	< 2	57	
	MW19B	17.8	02-May-94	150	< 0.01		< 0.01	0.4	0.10	0.015	**190**	< 2	< 2	18	190	< 1	8	3	18	50	510	30.5	0.4	< 2	9	12	
	MW19C	45.6	28-Apr-94	740	< 0.01		< 0.01	0.2	0.10	< 0.005	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
	MW19C		20-Jul-94	300	0.04		< 0.01	< 0.1	0.18	NA	60	< 2	< 2	23	66	< 0.4	< 2	2	< 2	180	510	< 0.2	0.6	12	2	4	
EE11/20	MW20A	10.2	28-Apr-94	13	< 0.01		< 0.01	0.1	0.03	NA	14	< 2	< 2	< 2	20	< 1	3	3	6	81	400	73.1	0.2	< 2	5	6	
	MW20A		19-Jul-94	10	< 0.01		< 0.01	< 0.1	0.07	NA	10	< 2	< 2	62	< 10	< 0.4	< 2	< 2	< 2	90	300	< 0.2	0.2	< 2	< 2	2	
	MW20B	16.7	28-Apr-94	28	< 0.01		< 0.01	0.1	0.02	< 0.005	15	< 2	< 2	< 2	14	< 1	3	3	6	95	440	34.6	0.1	2	9	6	
	MW20B		19-Jul-94	24	< 0.01		< 0.01	< 0.1	0.08	NA	37	< 2	< 2	12	30	< 0.4	< 2	2	2	100	460	< 0.2	< 0.1	2	3	7	
	MW20C	58.4	28-Apr-94	44	< 0.01		< 0.01	0.2	0.04	< 0.005	74	< 2	2	15	55	< 1	< 2	2	5	140	400	25.6	0.3	5	8	4	

TABLE E2: Duffins watershed groundwater chemistry data summary - minor ions and trace metals. Data from M.M. Dillon Limited, 1990; IWA, 1994 b,c,e; Gerber, unpublished).

Site Nest	Well No.	mid-scr mbgs	Date	Minor Ions B ug/L	PO4 mg/L	NO3 mg/L	NO2 mg/L	F mg/L	Br mg/L	I mg/L	Trace Metals Al µg/L	V µg/L	Cr µg/L	Mn µg/L	Fe µg/L	Co µg/L	Ni µg/L	Cu µg/L	Zn µg/L	Ba µg/L	Sr µg/L	Cd µg/L	Pb µg/L	As µg/L	Sb µg/L	Mo µg/L	P mg/L
	MW20C		19-Jul-94	42	0.02		< 0.01	< 0.1	0.12	NA	35	< 2	< 2	23	30	< 0.4	< 2	4	< 2	130	380	< 0.2	0.1	5	2	3	
EE11/21	MW21A	15.1	03-May-94	230	< 0.01		< 0.01	1.1	0.08	NA	40	< 2	< 2	9	40	< 1	8	8	6	33	390	23.3	0.2	< 2	9	23	
	MW21A		20-Jul-94	420	< 0.01		< 0.01	0.8	0.22	NA	17	< 2	< 2	13	12	< 0.4	9	7	6	33	2200	< 0.2	0.2	< 2	4	54	
	MW21B	26.5	03-May-94	110	< 0.01		< 0.01	0.5	0.03	0.005	32	< 2	< 2	14	30	< 1	< 2	< 2	5	64	240	13.0	0.2	3	3	8	
	MW21B		20-Jul-94	100	0.02		< 0.01	0.2	0.13	NA	**130**	2	< 2	18	160	< 0.4	< 2	3	4	63	210	< 0.2	0.3	4	2	8	
	MW21C	52.3	03-May-94	22	< 0.01		< 0.01	< 0.1	0.05	< 0.005	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
	MW21C		20-Jul-94	27	< 0.01		< 0.01	< 0.1	0.09	NA	25	< 2	< 2	17	72	< 0.4	< 2	< 2	< 2	160	350	< 0.2	0.2	4	3	2	
EE11/GT1	MWGT-1	23.9	02-May-94	62	< 0.01		< 0.01	0.2	0.05	NA	87	3	< 2	13	85	< 1	< 2	3	5	180	470	15.3	0.3	< 2	9	3	
	MWGT-1		14-Jul-94	62	0.03		< 0.01	0.1	0.10	NA	48	< 2	< 2	13	60	< 0.4	< 2	11	< 2	150	420	< 0.2	0.2	< 2	3	4	
EE11/GT2	MWGT-2	26.5	25-Apr-94	110	< 0.01		< 0.01	0.2	0.07	<0.01	69	2	2	7	54	< 1	< 2	2	5	80	280	12.4	0.2	8	6	7	
	MWGT-2		14-Jul-94	120	0.07		< 0.01	0.2	0.15	NA	**2100**	6	4	110	3100	2	4	6	10	98	310	< 0.2	2.3	7	3	7	
1/94	1/94-1	43.1	24-Jan-95		nd	0.384	-		nd					23	294				8	147	379						
	1/94-2	21.5	24-Jan-95		nd	0.186	-		nd		63			13	651					131	351						
	1/94-3	9.7	24-Jan-95		nd	0.274	-		nd		436		12	1540	6020				9	192	1450						771
	1/94-4	30.8	24-Jan-95		nd	0.543	-		0.086		2060	11		1080	6950		13		25	365	1410					25	1780
2/94	2/94-1	28.8	30-Jan-95		nd	0.107	-		nd		113				115					35	305						67
	2/94-2	62.7	31-Jan-95		0.069	0	-		nd					23	206					199	423						81
	2/94-3	13.0	30-Jan-95		nd	0.701	-		nd		147			14	365					115	337						76
	2/94-5A	37.5	30-Jan-95		nd	0	-		nd		57			6					21	28	504					548	105
	2/94-5B	43.2	30-Jan-95		nd	0	-		nd		122							8	10	22	213					100	68

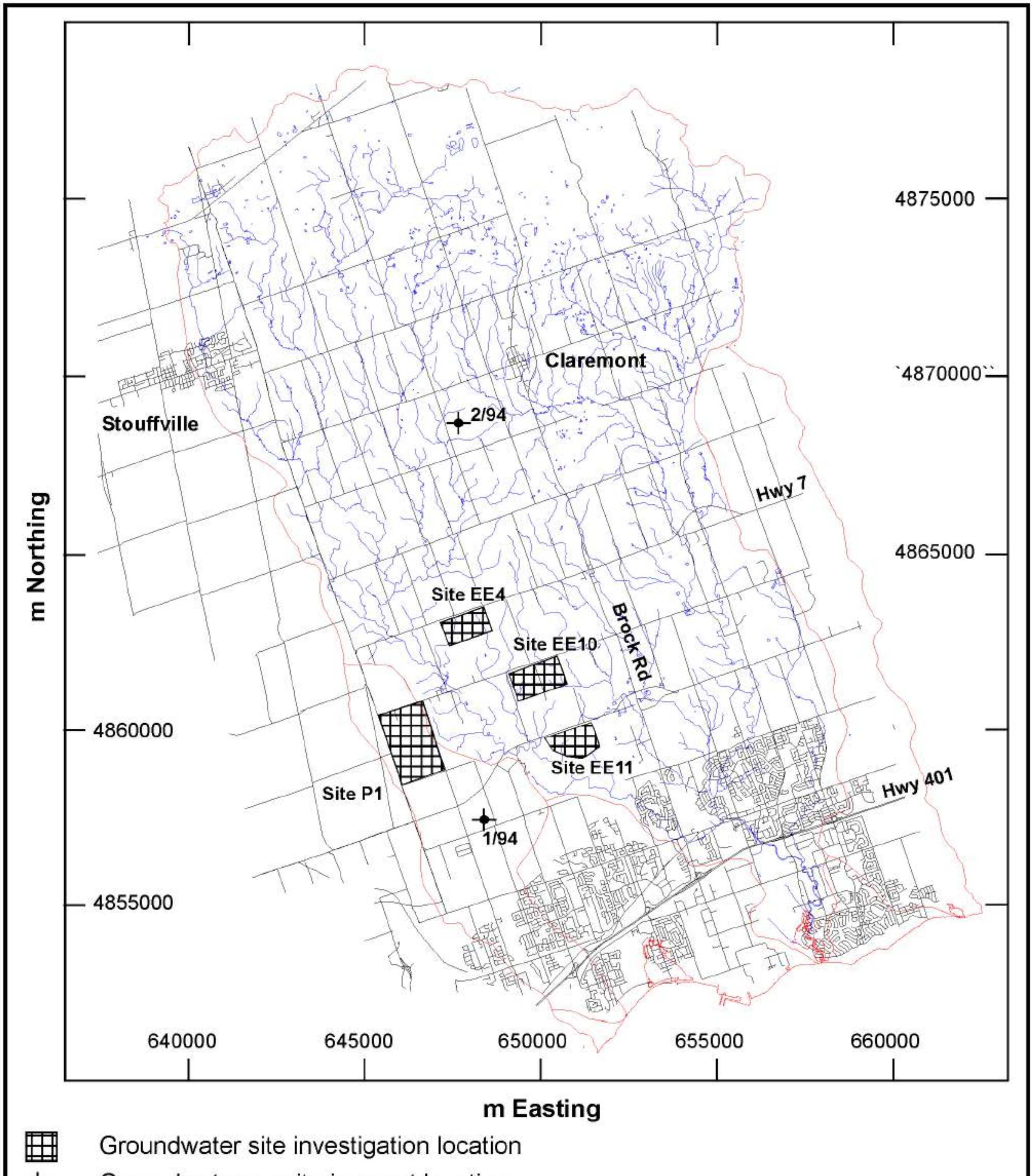


FIGURE E1: Duffins watershed groundwater chemistry sample locations.

Duffins Hydrogeology	Gerber Geosciences Inc., March 10, 2003

Figure E2: Site P1 Major ion chemistry (1990 & 1993 samples). Data from M.M. Dillon Limited, 1990)

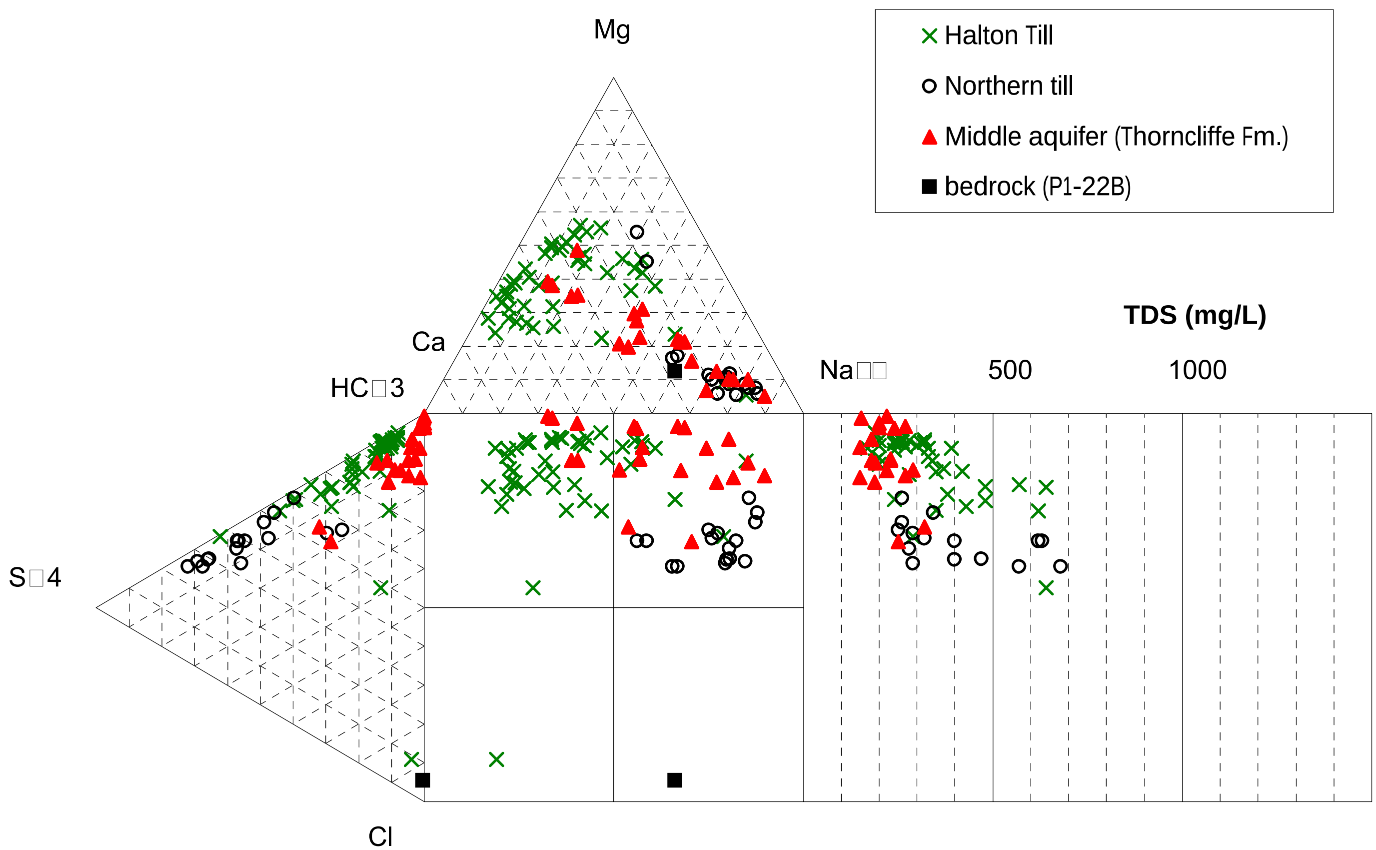


Figure E3: Site EE11 major ion chemistry (1994 samples). Data from IWA, 1994e.

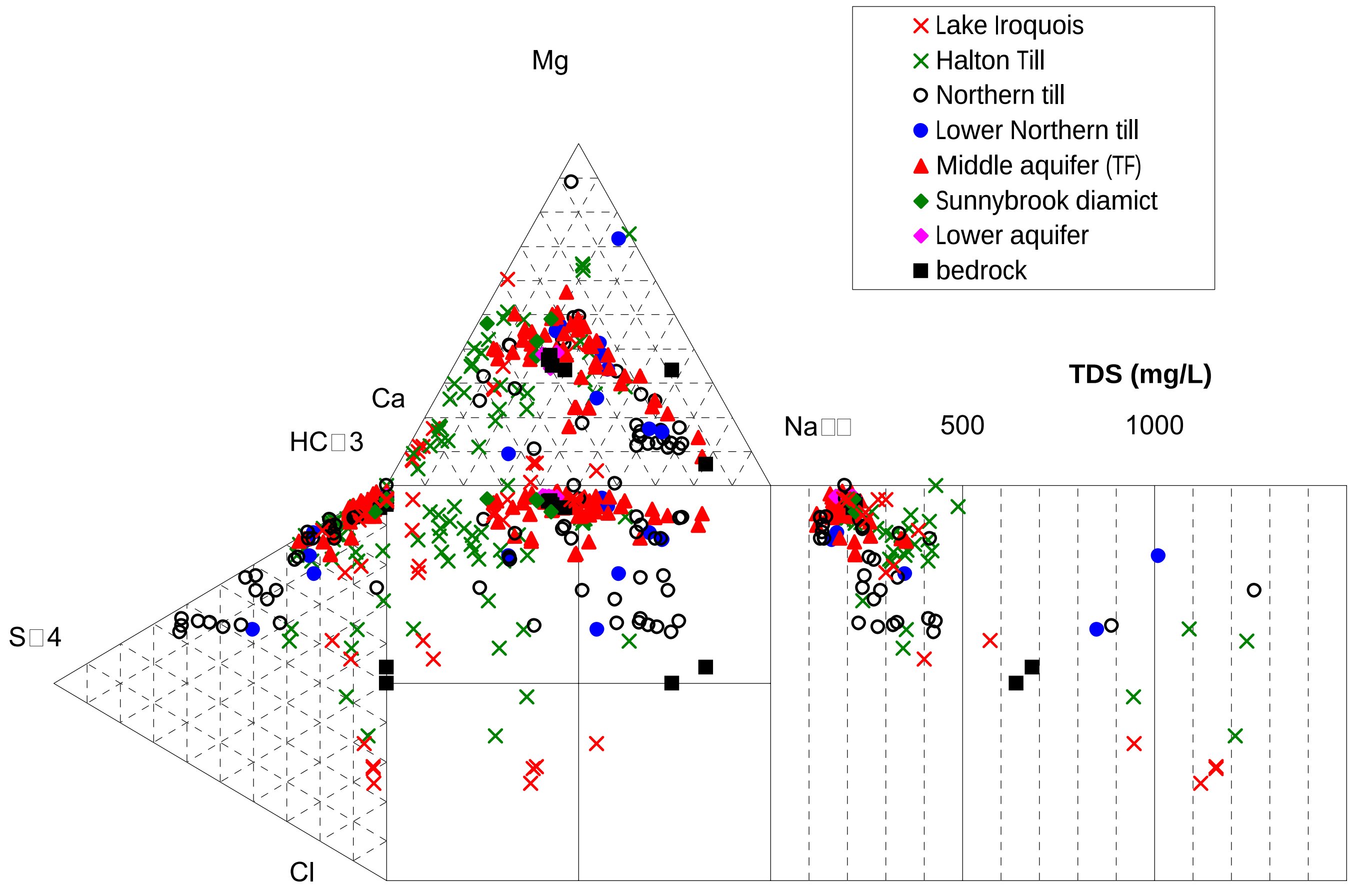


Table F1-1a: AES Thornthwaite SMC=100mm - summary. Stouffville WPCP #6158084.

Stouffville, Ontario WATER BUDGET MEANS FOR THE PERIOD 1972-1991 DC20492
LAT.... 43.97 WATER HOLDING CAPACITY...100 MM HEAT INDEX... 36.31
LONG... 79.24 LOWER ZONE............... 60 MM A............ 1.074

DATE	TEMP (C)		PCPN	RAIN	MELT	PE	AE	DEF	SURP	SNOW	SOIL	ACC P
31- 1	-7.5		52	10	18	1	1	0	27	50	95	282
28- 2	-6.6		50	17	27	1	1	0	41	56	97	332
31- 3	-1.3		65	41	64	8	8	0	95	17	100	397
30- 4	6.1		64	60	20	34	34	0	47	0	100	461
31- 5	13.0		82	82	0	80	80	0	16	0	86	545
30- 6	17.5		75	75	0	110	110	-1	0	0	51	621
31- 7	20.7		71	71	0	133	104	-29	0	0	18	694
31- 8	19.5		95	95	0	116	96	-20	2	0	15	790
30- 9	14.7		81	81	0	75	65	-10	7	0	23	872
31-10	8.2		80	80	0	37	36	0	6	0	61	80
30-11	2.5		79	72	5	12	12	0	34	2	92	159
31-12	-4.4		69	24	21	2	2	0	38	26	97	226
AVE	6.9	TTL	864	708	155	609	549	-60	313			

Stouffville, Ontario STANDARD DEVIATIONS FOR THE PERIOD 1972-1991 DC20492

DATE	TEMP (C)	PCPN	RAIN	MELT	PE	AE	DEF	SURP	SNOW	SOIL	ACC P
31- 1	2.8	16	10	18	1	1	0	25	38	12	55
28- 2	2.6	29	19	29	2	2	0	43	44	8	57
31- 3	2.2	24	23	40	5	5	0	47	35	0	66
30- 4	1.8	22	24	37	9	9	0	44	0	1	73
31- 5	2.0	27	27	0	13	13	0	20	0	20	75
30- 6	1.4	28	28	0	9	9	2	1	0	29	77
31- 7	1.0	40	40	0	7	30	34	0	0	28	90
31- 8	1.2	37	37	0	8	18	20	9	0	28	90
30- 9	.8	38	38	0	5	10	10	28	0	34	106
31-10	1.6	31	31	0	7	7	1	14	0	31	32
30-11	1.4	32	32	5	4	4	0	33	4	19	47
31-12	2.8	23	22	14	2	2	0	31	23	11	56

Table F1-1b: AES Thornthwaite SMC=100mm - monthly estimates. Stouffville WPCP #6158084.
Stouffville, Ontario Water Budget Values for the Period 1972-1991 DC20492 Calculated Daily
Method: AES Thornthwaite and Mather (Johnstone and Louie, 1983) SMC = 100 mm

YR	MO	TEMP(C)	PCPN	RAIN	MELT	PE	AE	DEF	SURP	SNOW	SOIL	ACC P
1972-	1	-7.5	34.1	10.2	2.3	0	0	0	0	21.6	72.5	34.1
1972-	2	-9.1	70.6	5.1	0	0	0	0	0	87.1	77.6	104.7
1972-	3	-4.8	68.6	22.9	26.9	0.8	0.8	0	26.6	105.9	100	173.3
1972-	4	2.6	50	42.4	113.5	19.3	19.3	0	136.6	0	100	223.3
1972-	5	13.6	60.9	60.9	0	83.5	83.5	0	0	0	77.4	284.2
1972-	6	15.9	54.4	54.4	0	99.5	99.5	0	0	0	32.3	338.6
1972-	7	20.1	25.1	25.1	0	129.6	57.4	-72.3	0	0	0	363.7
1972-	8	18.2	73.8	73.8	0	107.3	73.8	-33.5	0	0	0	437.5
1972-	9	15.6	64.6	64.6	0	79.5	64.6	-14.9	0	0	0	502.1
1972-	10	6	91.3	91.3	0	27.2	27.2	0	0	0	64.1	91.3
1972-	11	0.7	69.7	65.9	3.8	7.2	7.2	0	26.6	0	100	161
1972-	12	-3.9	99	5.3	17.6	0.4	0.4	0	22.4	76.1	100	260
1973-	1	-5.4	28.1	4.6	51.9	1.5	1.5	0	55	47.7	100	288.1
1973-	2	-8	27.7	15.7	12.4	0.3	0.3	0	27.8	47.3	100	315.8
1973-	3	2.8	110.9	110.9	47.3	16.6	16.6	0	141.7	0	100	426.7
1973-	4	6.4	72	72	0	34.4	34.4	0	37.6	0	100	498.7
1973-	5	11	87.7	87.7	0	66.3	66.3	0	21.4	0	100	586.4
1973-	6	18.9	67.1	67.1	0	119.3	119.3	0	0	0	47.8	653.5
1973-	7	20.5	57.9	57.9	0	131.8	105.7	-26.1	0	0	0	711.4
1973-	8	21.5	91.9	91.9	0	128.9	91.9	-37	0	0	0	803.3
1973-	9	15.3	39.9	39.9	0	78.5	39.9	-38.6	0	0	0	843.2
1973-	10	10.7	97.3	97.3	0	48.7	48.7	0	0	0	48.6	97.3
1973-	11	2.9	75.3	74.5	0.8	11.9	11.9	0	12	0	100	172.6
1973-	12	-4.8	74.1	26.7	15.6	2.6	2.6	0	39.7	31.8	100	246.7
1974-	1	-6.8	65.4	2	30.1	0.8	0.8	0	31.3	65.1	100	312.1
1974-	2	-8.9	48.8	12.8	18.1	0.6	0.6	0	30.4	82.9	100	360.9
1974-	3	-2	60	44.5	96.1	3.7	3.7	0	136.8	2.3	100	420.9
1974-	4	7.3	87.1	87.1	2.3	39.6	39.6	0	49.8	0	100	508
1974-	5	10.4	111.9	111.9	0	62.9	62.9	0	49	0	100	619.9
1974-	6	16.9	97.7	97.7	0	105.6	105.6	0	0	0	92.1	717.6
1974-	7	20.3	75.2	75.2	0	130.6	130.6	0	0	0	36.7	792.8
1974-	8	19.8	51.3	51.3	0	117.7	88	-29.6	0	0	0	844.1
1974-	9	13.8	48.1	48.1	0	69.8	48.1	-21.7	0	0	0	892.2
1974-	10	6.7	35.4	35.4	0	30.2	30.2	0	0	0	5.2	35.4
1974-	11	2.5	81	67.5	0.5	13.8	13.8	0	0	13	59.4	116.4
1974-	12	-2	38.6	8.4	38.1	0.9	0.9	0	5	5.1	100	155
1975-	1	-4.7	36.6	20.3	9.3	1.6	1.6	0	28	12.1	100	191.6
1975-	2	-4.9	76.7	45.6	27.3	0.7	0.7	0	72.2	15.9	100	268.3
1975-	3	-3.2	67.2	41.2	38.1	2.5	2.5	0	76.9	3.8	100	335.5
1975-	4	2.3	74.5	41.4	36.9	19.9	19.9	0	58.4	0	100	410
1975-	5	16.2	48.8	48.8	0	100.5	100.5	0	0	0	48.3	458.8
1975-	6	18.5	74.2	74.2	0	117.1	108.7	-8.4	0	0	13.8	533
1975-	7	21.4	48	48	0	138.2	61.8	-76.4	0	0	0	581
1975-	8	19.6	66.6	66.6	0	117	66.6	-50.4	0	0	0	647.6
1975-	9	13.3	52.3	52.3	0	67	52.3	-14.7	0	0	0	699.9
1975-	10	9.9	38.7	38.7	0	44.7	38.7	-6	0	0	0	38.7
1975-	11	5.7	56.7	44	12.7	22.6	22.6	0	0	0	34.1	95.4
1975-	12	-5.8	106.6	17	31.5	1.1	1.1	0	0	58.1	81.6	202
1976-	1	-10.1	66.8	0	0	0	0	0	0	124.9	81.6	268.8
1976-	2	-3.9	28.1	25.6	67.4	2.2	2.2	0	72.4	60	100	296.9
1976-	3	-0.9	97.9	33.4	124.5	10.1	10.1	0	147.8	0	100	394.8
1976-	4	7.7	50.8	50.8	0	41.7	41.7	0	9.1	0	100	445.6
1976-	5	10.4	87.4	87.4	0	62.9	62.9	0	24.5	0	100	533
1976-	6	19.1	65.1	65.1	0	120.6	120.6	0	0	0	44.5	598.1
1976-	7	18.7	156.9	156.9	0	119.9	119.9	0	0	0	81.6	755
1976-	8	18.4	39.4	39.4	0	109.1	109.1	0	0	0	11.9	794.4
1976-	9	14.1	51.5	51.5	0	71.6	55.5	-16.1	0	0	7.9	845.9
1976-	10	6	60.1	60.1	0	27.6	27.6	0	0	0	40.4	60.1
1976-	11	-0.5	17.7	8.1	9.6	3.8	3.8	0	0	0	54.3	77.8
1976-	12	-9	44.8	0	0	0	0	0	0	44.8	54.3	122.6
1977-	1	-12.6	60.7	0	0	0	0	0	0	105.5	54.3	183.3
1977-	2	-7.3	34.5	5	10.6	0.2	0.2	0	0	124.4	69.7	217.8
1977-	3	1.7	74.5	60.8	138.1	15.6	15.6	0	152.9	0	100	292.3
1977-	4	7.3	50.6	50.6	0	41.3	41.3	0	9.3	0	100	342.9
1977-	5	14.7	51	51	0	90.9	90.9	0	0	0	60.1	393.9
1977-	6	16.7	65.1	65.1	0	104.7	104.7	0	0	0	20.5	459
1977-	7	20	139.6	139.6	0	128.6	128.6	0	0	0	31.5	598.6

Table F1-1b: AES Thornthwaite SMC=100mm - monthly estimates. Stouffville WPCP #6158084.
Stouffville, Ontario Water Budget Values for the Period 1972-1991 DC20492 Calculated Daily
Method: AES Thornthwaite and Mather (Johnstone and Louie, 1983) SMC = 100 mm

YR	MO	TEMP(C)	PCPN	RAIN	MELT	PE	AE	DEF	SURP	SNOW	SOIL	ACC P
1977-	8	18.3	123.6	123.6	0	108.6	108.6	0	0	0	46.5	722.2
1977-	9	15	136	136	0	76.2	76.2	0	6.2	0	100	858.2
1977-	10	7.6	73.8	73.8	0	33.4	33.4	0	40.4	0	100	73.8
1977-	11	3.4	102.8	91.6	0.2	17.5	17.5	0	74.3	11	100	176.6
1977-	12	-5.5	67.3	13.9	28	1.1	1.1	0	40.8	36.4	100	243.9
1978-	1	-9.8	66	15	3.1	0	0	0	18	84.3	100	309.9
1978-	2	-10.8	14.1	0	0	0	0	0	0	98.4	100	324
1978-	3	-4.3	40.6	0.4	34.2	1.3	1.3	0	33.3	104.4	100	364.6
1978-	4	4.2	71.6	70.6	105.4	22.1	22.1	0	154	0	100	436.2
1978-	5	13.7	95	95	0	84.9	84.9	0	10.1	0	100	531.2
1978-	6	17	31.6	31.6	0	107	107	0	0	0	24.6	562.8
1978-	7	20.5	27.6	27.6	0	132.1	52.2	-79.9	0	0	0	590.4
1978-	8	19.9	119.1	119.1	0	118.5	118.5	0	0	0	0.6	709.5
1978-	9	14.3	125.9	125.9	0	72.9	72.9	0	0	0	53.6	835.4
1978-	10	7.7	49.5	49.5	0	34.4	34.4	0	0	0	68.8	49.5
1978-	11	2.1	57.6	51.6	0	12.9	12.9	0	7.4	6	100	107.1
1978-	12	-3.9	37.5	15.5	21	0.4	0.4	0	36	7	100	144.6
1979-	1	-8.7	74.5	0	6.9	0.1	0.1	0	6.8	74.6	100	219.1
1979-	2	-11.6	21	0	8	0.2	0.2	0	7.8	87.6	100	240.1
1979-	3	1	36.6	35.4	88.8	12.3	12.3	0	112	0	100	276.7
1979-	4	5	78.7	76.7	2	28.2	28.2	0	50.5	0	100	355.4
1979-	5	12.1	77.8	77.8	0	73.6	73.6	0	4.2	0	100	433.2
1979-	6	17.6	72.8	72.8	0	110.8	110.8	0	0	0	62	506
1979-	7	20.6	55.8	55.8	0	132.7	117.8	-14.9	0	0	0	561.8
1979-	8	18.8	77.8	77.8	0	111.4	77.8	-33.6	0	0	0	639.6
1979-	9	15	56.4	56.4	0	76.4	56.4	-20	0	0	0	696
1979-	10	7.7	143.2	143.2	0	34.7	34.7	0	8.5	0	100	143.2
1979-	11	3.6	93.2	88.6	4.6	14.3	14.3	0	78.9	0	100	236.4
1979-	12	-2.4	86.2	67	19.2	2.5	2.5	0	83.7	0	100	322.6
1980-	1	-6.1	61.9	30	20	0.4	0.4	0	49.6	11.9	100	384.5
1980-	2	-8.4	14.6	1	9.3	0.2	0.2	0	10.1	16.2	100	399.1
1980-	3	-3.3	84.5	58.4	42.3	5.1	5.1	0	95.6	0	100	483.6
1980-	4	6.2	120.4	120.4	0	32.7	32.7	0	87.7	0	100	604
1980-	5	14.5	35.9	35.9	0	89.2	89.2	0	0	0	46.7	639.9
1980-	6	14.7	91.9	91.9	0	91.6	91.6	0	0	0	47	731.8
1980-	7	20.3	140.7	140.7	0	130.6	130.6	0	0	0	57.1	872.5
1980-	8	20.8	67.9	67.9	0	124.1	121.3	-2.7	0	0	3.6	940.4
1980-	9	14.4	70.8	70.8	0	73.6	71	-2.6	0	0	3.5	1011.2
1980-	10	6.3	95.9	95.9	0	27.9	27.9	0	0	0	71.5	95.9
1980-	11	0.6	60.1	51.3	8.8	5.4	5.4	0	26.1	0	100	156
1980-	12	-7.7	84.7	50.1	8.2	1.1	1.1	0	57.2	26.4	100	240.7
1981-	1	-11.9	25.5	0	3	0	0	0	2.9	48.9	100	266.2
1981-	2	-3.2	92.5	39	102.4	5.3	5.3	0	136.1	0	100	358.7
1981-	3	-0.5	33.3	23.1	10.2	9.2	9.2	0	24.1	0	100	392
1981-	4	6.7	46.3	46.3	0	35.1	35.1	0	11.2	0	100	438.3
1981-	5	11.7	95.2	95.2	0	71	71	0	24.2	0	100	533.5
1981-	6	17.4	76.3	76.3	0	109.2	109.2	0	0	0	67.1	609.8
1981-	7	20.6	69.2	69.2	0	133.2	133.2	0	0	0	3.1	679
1981-	8	19.2	94.1	94.1	0	114.4	95.1	-19.2	0	0	2	773.1
1981-	9	14	100.9	100.9	0	71.3	71.3	0	0	0	31.7	874
1981-	10	6	140.7	140.7	0	26.1	26.1	0	46.2	0	100	140.7
1981-	11	2.9	63.2	62.2	1	12.6	12.6	0	50.6	0	100	203.9
1981-	12	-4.5	51.7	5	9.3	0.4	0.4	0	13.9	37.4	100	255.6
1982-	1	-11.4	76	5.8	10.9	0.3	0.3	0	16.5	96.7	100	331.6
1982-	2	-8	51.5	3	0	0	0	0	3	145.2	100	383.1
1982-	3	-2.9	72.9	48.2	92.6	3.3	3.3	0	137.4	77.3	100	456
1982-	4	3.8	49.5	37.5	89.3	26.7	26.7	0	100.1	0	100	505.5
1982-	5	14.8	45.3	45.3	0	90.9	90.9	0	0	0	54.4	550.8
1982-	6	15.6	148.5	148.5	0	96.9	96.9	0	6	0	100	699.3
1982-	7	20.7	118.4	118.4	0	133.5	133.5	0	0	0	84.9	817.7
1982-	8	16.9	92.4	92.4	0	99.8	99.8	0	0	0	77.6	910.1
1982-	9	14.5	73.8	73.8	0	73.2	73.2	0	0	0	78.2	983.9
1982-	10	9.6	59.8	59.8	0	43.1	43.1	0	0	0	94.9	59.8
1982-	11	3.4	124.5	111.3	13.2	15.1	15.1	0	104.3	0	100	184.3
1982-	12	-0.4	90.2	67.2	23	8.4	8.4	0	81.8	0	100	274.5
1983-	1	-5.1	47.8	12.8	19.1	0.4	0.4	0	31.5	15.9	100	322.3
1983-	2	-4.2	49.5	18.2	47.2	1.5	1.5	0	63.9	0	100	371.8

Table F1-1b: AES Thornthwaite SMC=100mm - monthly estimates. Stouffville WPCP #6158084.
Stouffville, Ontario Water Budget Values for the Period 1972-1991 DC20492 Calculated Daily
Method: AES Thornthwaite and Mather (Johnstone and Louie, 1983) SMC = 100 mm

YR	MO	TEMP(C)	PCPN	RAIN	MELT	PE	AE	DEF	SURP	SNOW	SOIL	ACC P
1983-	3	0.3	58.6	38.8	13.7	10.2	10.2	0	42.3	6.1	100	430.4
1983-	4	5.1	95.9	95.9	6.1	26.4	26.4	0	75.6	0	100	526.3
1983-	5	10	109.5	109.5	0	59.8	59.8	0	49.7	0	100	635.8
1983-	6	18.3	28.1	28.1	0	115.6	115.6	0	0	0	12.5	663.9
1983-	7	22.1	50.4	50.4	0	143.2	62.9	-80.4	0	0	0	714.3
1983-	8	21	111.4	111.4	0	125.8	111.4	-14.4	0	0	0	825.7
1983-	9	16.4	64.6	64.6	0	84.5	64.6	-19.9	0	0	0	890.3
1983-	10	9.4	81.8	81.8	0	42.8	42.8	0	0	0	39	81.8
1983-	11	2.4	122.7	122.7	0	12.2	12.2	0	49.5	0	100	204.5
1983-	12	-6.9	82.6	25	15	0.3	0.3	0	39.8	42.6	100	287.1
1984-	1	-9.8	44.7	6	3	0	0	0	8.9	78.3	100	331.8
1984-	2	-1.9	78.3	49.5	86.1	4.8	4.8	0	130.8	21	100	410.1
1984-	3	-5	75.6	47.2	49.4	2.7	2.7	0	93.9	0	100	485.7
1984-	4	7.2	53.8	53.8	0	37.5	37.5	0	16.3	0	100	539.5
1984-	5	10.2	124	124	0	61.6	61.6	0	62.4	0	100	663.5
1984-	6	18.3	58.8	58.8	0	115.4	115.4	0	0	0	43.4	722.3
1984-	7	19.8	63.5	63.5	0	127.2	106.9	-20.3	0	0	0	785.8
1984-	8	20.8	98	98	0	124.9	98	-26.9	0	0	0	883.8
1984-	9	13.7	111.7	111.7	0	69.4	69.4	0	0	0	42.3	995.5
1984-	10	10.4	47.8	47.8	0	46.6	46.6	0	0	0	43.5	47.8
1984-	11	2.9	56.5	56.5	0	13.2	13.2	0	0	0	86.8	104.3
1984-	12	-1.1	69.2	17.9	35.9	3.5	3.5	0	37.1	15.4	100	173.5
1985-	1	-8.8	74.4	0	0	0	0	0	0	89.8	100	247.9
1985-	2	-6.4	122.8	67.3	34.5	1.1	1.1	0	100.7	110.8	100	370.7
1985-	3	-0.7	78.9	41.9	139.4	5.3	5.3	0	176	8.4	100	449.6
1985-	4	6.9	27.1	19.5	16	39.6	39.6	0	0	0	95.9	476.7
1985-	5	13.2	108	108	0	80.4	80.4	0	23.4	0	100	584.7
1985-	6	15.4	69.4	69.4	0	96.1	96.1	0	0	0	73.3	654.1
1985-	7	19.7	59.2	59.2	0	126.4	126.4	0	0	0	6.2	713.3
1985-	8	19	124.8	124.8	0	113	113	0	0	0	18	838.1
1985-	9	16.7	69	69	0	85.5	73.9	-11.5	0	0	13	907.1
1985-	10	9.5	69.1	69.1	0	42.4	42.4	0	0	0	39.7	69.1
1985-	11	2.3	142.2	136	4.7	11.2	11.2	0	69.3	1.5	100	211.3
1985-	12	-6.1	60.6	7.8	1.5	0.7	0.7	0	8.6	52.8	100	271.9
1986-	1	-6.9	41.8	13.6	30.2	0.7	0.7	0	43.1	50.8	100	313.7
1986-	2	-7.3	48	5.4	11	0.3	0.3	0	16.1	82.4	100	361.7
1986-	3	-0.2	54.4	30.6	106.2	12.9	12.9	0	123.9	0	100	416.1
1986-	4	7.9	39.3	39.3	0	41.8	41.8	0	0	0	97.5	455.4
1986-	5	14.7	66.3	66.3	0	90.9	90.9	0	0	0	72.8	521.7
1986-	6	16.4	127	127	0	102.9	102.9	0	0	0	96.9	648.7
1986-	7	20.6	81.4	81.4	0	132.9	132.9	0	0	0	45.5	730.1
1986-	8	18.1	202.2	202.2	0	107.2	107.2	0	40.5	0	100	932.3
1986-	9	14.3	198	198	0	72.2	72.2	0	125.8	0	100	1130.3
1986-	10	8.5	64.8	64.8	0	38	38	0	26.8	0	100	64.8
1986-	11	1.2	37.2	21.2	16	8.7	8.7	0	28.5	0	100	102
1986-	12	-2.1	62.1	27.1	33.1	0.7	0.7	0	59.5	1.9	100	164.1
1987-	1	-5.4	51	3.8	15.7	0.4	0.4	0	19.1	33.5	100	215.1
1987-	2	-6.2	28.2	8	9.6	0.2	0.2	0	17.4	44	100	243.3
1987-	3	1.4	59.1	37.1	44	14.6	14.6	0	66.5	22	100	302.4
1987-	4	8.9	47.3	44.7	24.6	48.3	48.3	0	21	0	100	349.7
1987-	5	14.3	102.4	102.4	0	88.2	88.2	0	14.2	0	100	452.1
1987-	6	19.1	79.2	79.2	0	120.6	120.6	0	0	0	58.6	531.3
1987-	7	22	67.9	67.9	0	142.8	126.5	-16.3	0	0	0	599.2
1987-	8	18.8	79.2	79.2	0	111.8	79.2	-32.6	0	0	0	678.4
1987-	9	15.3	70	70	0	77.9	70	-7.9	0	0	0	748.4
1987-	10	6.9	54.8	54.8	0	30.5	30.5	0	0	0	24.3	54.8
1987-	11	2.7	92.5	88.5	4	13.8	13.8	0	3	0	100	147.3
1987-	12	-1.4	67	43.2	23.8	2.8	2.8	0	64.2	0	100	214.3
1988-	1	-6.1	43.6	25.6	18	2.2	2.2	0	41.4	0	100	257.9
1988-	2	-6.9	77.3	8.7	8	0.2	0.2	0	16.4	60.6	100	335.2
1988-	3	-1.7	39.5	29.9	70.2	6.8	6.8	0	93.4	0	100	374.7
1988-	4	5.7	76.2	76.2	0	29	29	0	47.2	0	100	450.9
1988-	5	14.1	85.8	85.8	0	86.8	86.8	0	0	0	99	536.7
1988-	6	17.8	56	56	0	112.2	112.2	0	0	0	42.8	592.7
1988-	7	22.8	40	40	0	147.9	82.8	-65.1	0	0	0	632.7
1988-	8	20.8	86	86	0	125.3	86	-39.3	0	0	0	718.7
1988-	9	14.7	79.4	79.4	0	74.6	74.6	0	0	0	4.8	798.1

Table F1-1b: AES Thornthwaite SMC=100mm - monthly estimates. Stouffville WPCP #6158084.
Stouffville, Ontario Water Budget Values for the Period 1972-1991 DC20492 Calculated Daily
Method: AES Thornthwaite and Mather (Johnstone and Louie, 1983) SMC = 100 mm

YR	MO	TEMP(C)	PCPN	RAIN	MELT	PE	AE	DEF	SURP	SNOW	SOIL	ACC P
1988-	10	6.5	89.4	89.4	0	28.9	28.9	0	0	0	65.3	89.4
1988-	11	4.1	72.2	72.2	0	14.9	14.9	0	22.7	0	100	161.6
1988-	12	-3.9	51.8	8	17.8	1.6	1.6	0	24.3	26	100	213.4
1989-	1	-3.4	44.8	16.4	54.4	1.5	1.5	0	69.3	0	100	258.2
1989-	2	-7	32.6	6.6	8.6	0.2	0.2	0	15	17.4	100	290.8
1989-	3	-3.1	36	10.6	42.8	5.9	5.9	0	47.4	0	100	326.8
1989-	4	4.7	49.4	48.6	0.8	24.7	24.7	0	24.7	0	100	376.2
1989-	5	13	125.6	125.6	0	79.6	79.6	0	46	0	100	501.8
1989-	6	18.5	96.6	96.6	0	116.5	116.5	0	0	0	80.1	598.4
1989-	7	21.9	6.2	6.2	0	141.9	86.3	-55.6	0	0	0	604.6
1989-	8	19.4	144.2	144.2	0	115.8	115.8	0	0	0	28.4	748.8
1989-	9	15	72.2	72.2	0	76.8	74.4	-2.4	0	0	26.2	821
1989-	10	9.5	93.4	93.4	0	42.4	42.4	0	0	0	77.2	93.4
1989-	11	1.4	124	107.6	11.4	10.5	10.5	0	85.7	5	100	217.4
1989-	12	-11	44.2	0	0	0	0	0	0	49.2	100	261.6
1990-	1	-2.2	58.9	30.1	56.4	1.4	1.4	0	85.1	21.6	100	320.5
1990-	2	-4.6	61.8	23.2	36.9	1.7	1.7	0	58.3	23.4	100	382.3
1990-	3	0	43.1	39.2	27.3	12.2	12.2	0	54.2	0	100	425.4
1990-	4	7.9	55.4	55.4	0	43.7	43.7	0	11.7	0	100	480.8
1990-	5	11.4	63.7	63.7	0	68.8	68.8	0	0	0	94.9	544.5
1990-	6	18.1	86.7	86.7	0	113.8	113.8	0	0	0	67.8	631.2
1990-	7	20.3	68	68	0	130.4	130.4	0	0	0	5.5	699.2
1990-	8	19.8	99	99	0	117.8	100.7	-17.1	0	0	3.7	798.2
1990-	9	14.6	66.6	66.6	0	74.4	67.1	-7.3	0	0	3.3	864.8
1990-	10	8.7	126.5	126.5	0	39.3	39.3	0	0	0	90.5	126.5
1990-	11	3.7	53.9	53.9	0	14.7	14.7	0	29.7	0	100	180.4
1990-	12	-1.9	117.6	59.9	57.5	2.5	2.5	0	114.9	0.2	100	298
1991-	1	-7.1	45	6.6	19.9	0.4	0.4	0	26.1	18.7	100	343
1991-	2	-3.6	26.4	3.7	36.6	3	3	0	37.3	4.8	100	369.4
1991-	3	0.3	115.9	72.8	46.1	9	9	0	109.9	1.8	100	485.3
1991-	4	8	74.3	74.3	1.8	42.3	42.3	0	33.8	0	100	559.6
1991-	5	16	64.8	64.8	0	99.6	99.6	0	0	0	65.2	624.4
1991-	6	19.9	58.6	58.6	0	126.6	123.8	-2.8	0	0	0	683
1991-	7	21.1	61.3	61.3	0	136.1	61.3	-74.8	0	0	0	744.3
1991-	8	20.8	59.9	59.9	0	124	59.9	-64.1	0	0	0	804.2
1991-	9	14.7	62.4	62.4	0	75.7	62.4	-13.3	0	0	0	866.6
1991-	10	9.9	91.5	91.5	0	44.7	44.7	0	0	0	46.8	91.5
1991-	11	1.9	67.2	67.2	0	9.9	9.9	0	4.1	0	100	158.7
1991-	12	-3.5	50.2	16.4	27.5	2.9	2.9	0	41	6.3	100	208.9

Values in mm.

Table F1-2a: AES Thornthwaite SMC=150mm - summary. Stouffville WPCP #6158084.

Stouffville, Ontario WATER BUDGET MEANS FOR THE PERIOD 1972-1991 DC20492

LAT.... 43.97 WATER HOLDING CAPACITY...150 MM HEAT INDEX... 36.31
LONG... 79.24 LOWER ZONE............... 90 MM A............ 1.074

DATE	TEMP (C)	PCPN	RAIN	MELT	PE	AE	DEF	SURP	SNOW	SOIL	ACC P
31- 1	-7.5	52	10	18	1	1	0	25	50	141	282
28- 2	-6.6	50	17	27	1	1	0	38	56	146	332
31- 3	-1.3	65	41	64	8	8	0	93	17	150	397
30- 4	6.1	64	60	20	34	34	0	47	0	150	461
31- 5	13.0	82	82	0	80	80	0	16	0	136	545
30- 6	17.5	75	75	0	110	110	0	0	0	101	621
31- 7	20.7	71	71	0	133	125	-9	0	0	47	694
31- 8	19.5	95	95	0	116	101	-15	2	0	39	790
30- 9	14.7	81	81	0	75	67	-8	7	0	45	872
31-10	8.2	80	80	0	37	36	0	5	0	84	80
30-11	2.5	79	72	5	12	12	0	22	2	126	159
31-12	-4.4	69	24	21	2	2	0	28	26	142	226
AVE	6.9 TTL	864	708	155	609	577	-32	283			

Stouffville, Ontario STANDARD DEVIATIONS FOR THE PERIOD 1972-1991 DC20492

DATE	TEMP (C)	PCPN	RAIN	MELT	PE	AE	DEF	SURP	SNOW	SOIL	ACC P
31- 1	2.8	16	10	18	1	1	0	25	38	21	55
28- 2	2.6	29	19	29	2	2	0	42	44	13	57
31- 3	2.2	24	23	40	5	5	0	48	35	0	66
30- 4	1.8	22	24	37	9	9	0	44	0	1	73
31- 5	2.0	27	27	0	13	13	0	20	0	20	75
30- 6	1.4	28	28	0	9	9	0	1	0	30	77
31- 7	1.0	40	40	0	7	13	14	0	0	46	90
31- 8	1.2	37	37	0	8	17	18	9	0	43	90
30- 9	.8	38	38	0	5	9	9	28	0	48	106
31-10	1.6	31	31	0	7	7	1	13	0	46	32
30-11	1.4	32	32	5	4	4	0	31	4	31	47
31-12	2.8	23	22	14	2	2	0	35	23	20	56

Table F1-2b: AES Thornthwaite SMC=150mm - summary. Stouffville WPCP #6158084.
Stouffville, Ontario Water Budget Values for the Period 1972-1991 DC20492 Calculated Daily
Method: AES Thornthwaite and Mather (Johnstone and Louie, 1983) SMC = 150 mm

YR	MO	TEMP(C)	PCPN	RAIN	MELT	PE	AE	DEF	SURP	SNOW	SOIL	ACC P
1972-	1	-7.5	34.1	10.2	2.3	0	0	0	0	21.6	102.5	34.1
1972-	2	-9.1	70.6	5.1	0	0	0	0	0	87.1	107.6	104.7
1972-	3	-4.8	68.6	22.9	26.9	0.8	0.8	0	6.6	105.9	150	173.3
1972-	4	2.6	50	42.4	113.5	19.3	19.3	0	136.6	0	150	223.3
1972-	5	13.6	60.9	60.9	0	83.5	83.5	0	0	0	127.4	284.2
1972-	6	15.9	54.4	54.4	0	99.5	99.5	0	0	0	82.3	338.6
1972-	7	20.1	25.1	25.1	0	129.6	107.4	-22.3	0	0	0	363.7
1972-	8	18.2	73.8	73.8	0	107.3	73.8	-33.5	0	0	0	437.5
1972-	9	15.6	64.6	64.6	0	79.5	64.6	-14.9	0	0	0	502.1
1972-	10	6	91.3	91.3	0	27.2	27.2	0	0	0	64.1	91.3
1972-	11	0.7	69.7	65.9	3.8	7.2	7.2	0	0	0	126.6	161
1972-	12	-3.9	99	5.3	17.6	0.4	0.4	0	0	76.1	149	260
1973-	1	-5.4	28.1	4.6	51.9	1.5	1.5	0	54	47.7	150	288.1
1973-	2	-8	27.7	15.7	12.4	0.3	0.3	0	27.8	47.3	150	315.8
1973-	3	2.8	110.9	110.9	47.3	16.6	16.6	0	141.7	0	150	426.7
1973-	4	6.4	72	72	0	34.4	34.4	0	37.6	0	150	498.7
1973-	5	11	87.7	87.7	0	66.3	66.3	0	21.4	0	150	586.4
1973-	6	18.9	67.1	67.1	0	119.3	119.3	0	0	0	97.8	653.5
1973-	7	20.5	57.9	57.9	0	131.8	131.8	0	0	0	23.9	711.4
1973-	8	21.5	91.9	91.9	0	128.9	101.7	-27.2	0	0	14.1	803.3
1973-	9	15.3	39.9	39.9	0	78.5	45.9	-32.6	0	0	8	843.2
1973-	10	10.7	97.3	97.3	0	48.7	48.7	0	0	0	56.6	97.3
1973-	11	2.9	75.3	74.5	0.8	11.9	11.9	0	0	0	120	172.6
1973-	12	-4.8	74.1	26.7	15.6	2.6	2.6	0	9.8	31.8	150	246.7
1974-	1	-6.8	65.4	2	30.1	0.8	0.8	0	31.3	65.1	150	312.1
1974-	2	-8.9	48.8	12.8	18.1	0.6	0.6	0	30.4	82.9	150	360.9
1974-	3	-2	60	44.5	96.1	3.7	3.7	0	136.8	2.3	150	420.9
1974-	4	7.3	87.1	87.1	2.3	39.6	39.6	0	49.8	0	150	508
1974-	5	10.4	111.9	111.9	0	62.9	62.9	0	49	0	150	619.9
1974-	6	16.9	97.7	97.7	0	105.6	105.6	0	0	0	142.1	717.6
1974-	7	20.3	75.2	75.2	0	130.6	130.6	0	0	0	86.7	792.8
1974-	8	19.8	51.3	51.3	0	117.7	115.3	-2.4	0	0	22.8	844.1
1974-	9	13.8	48.1	48.1	0	69.8	53.6	-16.2	0	0	17.3	892.2
1974-	10	6.7	35.4	35.4	0	30.2	30.2	0	0	0	22.5	35.4
1974-	11	2.5	81	67.5	0.5	13.8	13.8	0	0	13	76.6	116.4
1974-	12	-2	38.6	8.4	38.1	0.9	0.9	0	0	5.1	122.2	155
1975-	1	-4.7	36.6	20.3	9.3	1.6	1.6	0	0.3	12.1	150	191.6
1975-	2	-4.9	76.7	45.6	27.3	0.7	0.7	0	72.2	15.9	150	268.3
1975-	3	-3.2	67.2	41.2	38.1	2.5	2.5	0	76.9	3.8	150	335.5
1975-	4	2.3	74.5	41.4	36.9	19.9	19.9	0	58.4	0	150	410
1975-	5	16.2	48.8	48.8	0	100.5	100.5	0	0	0	98.3	458.8
1975-	6	18.5	74.2	74.2	0	117.1	117.1	0	0	0	55.4	533
1975-	7	21.4	48	48	0	138.2	103.4	-34.8	0	0	0	581
1975-	8	19.6	66.6	66.6	0	117	66.6	-50.4	0	0	0	647.6
1975-	9	13.3	52.3	52.3	0	67	52.3	-14.7	0	0	0	699.9
1975-	10	9.9	38.7	38.7	0	44.7	38.7	-6	0	0	0	38.7
1975-	11	5.7	56.7	44	12.7	22.6	22.6	0	0	0	34.1	95.4
1975-	12	-5.8	106.6	17	31.5	1.1	1.1	0	0	58.1	81.6	202
1976-	1	-10.1	66.8	0	0	0	0	0	0	124.9	81.6	268.8
1976-	2	-3.9	28.1	25.6	67.4	2.2	2.2	0	22.4	60	150	296.9
1976-	3	-0.9	97.9	33.4	124.5	10.1	10.1	0	147.8	0	150	394.8
1976-	4	7.7	50.8	50.8	0	41.7	41.7	0	9.1	0	150	445.6
1976-	5	10.4	87.4	87.4	0	62.9	62.9	0	24.5	0	150	533
1976-	6	19.1	65.1	65.1	0	120.6	120.6	0	0	0	94.5	598.1
1976-	7	18.7	156.9	156.9	0	119.9	119.9	0	0	0	131.6	755
1976-	8	18.4	39.4	39.4	0	109.1	109.1	0	0	0	61.9	794.4
1976-	9	14.1	51.5	51.5	0	71.6	65.3	-6.3	0	0	48	845.9
1976-	10	6	60.1	60.1	0	27.6	27.6	0	0	0	80.6	60.1
1976-	11	-0.5	17.7	8.1	9.6	3.8	3.8	0	0	0	94.4	77.8
1976-	12	-9	44.8	0	0	0	0	0	0	44.8	94.4	122.6
1977-	1	-12.6	60.7	0	0	0	0	0	0	105.5	94.4	183.3
1977-	2	-7.3	34.5	5	10.6	0.2	0.2	0	0	124.4	109.8	217.8
1977-	3	1.7	74.5	60.8	138.1	15.6	15.6	0	143.1	0	150	292.3
1977-	4	7.3	50.6	50.6	0	41.3	41.3	0	9.3	0	150	342.9
1977-	5	14.7	51	51	0	90.9	90.9	0	0	0	110.1	393.9
1977-	6	16.7	65.1	65.1	0	104.7	104.7	0	0	0	70.5	459
1977-	7	20	139.6	139.6	0	128.6	128.6	0	0	0	81.5	598.6

Table F1-2b: AES Thornthwaite SMC=150mm - summary. Stouffville WPCP #6158084.
Stouffville, Ontario Water Budget Values for the Period 1972-1991 DC20492 Calculated Daily
Method: AES Thornthwaite and Mather (Johnstone and Louie, 1983) SMC = 150 mm

YR	MO	TEMP(C)	PCPN	RAIN	MELT	PE	AE	DEF	SURP	SNOW	SOIL	ACC P
1977-	8	18.3	123.6	123.6	0	108.6	108.6	0	0	0	96.5	722.2
1977-	9	15	136	136	0	76.2	76.2	0	6.2	0	150	858.2
1977-	10	7.6	73.8	73.8	0	33.4	33.4	0	40.4	0	150	73.8
1977-	11	3.4	102.8	91.6	0.2	17.5	17.5	0	74.3	11	150	176.6
1977-	12	-5.5	67.3	13.9	28	1.1	1.1	0	40.8	36.4	150	243.9
1978-	1	-9.8	66	15	3.1	0	0	0	18	84.3	150	309.9
1978-	2	-10.8	14.1	0	0	0	0	0	0	98.4	150	324
1978-	3	-4.3	40.6	0.4	34.2	1.3	1.3	0	33.3	104.4	150	364.6
1978-	4	4.2	71.6	70.6	105.4	22.1	22.1	0	154	0	150	436.2
1978-	5	13.7	95	95	0	84.9	84.9	0	10.1	0	150	531.2
1978-	6	17	31.6	31.6	0	107	107	0	0	0	74.6	562.8
1978-	7	20.5	27.6	27.6	0	132.1	102.2	-29.9	0	0	0	590.4
1978-	8	19.9	119.1	119.1	0	118.5	118.5	0	0	0	0.6	709.5
1978-	9	14.3	125.9	125.9	0	72.9	72.9	0	0	0	53.6	835.4
1978-	10	7.7	49.5	49.5	0	34.4	34.4	0	0	0	68.8	49.5
1978-	11	2.1	57.6	51.6	0	12.9	12.9	0	0	6	107.4	107.1
1978-	12	-3.9	37.5	15.5	21	0.4	0.4	0	0	7	143.5	144.6
1979-	1	-8.7	74.5	0	6.9	0.1	0.1	0	0.3	74.6	150	219.1
1979-	2	-11.6	21	0	8	0.2	0.2	0	7.8	87.6	150	240.1
1979-	3	1	36.6	35.4	88.8	12.3	12.3	0	112	0	150	276.7
1979-	4	5	78.7	76.7	2	28.2	28.2	0	50.5	0	150	355.4
1979-	5	12.1	77.8	77.8	0	73.6	73.6	0	4.2	0	150	433.2
1979-	6	17.6	72.8	72.8	0	110.8	110.8	0	0	0	112	506
1979-	7	20.6	55.8	55.8	0	132.7	132.7	0	0	0	35.1	561.8
1979-	8	18.8	77.8	77.8	0	111.4	90.9	-20.5	0	0	22	639.6
1979-	9	15	56.4	56.4	0	76.4	61.3	-15.1	0	0	17.1	696
1979-	10	7.7	143.2	143.2	0	34.7	34.7	0	0	0	125.6	143.2
1979-	11	3.6	93.2	88.6	4.6	14.3	14.3	0	54.6	0	150	236.4
1979-	12	-2.4	86.2	67	19.2	2.5	2.5	0	83.7	0	150	322.6
1980-	1	-6.1	61.9	30	20	0.4	0.4	0	49.6	11.9	150	384.5
1980-	2	-8.4	14.6	1	9.3	0.2	0.2	0	10.1	16.2	150	399.1
1980-	3	-3.3	84.5	58.4	42.3	5.1	5.1	0	95.6	0	150	483.6
1980-	4	6.2	120.4	120.4	0	32.7	32.7	0	87.7	0	150	604
1980-	5	14.5	35.9	35.9	0	89.2	89.2	0	0	0	96.7	639.9
1980-	6	14.7	91.9	91.9	0	91.6	91.6	0	0	0	97	731.8
1980-	7	20.3	140.7	140.7	0	130.6	130.6	0	0	0	107.1	872.5
1980-	8	20.8	67.9	67.9	0	124.1	124.1	0	0	0	50.9	940.4
1980-	9	14.4	70.8	70.8	0	73.6	72.4	-1.2	0	0	49.4	1011.2
1980-	10	6.3	95.9	95.9	0	27.9	27.9	0	0	0	117.3	95.9
1980-	11	0.6	60.1	51.3	8.8	5.4	5.4	0	22	0	150	156
1980-	12	-7.7	84.7	50.1	8.2	1.1	1.1	0	57.2	26.4	150	240.7
1981-	1	-11.9	25.5	0	3	0	0	0	2.9	48.9	150	266.2
1981-	2	-3.2	92.5	39	102.4	5.3	5.3	0	136.1	0	150	358.7
1981-	3	-0.5	33.3	23.1	10.2	9.2	9.2	0	24.1	0	150	392
1981-	4	6.7	46.3	46.3	0	35.1	35.1	0	11.2	0	150	438.3
1981-	5	11.7	95.2	95.2	0	71	71	0	24.2	0	150	533.5
1981-	6	17.4	76.3	76.3	0	109.2	109.2	0	0	0	117.1	609.8
1981-	7	20.6	69.2	69.2	0	133.2	133.2	0	0	0	53.1	679
1981-	8	19.2	94.1	94.1	0	114.4	106	-8.3	0	0	41.1	773.1
1981-	9	14	100.9	100.9	0	71.3	71.3	0	0	0	70.8	874
1981-	10	6	140.7	140.7	0	26.1	26.1	0	35.3	0	150	140.7
1981-	11	2.9	63.2	62.2	1	12.6	12.6	0	50.6	0	150	203.9
1981-	12	-4.5	51.7	5	9.3	0.4	0.4	0	13.9	37.4	150	255.6
1982-	1	-11.4	76	5.8	10.9	0.3	0.3	0	16.5	96.7	150	331.6
1982-	2	-8	51.5	3	0	0	0	0	3	145.2	150	383.1
1982-	3	-2.9	72.9	48.2	92.6	3.3	3.3	0	137.4	77.3	150	456
1982-	4	3.8	49.5	37.5	89.3	26.7	26.7	0	100.1	0	150	505.5
1982-	5	14.8	45.3	45.3	0	90.9	90.9	0	0	0	104.4	550.8
1982-	6	15.6	148.5	148.5	0	96.9	96.9	0	6	0	150	699.3
1982-	7	20.7	118.4	118.4	0	133.5	133.5	0	0	0	134.9	817.7
1982-	8	16.9	92.4	92.4	0	99.8	99.8	0	0	0	127.6	910.1
1982-	9	14.5	73.8	73.8	0	73.2	73.2	0	0	0	128.2	983.9
1982-	10	9.6	59.8	59.8	0	43.1	43.1	0	0	0	144.9	59.8
1982-	11	3.4	124.5	111.3	13.2	15.1	15.1	0	104.3	0	150	184.3
1982-	12	-0.4	90.2	67.2	23	8.4	8.4	0	81.8	0	150	274.5
1983-	1	-5.1	47.8	12.8	19.1	0.4	0.4	0	31.5	15.9	150	322.3
1983-	2	-4.2	49.5	18.2	47.2	1.5	1.5	0	63.9	0	150	371.8

Table F1-2b: AES Thornthwaite SMC=150mm - summary. Stouffville WPCP #6158084.
Stouffville, Ontario Water Budget Values for the Period 1972-1991 DC20492 Calculated Daily
Method: AES Thornthwaite and Mather (Johnstone and Louie, 1983) SMC = 150 mm

YR	MO	TEMP(C)	PCPN	RAIN	MELT	PE	AE	DEF	SURP	SNOW	SOIL	ACC P
1983-	3	0.3	58.6	38.8	13.7	10.2	10.2	0	42.3	6.1	150	430.4
1983-	4	5.1	95.9	95.9	6.1	26.4	26.4	0	75.6	0	150	526.3
1983-	5	10	109.5	109.5	0	59.8	59.8	0	49.7	0	150	635.8
1983-	6	18.3	28.1	28.1	0	115.6	115.6	0	0	0	62.5	663.9
1983-	7	22.1	50.4	50.4	0	143.2	112.9	-30.4	0	0	0	714.3
1983-	8	21	111.4	111.4	0	125.8	111.4	-14.4	0	0	0	825.7
1983-	9	16.4	64.6	64.6	0	84.5	64.6	-19.9	0	0	0	890.3
1983-	10	9.4	81.8	81.8	0	42.8	42.8	0	0	0	39	81.8
1983-	11	2.4	122.7	122.7	0	12.2	12.2	0	0	0	149.5	204.5
1983-	12	-6.9	82.6	25	15	0.3	0.3	0	39.3	42.6	150	287.1
1984-	1	-9.8	44.7	6	3	0	0	0	8.9	78.3	150	331.8
1984-	2	-1.9	78.3	49.5	86.1	4.8	4.8	0	130.8	21	150	410.1
1984-	3	-5	75.6	47.2	49.4	2.7	2.7	0	93.9	0	150	485.7
1984-	4	7.2	53.8	53.8	0	37.5	37.5	0	16.3	0	150	539.5
1984-	5	10.2	124	124	0	61.6	61.6	0	62.4	0	150	663.5
1984-	6	18.3	58.8	58.8	0	115.4	115.4	0	0	0	93.4	722.3
1984-	7	19.8	63.5	63.5	0	127.2	127.2	0	0	0	29.7	785.8
1984-	8	20.8	98	98	0	124.9	106.9	-18.1	0	0	20.8	883.8
1984-	9	13.7	111.7	111.7	0	69.4	69.4	0	0	0	63.1	995.5
1984-	10	10.4	47.8	47.8	0	46.6	46.6	0	0	0	64.3	47.8
1984-	11	2.9	56.5	56.5	0	13.2	13.2	0	0	0	107.6	104.3
1984-	12	-1.1	69.2	17.9	35.9	3.5	3.5	0	7.9	15.4	150	173.5
1985-	1	-8.8	74.4	0	0	0	0	0	0	89.8	150	247.9
1985-	2	-6.4	122.8	67.3	34.5	1.1	1.1	0	100.7	110.8	150	370.7
1985-	3	-0.7	78.9	41.9	139.4	5.3	5.3	0	176	8.4	150	449.6
1985-	4	6.9	27.1	19.5	16	39.6	39.6	0	0	0	145.9	476.7
1985-	5	13.2	108	108	0	80.4	80.4	0	23.4	0	150	584.7
1985-	6	15.4	69.4	69.4	0	96.1	96.1	0	0	0	123.3	654.1
1985-	7	19.7	59.2	59.2	0	126.4	126.4	0	0	0	56.2	713.3
1985-	8	19	124.8	124.8	0	113	113	0	0	0	68	838.1
1985-	9	16.7	69	69	0	85.5	81.4	-4	0	0	55.5	907.1
1985-	10	9.5	69.1	69.1	0	42.4	42.4	0	0	0	82.2	69.1
1985-	11	2.3	142.2	136	4.7	11.2	11.2	0	61.8	1.5	150	211.3
1985-	12	-6.1	60.6	7.8	1.5	0.7	0.7	0	8.6	52.8	150	271.9
1986-	1	-6.9	41.8	13.6	30.2	0.7	0.7	0	43.1	50.8	150	313.7
1986-	2	-7.3	48	5.4	11	0.3	0.3	0	16.1	82.4	150	361.7
1986-	3	-0.2	54.4	30.6	106.2	12.9	12.9	0	123.9	0	150	416.1
1986-	4	7.9	39.3	39.3	0	41.8	41.8	0	0	0	147.5	455.4
1986-	5	14.7	66.3	66.3	0	90.9	90.9	0	0	0	122.8	521.7
1986-	6	16.4	127	127	0	102.9	102.9	0	0	0	146.9	648.7
1986-	7	20.6	81.4	81.4	0	132.9	132.9	0	0	0	95.5	730.1
1986-	8	18.1	202.2	202.2	0	107.2	107.2	0	40.5	0	150	932.3
1986-	9	14.3	198	198	0	72.2	72.2	0	125.8	0	150	1130.3
1986-	10	8.5	64.8	64.8	0	38	38	0	26.8	0	150	64.8
1986-	11	1.2	37.2	21.2	16	8.7	8.7	0	28.5	0	150	102
1986-	12	-2.1	62.1	27.1	33.1	0.7	0.7	0	59.5	1.9	150	164.1
1987-	1	-5.4	51	3.8	15.7	0.4	0.4	0	19.1	33.5	150	215.1
1987-	2	-6.2	28.2	8	9.6	0.2	0.2	0	17.4	44	150	243.3
1987-	3	1.4	59.1	37.1	44	14.6	14.6	0	66.5	22	150	302.4
1987-	4	8.9	47.3	44.7	24.6	48.3	48.3	0	21	0	150	349.7
1987-	5	14.3	102.4	102.4	0	88.2	88.2	0	14.2	0	150	452.1
1987-	6	19.1	79.2	79.2	0	120.6	120.6	0	0	0	108.6	531.3
1987-	7	22	67.9	67.9	0	142.8	142.8	0	0	0	33.7	599.2
1987-	8	18.8	79.2	79.2	0	111.8	91.4	-20.4	0	0	21.5	678.4
1987-	9	15.3	70	70	0	77.9	71.9	-6	0	0	19.6	748.4
1987-	10	6.9	54.8	54.8	0	30.5	30.5	0	0	0	43.9	54.8
1987-	11	2.7	92.5	88.5	4	13.8	13.8	0	0	0	122.6	147.3
1987-	12	-1.4	67	43.2	23.8	2.8	2.8	0	36.8	0	150	214.3
1988-	1	-6.1	43.6	25.6	18	2.2	2.2	0	41.4	0	150	257.9
1988-	2	-6.9	77.3	8.7	8	0.2	0.2	0	16.4	60.6	150	335.2
1988-	3	-1.7	39.5	29.9	70.2	6.8	6.8	0	93.4	0	150	374.7
1988-	4	5.7	76.2	76.2	0	29	29	0	47.2	0	150	450.9
1988-	5	14.1	85.8	85.8	0	86.8	86.8	0	0	0	149	536.7
1988-	6	17.8	56	56	0	112.2	112.2	0	0	0	92.8	592.7
1988-	7	22.8	40	40	0	147.9	132.8	-15.1	0	0	0	632.7
1988-	8	20.8	86	86	0	125.3	86	-39.3	0	0	0	718.7
1988-	9	14.7	79.4	79.4	0	74.6	74.6	0	0	0	4.8	798.1

Table F1-2b: AES Thornthwaite SMC=150mm - summary. Stouffville WPCP #6158084.
Stouffville, Ontario Water Budget Values for the Period 1972-1991 DC20492 Calculated Daily
Method: AES Thornthwaite and Mather (Johnstone and Louie, 1983) SMC = 150 mm

YR	MO	TEMP(C)	PCPN	RAIN	MELT	PE	AE	DEF	SURP	SNOW	SOIL	ACC P
1988-	10	6.5	89.4	89.4	0	28.9	28.9	0	0	0	65.3	89.4
1988-	11	4.1	72.2	72.2	0	14.9	14.9	0	0	0	122.7	161.6
1988-	12	-3.9	51.8	8	17.8	1.6	1.6	0	0	26	146.9	213.4
1989-	1	-3.4	44.8	16.4	54.4	1.5	1.5	0	66.2	0	150	258.2
1989-	2	-7	32.6	6.6	8.6	0.2	0.2	0	15	17.4	150	290.8
1989-	3	-3.1	36	10.6	42.8	5.9	5.9	0	47.4	0	150	326.8
1989-	4	4.7	49.4	48.6	0.8	24.7	24.7	0	24.7	0	150	376.2
1989-	5	13	125.6	125.6	0	79.6	79.6	0	46	0	150	501.8
1989-	6	18.5	96.6	96.6	0	116.5	116.5	0	0	0	130.1	598.4
1989-	7	21.9	6.2	6.2	0	141.9	136.3	-5.6	0	0	0	604.6
1989-	8	19.4	144.2	144.2	0	115.8	115.8	0	0	0	28.4	748.8
1989-	9	15	72.2	72.2	0	76.8	73.6	-3.1	0	0	26.9	821
1989-	10	9.5	93.4	93.4	0	42.4	42.4	0	0	0	77.9	93.4
1989-	11	1.4	124	107.6	11.4	10.5	10.5	0	36.4	5	150	217.4
1989-	12	-11	44.2	0	0	0	0	0	0	49.2	150	261.6
1990-	1	-2.2	58.9	30.1	56.4	1.4	1.4	0	85.1	21.6	150	320.5
1990-	2	-4.6	61.8	23.2	36.9	1.7	1.7	0	58.3	23.4	150	382.3
1990-	3	0	43.1	39.2	27.3	12.2	12.2	0	54.2	0	150	425.4
1990-	4	7.9	55.4	55.4	0	43.7	43.7	0	11.7	0	150	480.8
1990-	5	11.4	63.7	63.7	0	68.8	68.8	0	0	0	144.9	544.5
1990-	6	18.1	86.7	86.7	0	113.8	113.8	0	0	0	117.8	631.2
1990-	7	20.3	68	68	0	130.4	130.4	0	0	0	55.5	699.2
1990-	8	19.8	99	99	0	117.8	110.6	-7.2	0	0	43.9	798.2
1990-	9	14.6	66.6	66.6	0	74.4	70.4	-4	0	0	40.1	864.8
1990-	10	8.7	126.5	126.5	0	39.3	39.3	0	0	0	127.3	126.5
1990-	11	3.7	53.9	53.9	0	14.7	14.7	0	16.5	0	150	180.4
1990-	12	-1.9	117.6	59.9	57.5	2.5	2.5	0	114.9	0.2	150	298
1991-	1	-7.1	45	6.6	19.9	0.4	0.4	0	26.1	18.7	150	343
1991-	2	-3.6	26.4	3.7	36.6	3	3	0	37.3	4.8	150	369.4
1991-	3	0.3	115.9	72.8	46.1	9	9	0	109.9	1.8	150	485.3
1991-	4	8	74.3	74.3	1.8	42.3	42.3	0	33.8	0	150	559.6
1991-	5	16	64.8	64.8	0	99.6	99.6	0	0	0	115.2	624.4
1991-	6	19.9	58.6	58.6	0	126.6	126.6	0	0	0	47.2	683
1991-	7	21.1	61.3	61.3	0	136.1	100.5	-35.6	0	0	8	744.3
1991-	8	20.8	59.9	59.9	0	124	65.6	-58.4	0	0	2.3	804.2
1991-	9	14.7	62.4	62.4	0	75.7	62.7	-13	0	0	2	866.6
1991-	10	9.9	91.5	91.5	0	44.7	44.7	0	0	0	48.7	91.5
1991-	11	1.9	67.2	67.2	0	9.9	9.9	0	0	0	106	158.7
1991-	12	-3.5	50.2	16.4	27.5	2.9	2.9	0	0	6.3	147	208.9

Table F1-3a: AES Thornthwaite SMC=200mm - summary. Stouffville WPCP #6158084.

AES, Thornthwaite and Mather, calculated daily, summarized monthly R. Gerber
Oct. 21, 2001

Stouffville, Ontario WATER BUDGET MEANS FOR THE PERIOD 1972-1991 DC20492

LAT.... 43.97 WATER HOLDING CAPACITY...200 MM HEAT INDEX... 36.31
LONG... 79.24 LOWER ZONE...............120 MM A............ 1.074

DATE	TEMP (C)		PCPN	RAIN	MELT	PE	AE	DEF	SURP	SNOW	SOIL	ACC P
31- 1	-7.5		52	10	18	1	1	0	21	50	186	282
28- 2	-6.6		50	17	27	1	1	0	36	56	193	332
31- 3	-1.3		65	41	64	8	8	0	91	17	199	397
30- 4	6.1		64	60	20	34	34	0	46	0	200	461
31- 5	13.0		82	82	0	80	80	0	16	0	186	545
30- 6	17.5		75	75	0	110	110	0	0	0	151	621
31- 7	20.7		71	71	0	133	132	-2	0	0	89	694
31- 8	19.5		95	95	0	116	106	-10	2	0	76	790
30- 9	14.7		81	81	0	75	70	-5	7	0	81	872
31-10	8.2		80	80	0	37	36	0	5	0	120	80
30-11	2.5		79	72	5	12	12	0	21	2	163	159
31-12	-4.4		69	24	21	2	2	0	25	26	182	226
AVE	6.9	TTL	864	708	155	609	592	-17	270			

Stouffville, Ontario STANDARD DEVIATIONS FOR THE PERIOD 1972-1991 DC20492

DATE	TEMP (C)	PCPN	RAIN	MELT	PE	AE	DEF	SURP	SNOW	SOIL	ACC P
31- 1	2.8	16	10	18	1	1	0	22	38	30	55
28- 2	2.6	29	19	29	2	2	0	43	44	17	57
31- 3	2.2	24	23	40	5	5	0	47	35	3	66
30- 4	1.8	22	24	37	9	9	0	43	0	1	73
31- 5	2.0	27	27	0	13	13	0	20	0	20	75
30- 6	1.4	28	28	0	9	9	0	1	0	30	77
31- 7	1.0	40	40	0	7	7	4	0	0	54	90
31- 8	1.2	37	37	0	8	13	14	9	0	54	90
30- 9	.8	38	38	0	5	7	7	28	0	58	106
31-10	1.6	31	31	0	7	7	1	12	0	56	32
30-11	1.4	32	32	5	4	4	0	30	4	42	47
31-12	2.8	23	22	14	2	2	0	36	23	28	56

Table F1-3b: AES Thornthwaite SMC=200mm - summary. Stouffville WPCP #6158084.
Stouffville, Ontario Water Budget Values for the Period 1972-1991 DC20492 Calculated Daily
Method: AES Thornthwaite and Mather (Johnstone and Louie, 1983) SMC = 200 mm

YR	MO	TEMP(C)	PCPN	RAIN	MELT	PE	AE	DEF	SURP	SNOW	SOIL	ACC P
1972-	1	-7.5	34.1	10.2	2.3	0	0	0	0	21.6	132.5	34.1
1972-	2	-9.1	70.6	5.1	0	0	0	0	0	87.1	137.6	104.7
1972-	3	-4.8	68.6	22.9	26.9	0.8	0.8	0	0	105.9	186.6	173.3
1972-	4	2.6	50	42.4	113.5	19.3	19.3	0	123.2	0	200	223.3
1972-	5	13.6	60.9	60.9	0	83.5	83.5	0	0	0	177.4	284.2
1972-	6	15.9	54.4	54.4	0	99.5	99.5	0	0	0	132.3	338.6
1972-	7	20.1	25.1	25.1	0	129.6	129.6	0	0	0	27.7	363.7
1972-	8	18.2	73.8	73.8	0	107.3	81.5	-25.7	0	0	20	437.5
1972-	9	15.6	64.6	64.6	0	79.5	67.1	-12.4	0	0	17.5	502.1
1972-	10	6	91.3	91.3	0	27.2	27.2	0	0	0	81.6	91.3
1972-	11	0.7	69.7	65.9	3.8	7.2	7.2	0	0	0	144.1	161
1972-	12	-3.9	99	5.3	17.6	0.4	0.4	0	0	76.1	166.6	260
1973-	1	-5.4	28.1	4.6	51.9	1.5	1.5	0	21.6	47.7	200	288.1
1973-	2	-8	27.7	15.7	12.4	0.3	0.3	0	27.8	47.3	200	315.8
1973-	3	2.8	110.9	110.9	47.3	16.6	16.6	0	141.7	0	200	426.7
1973-	4	6.4	72	72	0	34.4	34.4	0	37.6	0	200	498.7
1973-	5	11	87.7	87.7	0	66.3	66.3	0	21.4	0	200	586.4
1973-	6	18.9	67.1	67.1	0	119.3	119.3	0	0	0	147.8	653.5
1973-	7	20.5	57.9	57.9	0	131.8	131.8	0	0	0	73.9	711.4
1973-	8	21.5	91.9	91.9	0	128.9	114.7	-14.2	0	0	51.1	803.3
1973-	9	15.3	39.9	39.9	0	78.5	56.3	-22.2	0	0	34.7	843.2
1973-	10	10.7	97.3	97.3	0	48.7	48.7	0	0	0	83.3	97.3
1973-	11	2.9	75.3	74.5	0.8	11.9	11.9	0	0	0	146.6	172.6
1973-	12	-4.8	74.1	26.7	15.6	2.6	2.6	0	0	31.8	186.4	246.7
1974-	1	-6.8	65.4	2	30.1	0.8	0.8	0	17.7	65.1	200	312.1
1974-	2	-8.9	48.8	12.8	18.1	0.6	0.6	0	30.4	82.9	200	360.9
1974-	3	-2	60	44.5	96.1	3.7	3.7	0	136.8	2.3	200	420.9
1974-	4	7.3	87.1	87.1	2.3	39.6	39.6	0	49.8	0	200	508
1974-	5	10.4	111.9	111.9	0	62.9	62.9	0	49	0	200	619.9
1974-	6	16.9	97.7	97.7	0	105.6	105.6	0	0	0	192.1	717.6
1974-	7	20.3	75.2	75.2	0	130.6	130.6	0	0	0	136.7	792.8
1974-	8	19.8	51.3	51.3	0	117.7	117.7	0	0	0	70.4	844.1
1974-	9	13.8	48.1	48.1	0	69.8	60.8	-9	0	0	57.6	892.2
1974-	10	6.7	35.4	35.4	0	30.2	30.2	0	0	0	62.8	35.4
1974-	11	2.5	81	67.5	0.5	13.8	13.8	0	0	13	117	116.4
1974-	12	-2	38.6	8.4	38.1	0.9	0.9	0	0	5.1	162.6	155
1975-	1	-4.7	36.6	20.3	9.3	1.6	1.6	0	0	12.1	190.6	191.6
1975-	2	-4.9	76.7	45.6	27.3	0.7	0.7	0	62.8	15.9	200	268.3
1975-	3	-3.2	67.2	41.2	38.1	2.5	2.5	0	76.9	3.8	200	335.5
1975-	4	2.3	74.5	41.4	36.9	19.9	19.9	0	58.4	0	200	410
1975-	5	16.2	48.8	48.8	0	100.5	100.5	0	0	0	148.3	458.8
1975-	6	18.5	74.2	74.2	0	117.1	117.1	0	0	0	105.4	533
1975-	7	21.4	48	48	0	138.2	127.2	-11	0	0	26.2	581
1975-	8	19.6	66.6	66.6	0	117	77.6	-39.4	0	0	15.2	647.6
1975-	9	13.3	52.3	52.3	0	67	54.2	-12.9	0	0	13.3	699.9
1975-	10	9.9	38.7	38.7	0	44.7	39.4	-5.4	0	0	12.6	38.7
1975-	11	5.7	56.7	44	12.7	22.6	22.6	0	0	0	46.8	95.4
1975-	12	-5.8	106.6	17	31.5	1.1	1.1	0	0	58.1	94.2	202
1976-	1	-10.1	66.8	0	0	0	0	0	0	124.9	94.2	268.8
1976-	2	-3.9	28.1	25.6	67.4	2.2	2.2	0	0	60	185	296.9
1976-	3	-0.9	97.9	33.4	124.5	10.1	10.1	0	132.8	0	200	394.8
1976-	4	7.7	50.8	50.8	0	41.7	41.7	0	9.1	0	200	445.6
1976-	5	10.4	87.4	87.4	0	62.9	62.9	0	24.5	0	200	533
1976-	6	19.1	65.1	65.1	0	120.6	120.6	0	0	0	144.5	598.1
1976-	7	18.7	156.9	156.9	0	119.9	119.9	0	0	0	181.6	755
1976-	8	18.4	39.4	39.4	0	109.1	109.1	0	0	0	111.9	794.4
1976-	9	14.1	51.5	51.5	0	71.6	70.3	-1.4	0	0	93.1	845.9
1976-	10	6	60.1	60.1	0	27.6	27.6	0	0	0	125.6	60.1
1976-	11	-0.5	17.7	8.1	9.6	3.8	3.8	0	0	0	139.5	77.8
1976-	12	-9	44.8	0	0	0	0	0	0	44.8	139.5	122.6
1977-	1	-12.6	60.7	0	0	0	0	0	0	105.5	139.5	183.3
1977-	2	-7.3	34.5	5	10.6	0.2	0.2	0	0	124.4	154.9	217.8
1977-	3	1.7	74.5	60.8	138.1	15.6	15.6	0	138.1	0	200	292.3
1977-	4	7.3	50.6	50.6	0	41.3	41.3	0	9.3	0	200	342.9
1977-	5	14.7	51	51	0	90.9	90.9	0	0	0	160.1	393.9
1977-	6	16.7	65.1	65.1	0	104.7	104.7	0	0	0	120.5	459
1977-	7	20	139.6	139.6	0	128.6	128.6	0	0	0	131.5	598.6

Table F1-3b: AES Thornthwaite SMC=200mm - summary. Stouffville WPCP #6158084.
Stouffville, Ontario Water Budget Values for the Period 1972-1991 DC20492 Calculated Daily
Method: AES Thornthwaite and Mather (Johnstone and Louie, 1983) SMC = 200 mm

YR	MO	TEMP(C)	PCPN	RAIN	MELT	PE	AE	DEF	SURP	SNOW	SOIL	ACC P
1977-	8	18.3	123.6	123.6	0	108.6	108.6	0	0	0	146.5	722.2
1977-	9	15	136	136	0	76.2	76.2	0	6.2	0	200	858.2
1977-	10	7.6	73.8	73.8	0	33.4	33.4	0	40.4	0	200	73.8
1977-	11	3.4	102.8	91.6	0.2	17.5	17.5	0	74.3	11	200	176.6
1977-	12	-5.5	67.3	13.9	28	1.1	1.1	0	40.8	36.4	200	243.9
1978-	1	-9.8	66	15	3.1	0	0	0	18	84.3	200	309.9
1978-	2	-10.8	14.1	0	0	0	0	0	0	98.4	200	324
1978-	3	-4.3	40.6	0.4	34.2	1.3	1.3	0	33.3	104.4	200	364.6
1978-	4	4.2	71.6	70.6	105.4	22.1	22.1	0	154	0	200	436.2
1978-	5	13.7	95	95	0	84.9	84.9	0	10.1	0	200	531.2
1978-	6	17	31.6	31.6	0	107	107	0	0	0	124.6	562.8
1978-	7	20.5	27.6	27.6	0	132.1	132.1	0	0	0	20.1	590.4
1978-	8	19.9	119.1	119.1	0	118.5	118.5	0	0	0	20.7	709.5
1978-	9	14.3	125.9	125.9	0	72.9	72.9	0	0	0	73.8	835.4
1978-	10	7.7	49.5	49.5	0	34.4	34.4	0	0	0	88.9	49.5
1978-	11	2.1	57.6	51.6	0	12.9	12.9	0	0	6	127.5	107.1
1978-	12	-3.9	37.5	15.5	21	0.4	0.4	0	0	7	163.6	144.6
1979-	1	-8.7	74.5	0	6.9	0.1	0.1	0	0	74.6	170.4	219.1
1979-	2	-11.6	21	0	8	0.2	0.2	0	0	87.6	178.1	240.1
1979-	3	1	36.6	35.4	88.8	12.3	12.3	0	90.1	0	200	276.7
1979-	4	5	78.7	76.7	2	28.2	28.2	0	50.5	0	200	355.4
1979-	5	12.1	77.8	77.8	0	73.6	73.6	0	4.2	0	200	433.2
1979-	6	17.6	72.8	72.8	0	110.8	110.8	0	0	0	162	506
1979-	7	20.6	55.8	55.8	0	132.7	132.7	0	0	0	85.1	561.8
1979-	8	18.8	77.8	77.8	0	111.4	101.6	-9.8	0	0	61.3	639.6
1979-	9	15	56.4	56.4	0	76.4	66.6	-9.8	0	0	51.1	696
1979-	10	7.7	143.2	143.2	0	34.7	34.7	0	0	0	159.6	143.2
1979-	11	3.6	93.2	88.6	4.6	14.3	14.3	0	38.5	0	200	236.4
1979-	12	-2.4	86.2	67	19.2	2.5	2.5	0	83.7	0	200	322.6
1980-	1	-6.1	61.9	30	20	0.4	0.4	0	49.6	11.9	200	384.5
1980-	2	-8.4	14.6	1	9.3	0.2	0.2	0	10.1	16.2	200	399.1
1980-	3	-3.3	84.5	58.4	42.3	5.1	5.1	0	95.6	0	200	483.6
1980-	4	6.2	120.4	120.4	0	32.7	32.7	0	87.7	0	200	604
1980-	5	14.5	35.9	35.9	0	89.2	89.2	0	0	0	146.7	639.9
1980-	6	14.7	91.9	91.9	0	91.6	91.6	0	0	0	147	731.8
1980-	7	20.3	140.7	140.7	0	130.6	130.6	0	0	0	157.1	872.5
1980-	8	20.8	67.9	67.9	0	124.1	124.1	0	0	0	100.9	940.4
1980-	9	14.4	70.8	70.8	0	73.6	73.1	-0.4	0	0	98.6	1011.2
1980-	10	6.3	95.9	95.9	0	27.9	27.9	0	0	0	166.6	95.9
1980-	11	0.6	60.1	51.3	8.8	5.4	5.4	0	21.2	0	200	156
1980-	12	-7.7	84.7	50.1	8.2	1.1	1.1	0	57.2	26.4	200	240.7
1981-	1	-11.9	25.5	0	3	0	0	0	2.9	48.9	200	266.2
1981-	2	-3.2	92.5	39	102.4	5.3	5.3	0	136.1	0	200	358.7
1981-	3	-0.5	33.3	23.1	10.2	9.2	9.2	0	24.1	0	200	392
1981-	4	6.7	46.3	46.3	0	35.1	35.1	0	11.2	0	200	438.3
1981-	5	11.7	95.2	95.2	0	71	71	0	24.2	0	200	533.5
1981-	6	17.4	76.3	76.3	0	109.2	109.2	0	0	0	167.1	609.8
1981-	7	20.6	69.2	69.2	0	133.2	133.2	0	0	0	103.1	679
1981-	8	19.2	94.1	94.1	0	114.4	111.5	-2.9	0	0	85.7	773.1
1981-	9	14	100.9	100.9	0	71.3	71.3	0	0	0	115.3	874
1981-	10	6	140.7	140.7	0	26.1	26.1	0	29.9	0	200	140.7
1981-	11	2.9	63.2	62.2	1	12.6	12.6	0	50.6	0	200	203.9
1981-	12	-4.5	51.7	5	9.3	0.4	0.4	0	13.9	37.4	200	255.6
1982-	1	-11.4	76	5.8	10.9	0.3	0.3	0	16.5	96.7	200	331.6
1982-	2	-8	51.5	3	0	0	0	0	3	145.2	200	383.1
1982-	3	-2.9	72.9	48.2	92.6	3.3	3.3	0	137.4	77.3	200	456
1982-	4	3.8	49.5	37.5	89.3	26.7	26.7	0	100.1	0	200	505.5
1982-	5	14.8	45.3	45.3	0	90.9	90.9	0	0	0	154.4	550.8
1982-	6	15.6	148.5	148.5	0	96.9	96.9	0	6	0	200	699.3
1982-	7	20.7	118.4	118.4	0	133.5	133.5	0	0	0	184.9	817.7
1982-	8	16.9	92.4	92.4	0	99.8	99.8	0	0	0	177.6	910.1
1982-	9	14.5	73.8	73.8	0	73.2	73.2	0	0	0	178.2	983.9
1982-	10	9.6	59.8	59.8	0	43.1	43.1	0	0	0	194.9	59.8
1982-	11	3.4	124.5	111.3	13.2	15.1	15.1	0	104.3	0	200	184.3
1982-	12	-0.4	90.2	67.2	23	8.4	8.4	0	81.8	0	200	274.5
1983-	1	-5.1	47.8	12.8	19.1	0.4	0.4	0	31.5	15.9	200	322.3
1983-	2	-4.2	49.5	18.2	47.2	1.5	1.5	0	63.9	0	200	371.8

Table F1-3b: AES Thornthwaite SMC=200mm - summary. Stouffville WPCP #6158084.
Stouffville, Ontario Water Budget Values for the Period 1972-1991 DC20492 Calculated Daily
Method: AES Thornthwaite and Mather (Johnstone and Louie, 1983) SMC = 200 mm

YR	MO	TEMP(C)	PCPN	RAIN	MELT	PE	AE	DEF	SURP	SNOW	SOIL	ACC P
1983-	3	0.3	58.6	38.8	13.7	10.2	10.2	0	42.3	6.1	200	430.4
1983-	4	5.1	95.9	95.9	6.1	26.4	26.4	0	75.6	0	200	526.3
1983-	5	10	109.5	109.5	0	59.8	59.8	0	49.7	0	200	635.8
1983-	6	18.3	28.1	28.1	0	115.6	115.6	0	0	0	112.5	663.9
1983-	7	22.1	50.4	50.4	0	143.2	137.4	-5.8	0	0	25.4	714.3
1983-	8	21	111.4	111.4	0	125.8	114.4	-11.3	0	0	22.4	825.7
1983-	9	16.4	64.6	64.6	0	84.5	68.3	-16.2	0	0	18.7	890.3
1983-	10	9.4	81.8	81.8	0	42.8	42.8	0	0	0	57.7	81.8
1983-	11	2.4	122.7	122.7	0	12.2	12.2	0	0	0	168.2	204.5
1983-	12	-6.9	82.6	25	15	0.3	0.3	0	8	42.6	200	287.1
1984-	1	-9.8	44.7	6	3	0	0	0	8.9	78.3	200	331.8
1984-	2	-1.9	78.3	49.5	86.1	4.8	4.8	0	130.8	21	200	410.1
1984-	3	-5	75.6	47.2	49.4	2.7	2.7	0	93.9	0	200	485.7
1984-	4	7.2	53.8	53.8	0	37.5	37.5	0	16.3	0	200	539.5
1984-	5	10.2	124	124	0	61.6	61.6	0	62.4	0	200	663.5
1984-	6	18.3	58.8	58.8	0	115.4	115.4	0	0	0	143.4	722.3
1984-	7	19.8	63.5	63.5	0	127.2	127.2	0	0	0	79.7	785.8
1984-	8	20.8	98	98	0	124.9	115.9	-9.1	0	0	61.8	883.8
1984-	9	13.7	111.7	111.7	0	69.4	69.4	0	0	0	104.1	995.5
1984-	10	10.4	47.8	47.8	0	46.6	46.6	0	0	0	105.3	47.8
1984-	11	2.9	56.5	56.5	0	13.2	13.2	0	0	0	148.6	104.3
1984-	12	-1.1	69.2	17.9	35.9	3.5	3.5	0	0	15.4	198.9	173.5
1985-	1	-8.8	74.4	0	0	0	0	0	0	89.8	198.9	247.9
1985-	2	-6.4	122.8	67.3	34.5	1.1	1.1	0	99.6	110.8	200	370.7
1985-	3	-0.7	78.9	41.9	139.4	5.3	5.3	0	176	8.4	200	449.6
1985-	4	6.9	27.1	19.5	16	39.6	39.6	0	0	0	195.9	476.7
1985-	5	13.2	108	108	0	80.4	80.4	0	23.4	0	200	584.7
1985-	6	15.4	69.4	69.4	0	96.1	96.1	0	0	0	173.3	654.1
1985-	7	19.7	59.2	59.2	0	126.4	126.4	0	0	0	106.2	713.3
1985-	8	19	124.8	124.8	0	113	113	0	0	0	118	838.1
1985-	9	16.7	69	69	0	85.5	85.2	-0.3	0	0	101.8	907.1
1985-	10	9.5	69.1	69.1	0	42.4	42.4	0	0	0	128.5	69.1
1985-	11	2.3	142.2	136	4.7	11.2	11.2	0	58	1.5	200	211.3
1985-	12	-6.1	60.6	7.8	1.5	0.7	0.7	0	8.6	52.8	200	271.9
1986-	1	-6.9	41.8	13.6	30.2	0.7	0.7	0	43.1	50.8	200	313.7
1986-	2	-7.3	48	5.4	11	0.3	0.3	0	16.1	82.4	200	361.7
1986-	3	-0.2	54.4	30.6	106.2	12.9	12.9	0	123.9	0	200	416.1
1986-	4	7.9	39.3	39.3	0	41.8	41.8	0	0	0	197.5	455.4
1986-	5	14.7	66.3	66.3	0	90.9	90.9	0	0	0	172.8	521.7
1986-	6	16.4	127	127	0	102.9	102.9	0	0	0	196.9	648.7
1986-	7	20.6	81.4	81.4	0	132.9	132.9	0	0	0	145.5	730.1
1986-	8	18.1	202.2	202.2	0	107.2	107.2	0	40.5	0	200	932.3
1986-	9	14.3	198	198	0	72.2	72.2	0	125.8	0	200	1130.3
1986-	10	8.5	64.8	64.8	0	38	38	0	26.8	0	200	64.8
1986-	11	1.2	37.2	21.2	16	8.7	8.7	0	28.5	0	200	102
1986-	12	-2.1	62.1	27.1	33.1	0.7	0.7	0	59.5	1.9	200	164.1
1987-	1	-5.4	51	3.8	15.7	0.4	0.4	0	19.1	33.5	200	215.1
1987-	2	-6.2	28.2	8	9.6	0.2	0.2	0	17.4	44	200	243.3
1987-	3	1.4	59.1	37.1	44	14.6	14.6	0	66.5	22	200	302.4
1987-	4	8.9	47.3	44.7	24.6	48.3	48.3	0	21	0	200	349.7
1987-	5	14.3	102.4	102.4	0	88.2	88.2	0	14.2	0	200	452.1
1987-	6	19.1	79.2	79.2	0	120.6	120.6	0	0	0	158.6	531.3
1987-	7	22	67.9	67.9	0	142.8	142.8	0	0	0	83.7	599.2
1987-	8	18.8	79.2	79.2	0	111.8	102	-9.9	0	0	60.9	678.4
1987-	9	15.3	70	70	0	77.9	74	-3.9	0	0	56.9	748.4
1987-	10	6.9	54.8	54.8	0	30.5	30.5	0	0	0	81.2	54.8
1987-	11	2.7	92.5	88.5	4	13.8	13.8	0	0	0	159.9	147.3
1987-	12	-1.4	67	43.2	23.8	2.8	2.8	0	24.1	0	200	214.3
1988-	1	-6.1	43.6	25.6	18	2.2	2.2	0	41.4	0	200	257.9
1988-	2	-6.9	77.3	8.7	8	0.2	0.2	0	16.4	60.6	200	335.2
1988-	3	-1.7	39.5	29.9	70.2	6.8	6.8	0	93.4	0	200	374.7
1988-	4	5.7	76.2	76.2	0	29	29	0	47.2	0	200	450.9
1988-	5	14.1	85.8	85.8	0	86.8	86.8	0	0	0	199	536.7
1988-	6	17.8	56	56	0	112.2	112.2	0	0	0	142.8	592.7
1988-	7	22.8	40	40	0	147.9	147.9	0	0	0	34.9	632.7
1988-	8	20.8	86	86	0	125.3	97.4	-27.9	0	0	23.5	718.7
1988-	9	14.7	79.4	79.4	0	74.6	74.6	0	0	0	28.3	798.1

Table F1-3b: AES Thornthwaite SMC=200mm - summary. Stouffville WPCP #6158084.
Stouffville, Ontario Water Budget Values for the Period 1972-1991 DC20492 Calculated Daily
Method: AES Thornthwaite and Mather (Johnstone and Louie, 1983) SMC = 200 mm

YR	MO	TEMP(C)	PCPN	RAIN	MELT	PE	AE	DEF	SURP	SNOW	SOIL	ACC P
1988-	10	6.5	89.4	89.4	0	28.9	28.9	0	0	0	88.8	89.4
1988-	11	4.1	72.2	72.2	0	14.9	14.9	0	0	0	146.1	161.6
1988-	12	-3.9	51.8	8	17.8	1.6	1.6	0	0	26	170.4	213.4
1989-	1	-3.4	44.8	16.4	54.4	1.5	1.5	0	39.7	0	200	258.2
1989-	2	-7	32.6	6.6	8.6	0.2	0.2	0	15	17.4	200	290.8
1989-	3	-3.1	36	10.6	42.8	5.9	5.9	0	47.4	0	200	326.8
1989-	4	4.7	49.4	48.6	0.8	24.7	24.7	0	24.7	0	200	376.2
1989-	5	13	125.6	125.6	0	79.6	79.6	0	46	0	200	501.8
1989-	6	18.5	96.6	96.6	0	116.5	116.5	0	0	0	180.1	598.4
1989-	7	21.9	6.2	6.2	0	141.9	141.9	0	0	0	44.4	604.6
1989-	8	19.4	144.2	144.2	0	115.8	115.8	0	0	0	72.7	748.8
1989-	9	15	72.2	72.2	0	76.8	75	-1.8	0	0	70	821
1989-	10	9.5	93.4	93.4	0	42.4	42.4	0	0	0	120.9	93.4
1989-	11	1.4	124	107.6	11.4	10.5	10.5	0	29.5	5	200	217.4
1989-	12	-11	44.2	0	0	0	0	0	0	49.2	200	261.6
1990-	1	-2.2	58.9	30.1	56.4	1.4	1.4	0	85.1	21.6	200	320.5
1990-	2	-4.6	61.8	23.2	36.9	1.7	1.7	0	58.3	23.4	200	382.3
1990-	3	0	43.1	39.2	27.3	12.2	12.2	0	54.2	0	200	425.4
1990-	4	7.9	55.4	55.4	0	43.7	43.7	0	11.7	0	200	480.8
1990-	5	11.4	63.7	63.7	0	68.8	68.8	0	0	0	194.9	544.5
1990-	6	18.1	86.7	86.7	0	113.8	113.8	0	0	0	167.8	631.2
1990-	7	20.3	68	68	0	130.4	130.4	0	0	0	105.5	699.2
1990-	8	19.8	99	99	0	117.8	115.5	-2.3	0	0	88.9	798.2
1990-	9	14.6	66.6	66.6	0	74.4	72.4	-2	0	0	83.1	864.8
1990-	10	8.7	126.5	126.5	0	39.3	39.3	0	0	0	170.4	126.5
1990-	11	3.7	53.9	53.9	0	14.7	14.7	0	9.6	0	200	180.4
1990-	12	-1.9	117.6	59.9	57.5	2.5	2.5	0	114.9	0.2	200	298
1991-	1	-7.1	45	6.6	19.9	0.4	0.4	0	26.1	18.7	200	343
1991-	2	-3.6	26.4	3.7	36.6	3	3	0	37.3	4.8	200	369.4
1991-	3	0.3	115.9	72.8	46.1	9	9	0	109.9	1.8	200	485.3
1991-	4	8	74.3	74.3	1.8	42.3	42.3	0	33.8	0	200	559.6
1991-	5	16	64.8	64.8	0	99.6	99.6	0	0	0	165.2	624.4
1991-	6	19.9	58.6	58.6	0	126.6	126.6	0	0	0	97.2	683
1991-	7	21.1	61.3	61.3	0	136.1	121.9	-14.2	0	0	36.6	744.3
1991-	8	20.8	59.9	59.9	0	124	79.5	-44.5	0	0	17.1	804.2
1991-	9	14.7	62.4	62.4	0	75.7	64.3	-11.4	0	0	15.2	866.6
1991-	10	9.9	91.5	91.5	0	44.7	44.7	0	0	0	61.9	91.5
1991-	11	1.9	67.2	67.2	0	9.9	9.9	0	0	0	119.3	158.7
1991-	12	-3.5	50.2	16.4	27.5	2.9	2.9	0	0	6.3	160.2	208.9

Table F2-1 Clarifica Inc (May, 2002) water balance estimates for Duffins watershed.
Scenario Summary - Averages for 30 subcatchments (1986-2000).

Water Budget Component	Scenario Summary			
	Existing	Future	Future + Nat Heritage	Future + 50% Dev
Area (ha)	28301	28301	28301	28301
Imp A (ha)	1064	1991	1991	6001
Imp (%)	3.76	7.03	7.03	21.20
Precip [mm]	844	844	844	844
Runoff [mm]	145	170	162	274
GWI [mm]	206	197	195	162
ET [mm]	489	472	482	405

Basin Summary

Index	Imput Data								Results								
	Scenario	Basin	Area, A	Impervious, TIMP	Directly Connected Imp, XIMP	CN	Sat. Hyd Cond,	VEG_K3	PRECIP	RAIN	SNOW	RO	GWI	ET	Qout	Mass Balance (PRECIP-Qout)	
			[ha]	[Frac]	[Frac]	[#]	[mm/d]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[%]
1	Existing	1	281.55	0.022	0.000	79.5	64.79	6.09	844	702	142	156	200	483	839	-4.1	-0.38%
2	Existing	2	1085.19	0.091	0.071	83.7	59.95	5.86	844	702	142	219	177	443	839	-4.2	-0.41%
3	Existing	3	1897.99	0.023	0.017	78.1	97.55	6.14	844	702	142	145	208	485	839	-4.6	-0.44%
4	Existing	4	681.59	0.000	0.000	80.7	54.99	6.24	844	702	142	150	197	492	839	-4.7	-0.46%
5	Existing	5	920.64	0.000	0.000	59.8	313.26	6.66	844	702	142	60	231	549	839	-4.2	-0.30%
6	Existing	6	643.98	0.000	0.000	80.0	60.48	6.22	844	702	142	139	185	515	839	-4.7	-0.45%
7	Existing	7	1082.14	0.000	0.000	71.4	180.38	6.33	844	702	142	95	215	530	839	-4.6	-0.42%
8	Existing	8	516.51	0.000	0.000	75.4	166.26	6.21	844	702	142	108	210	521	839	-4.7	-0.44%
9	Existing	9	1073.12	0.000	0.000	79.5	54.73	6.05	844	702	142	140	184	514	839	-4.7	-0.45%
10	Existing	10	262.69	0.000	0.000	73.8	86.40	6.04	844	702	142	109	208	522	839	-4.5	-0.41%
11	Existing	11	2068.58	0.004	0.003	80.4	64.10	6.15	844	702	142	149	200	489	839	-4.7	-0.46%
12	Existing	11.1	425.03	0.000	0.000	83.9	40.31	6.05	844	702	142	177	180	482	839	-4.8	-0.48%
13	Existing	12	895.05	0.053	0.043	75.3	156.66	6.39	844	702	142	145	214	480	839	-4.5	-0.43%
14	Existing	13	1736.50	0.016	0.012	78.6	108.97	6.20	844	702	142	142	210	488	839	-4.7	-0.45%
15	Existing	14	622.51	0.023	0.018	78.1	103.95	6.27	844	702	142	143	209	487	839	-4.6	-0.44%
16	Existing	15	1702.66	0.000	0.000	61.7	493.98	6.42	844	702	142	62	237	540	839	-4.4	-0.37%
17	Existing	16	2625.02	0.000	0.000	72.3	284.89	6.90	844	702	142	94	232	513	839	-4.7	-0.44%
18	Existing	17	707.88	0.002	0.001	72.5	173.38	6.57	844	702	142	102	228	509	839	-4.6	-0.42%
19	Existing	18	506.83	0.000	0.000	76.8	135.35	6.51	844	702	142	120	217	502	839	-4.7	-0.45%
20	Existing	19	618.84	0.021	0.016	75.0	154.22	6.54	844	702	142	125	217	497	839	-4.6	-0.43%
21	Existing	20	1547.47	0.007	0.005	78.1	123.56	6.13	844	702	142	132	217	490	839	-4.7	-0.45%
22	Existing	21	509.20	0.134	0.101	86.4	140.40	5.88	844	702	142	247	175	418	840	-3.9	-0.38%
23	Existing	21.1	327.44	0.000	0.000	71.1	271.75	6.80	844	702	142	90	236	513	839	-4.6	-0.42%
24	Existing	22	632.59	0.000	0.000	85.3	70.84	6.21	844	702	142	175	185	478	839	-4.9	-0.50%
25	Existing	23	803.91	0.008	0.006	80.9	223.21	6.57	844	702	142	135	216	488	839	-4.8	-0.48%
26	Existing	24	713.77	0.000	0.000	78.9	64.80	6.13	844	702	142	140	206	494	839	-4.7	-0.45%
27	Existing	25	590.88	0.022	0.017	74.5	212.43	6.47	844	702	142	119	226	494	839	-4.6	-0.44%
28	Existing	26	522.68	0.337	0.298	90.6	120.32	5.55	844	702	142	392	120	328	840	-3.5	-0.35%
29	Existing	27	1698.16	0.230	0.172	79.2	256.03	5.84	844	702	142	257	171	412	840	-3.6	-0.34%
30	Existing	28	600.84	0.230	0.229	74.8	56.02	5.82	844	702	142	258	161	420	839	-4.6	-0.43%
31	Future	1	281.55	0.022	0.000	79.5	64.79	6.09	844	702	142	156	200	483	839	-4.1	-0.38%
32	Future	2	1085.19	0.182	0.139	86.9	59.95	5.64	844	702	142	290	151	398	840	-3.4	-0.32%
33	Future	3	1897.99	0.034	0.027	78.7	97.55	6.10	844	702	142	155	205	479	839	-4.6	-0.44%
34	Future	4	681.59	0.000	0.000	80.7	54.99	6.24	844	702	142	150	197	492	839	-4.7	-0.46%
35	Future	5	920.64	0.000	0.000	59.8	313.26	6.66	844	702	142	60	231	549	839	-4.2	-0.30%
36	Future	6	643.98	0.000	0.000	80.0	60.48	6.22	844	702	142	139	185	515	839	-4.7	-0.45%
37	Future	7	1082.14	0.000	0.000	71.4	180.38	6.33	844	702	142	95	215	530	839	-4.6	-0.42%
38	Future	8	516.51	0.000	0.000	75.4	166.26	6.21	844	702	142	108	210	521	839	-4.7	-0.44%
39	Future	9	1073.12	0.000	0.000	79.5	54.73	6.05	844	702	142	140	184	514	839	-4.7	-0.45%
40	Future	10	262.69	0.000	0.000	73.8	86.40	6.04	844	702	142	109	208	522	839	-4.5	-0.41%
41	Future	11	2068.58	0.025	0.019	80.6	64.10	6.04	844	702	142	163	198	479	839	-4.6	-0.44%

Table F2-1 Clarifica Inc (May, 2002) water balance estimates for Duffins watershed.
Scenario Summary - Averages for 30 subcatchments (1986-2000).

Water Budget Component	Scenario Summary			
	Existing	Future	Future + Nat Heritage	Future + 50% Dev
Area (ha)	28301	28301	28301	28301
Imp A (ha)	1064	1991	1991	6001
Imp (%)	3.76	7.03	7.03	21.20
Precip [mm]	844	844	844	844
Runoff [mm]	145	170	162	274
GWI [mm]	206	197	195	162
ET [mm]	489	472	482	405

Basin Summary

Index	Imput Data								Results								
	Scenario	Basin	Area, A	Impervious, TIMP	Directly Connected Imp, XIMP	CN	Sat. Hyd Cond,	VEG_K3	PRECIP	RAIN	SNOW	RO	GWI	ET	Qout	Mass Balance (PRECIP-Qout)	
			[ha]	[Frac]	[Frac]	[#]	[mm/d]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[%]
42	Future	11.1	425.03	0.000	0.000	83.9	40.31	6.05	844	702	142	177	180	482	839	-4.8	-0.48%
43	Future	12	895.05	0.192	0.145	80.7	156.66	5.95	844	702	142	250	180	410	840	-3.7	-0.35%
44	Future	13	1736.50	0.016	0.012	78.6	108.97	6.20	844	702	142	142	210	488	839	-4.7	-0.45%
45	Future	14	622.51	0.023	0.018	78.1	103.95	6.27	844	702	142	143	209	487	839	-4.6	-0.44%
46	Future	15	1702.66	0.000	0.000	61.7	493.98	6.42	844	702	142	62	237	540	839	-4.4	-0.37%
47	Future	16	2625.02	0.000	0.000	72.3	284.89	6.90	844	702	142	94	232	513	839	-4.7	-0.44%
48	Future	17	707.88	0.002	0.001	72.5	173.38	6.57	844	702	142	102	228	509	839	-4.6	-0.42%
49	Future	18	506.83	0.000	0.000	76.8	135.35	6.51	844	702	142	120	217	502	839	-4.7	-0.45%
50	Future	19	618.84	0.021	0.016	75.0	154.22	6.54	844	702	142	125	217	497	839	-4.6	-0.43%
51	Future	20	1547.47	0.007	0.005	78.1	123.56	6.13	844	702	142	132	217	490	839	-4.7	-0.45%
52	Future	21	509.20	0.231	0.174	88.5	140.40	5.58	844	702	142	316	151	373	841	-2.9	-0.27%
53	Future	21.1	327.44	0.007	0.005	71.4	271.75	6.78	844	702	142	95	235	509	839	-4.6	-0.42%
54	Future	22	632.59	0.028	0.021	86.0	70.84	6.13	844	702	142	196	179	465	839	-4.7	-0.47%
55	Future	23	803.91	0.222	0.167	90.1	223.21	5.78	844	702	142	320	150	371	841	-2.9	-0.28%
56	Future	24	713.77	0.119	0.090	82.0	64.80	5.77	844	702	142	225	179	435	840	-4.0	-0.38%
57	Future	25	590.88	0.255	0.191	84.3	212.43	5.74	844	702	142	300	165	375	840	-3.1	-0.29%
58	Future	26	522.68	0.337	0.283	90.0	120.32	5.43	844	702	142	388	124	329	841	-2.9	-0.27%
59	Future	27	1698.16	0.271	0.212	80.3	256.03	5.57	844	702	142	287	163	390	840	-3.5	-0.33%
60	Future	28	600.84	0.416	0.389	82.1	56.02	5.61	844	702	142	393	115	331	839	-4.2	-0.42%
61	ure + Nat Herit	1	281.55	0.022	0.000	76.4	64.79	6.55	844	702	142	141	201	498	839	-4.1	-0.37%
62	ure + Nat Herit	2	1085.19	0.182	0.139	84.9	59.95	5.83	844	702	142	277	157	406	840	-3.5	-0.33%
63	ure + Nat Herit	3	1897.99	0.034	0.027	76.6	97.55	6.47	844	702	142	145	204	489	839	-4.5	-0.43%
64	ure + Nat Herit	4	681.59	0.000	0.000	80.5	54.99	6.27	844	702	142	149	197	493	839	-4.7	-0.46%
65	ure + Nat Herit	5	920.64	0.000	0.000	55.0	313.26	7.40	844	702	142	51	218	571	840	-3.9	-0.20%
66	ure + Nat Herit	6	643.98	0.000	0.000	77.4	60.48	6.95	844	702	142	125	181	533	839	-4.6	-0.43%
67	ure + Nat Herit	7	1082.14	0.000	0.000	67.9	180.38	6.83	844	702	142	84	210	545	839	-4.4	-0.38%
68	ure + Nat Herit	8	516.51	0.000	0.000	75.2	166.26	6.25	844	702	142	107	209	522	839	-4.7	-0.44%
69	ure + Nat Herit	9	1073.12	0.000	0.000	79.0	54.73	6.20	844	702	142	137	183	518	839	-4.7	-0.45%
70	ure + Nat Herit	10	262.69	0.000	0.000	73.8	86.40	6.04	844	702	142	109	208	522	839	-4.5	-0.41%
71	ure + Nat Herit	11	2068.58	0.025	0.019	80.1	64.10	6.15	844	702	142	160	197	482	839	-4.6	-0.44%
72	ure + Nat Herit	11.1	425.03	0.000	0.000	83.2	40.31	6.20	844	702	142	172	181	487	839	-4.8	-0.47%
73	ure + Nat Herit	12	895.05	0.192	0.145	80.7	156.66	5.91	844	702	142	250	180	409	840	-3.7	-0.35%
74	ure + Nat Herit	13	1736.50	0.016	0.012	73.1	108.97	6.78	844	702	142	119	212	508	839	-4.5	-0.41%
75	ure + Nat Herit	14	622.51	0.023	0.018	75.7	103.95	6.60	844	702	142	133	209	497	839	-4.6	-0.43%
76	ure + Nat Herit	15	1702.66	0.000	0.000	52.1	493.98	7.35	844	702	142	46	222	572	840	-4.0	-0.20%
77	ure + Nat Herit	16	2625.02	0.000	0.000	68.8	284.89	7.43	844	702	142	83	228	528	839	-4.5	-0.40%
78	ure + Nat Herit	17	707.88	0.002	0.001	67.5	173.38	7.17	844	702	142	87	225	528	839	-4.4	-0.37%
79	ure + Nat Herit	18	506.83	0.000	0.000	69.9	135.35	7.35	844	702	142	95	215	529	839	-4.5	-0.39%
80	ure + Nat Herit	19	618.84	0.021	0.016	73.4	154.22	6.85	844	702	142	118	216	505	839	-4.5	-0.42%
81	ure + Nat Herit	20	1547.47	0.007	0.005	77.6	123.56	6.35	844	702	142	129	215	495	839	-4.7	-0.45%
82	ure + Nat Herit	21	509.20	0.231	0.174	88.5	140.40	5.57	844	702	142	316	151	373	841	-2.9	-0.27%

Table F2-1 Clarifica Inc (May, 2002) water balance estimates for Duffins watershed.
Scenario Summary - Averages for 30 subcatchments (1986-2000).

Water Budget Component	Scenario Summary			
	Existing	Future	Future + Nat Heritage	Future + 50% Dev
Area (ha)	28301	28301	28301	28301
Imp A (ha)	1064	1991	1991	6001
Imp (%)	3.76	7.03	7.03	21.20
Precip [mm]	844	844	844	844
Runoff [mm]	145	170	162	274
GWI [mm]	206	197	195	162
ET [mm]	489	472	482	405

Basin Summary

Index	Imput Data								Results								
	Scenario	Basin	Area, A	Impervious, TIMP	Directly Connected Imp, XIMP	CN	Sat. Hyd Cond,	VEG_K3	PRECIP	RAIN	SNOW	RO	GWI	ET	Qout	Mass Balance (PRECIP-Qout)	
			[ha]	[Frac]	[Frac]	[#]	[mm/d]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[%]
83	ure + Nat Herit	21.1	327.44	0.007	0.005	71.6	271.75	7.10	844	702	142	95	229	514	839	-4.6	-0.42%
84	ure + Nat Herit	22	632.59	0.028	0.021	85.7	70.84	6.19	844	702	142	193	179	466	839	-4.7	-0.47%
85	ure + Nat Herit	23	803.91	0.222	0.167	90.1	223.21	5.76	844	702	142	320	150	370	841	-2.9	-0.28%
86	ure + Nat Herit	24	713.77	0.119	0.090	81.8	64.80	5.81	844	702	142	224	180	436	840	-4.0	-0.38%
87	ure + Nat Herit	25	590.88	0.255	0.191	84.3	212.43	5.69	844	702	142	300	166	375	840	-3.1	-0.29%
88	ure + Nat Herit	26	522.68	0.337	0.283	90.0	120.32	5.47	844	702	142	388	124	329	841	-2.9	-0.27%
89	ure + Nat Herit	27	1698.16	0.271	0.212	80.2	256.03	5.61	844	702	142	287	163	390	840	-3.5	-0.33%
90	ure + Nat Herit	28	600.84	0.416	0.389	82.1	56.02	5.65	844	702	142	393	114	332	839	-4.2	-0.42%
91	uture + 50% De	1	281.55	0.022	0.000	79.5	64.79	6.09	844	702	142	156	200	483	839	-4.1	-0.38%
92	uture + 50% De	2	1085.19	0.219	0.167	87.2	59.95	5.61	844	702	142	312	144	384	841	-3.0	-0.28%
93	uture + 50% De	3	1897.99	0.042	0.033	78.9	97.55	6.11	844	702	142	161	203	475	839	-4.6	-0.44%
94	uture + 50% De	4	681.59	0.360	0.273	91.4	54.99	5.54	844	702	142	420	103	319	843	-0.8	-0.04%
95	uture + 50% De	5	920.64	0.000	0.000	59.8	313.26	6.66	844	702	142	60	231	549	839	-4.2	-0.30%
96	uture + 50% De	6	643.98	0.028	0.021	80.7	60.48	6.19	844	702	142	159	179	502	839	-4.5	-0.44%
97	uture + 50% De	7	1082.14	0.007	0.005	71.6	180.38	6.31	844	702	142	100	213	526	839	-4.5	-0.42%
98	uture + 50% De	8	516.51	0.390	0.296	85.9	166.26	5.50	844	702	142	384	123	335	842	-1.9	-0.16%
99	uture + 50% De	9	1073.12	0.343	0.261	89.1	54.73	5.51	844	702	142	388	107	348	842	-1.6	-0.13%
100	uture + 50% De	10	262.69	0.398	0.302	81.9	86.40	5.49	844	702	142	377	126	339	841	-2.1	-0.17%
101	uture + 50% De	11	2068.58	0.372	0.282	90.1	64.10	5.50	844	702	142	414	109	319	843	-1.0	-0.05%
102	uture + 50% De	11.1	425.03	0.433	0.329	97.3	40.31	5.35	844	702	142	543	48	255	847	3.0	0.41%
103	uture + 50% De	12	895.05	0.217	0.164	81.3	156.66	5.91	844	702	142	268	174	398	840	-3.5	-0.33%
104	uture + 50% De	13	1736.50	0.074	0.056	80.1	108.97	6.13	844	702	142	183	196	461	839	-4.4	-0.42%
105	uture + 50% De	14	622.51	0.242	0.184	83.7	103.95	5.91	844	702	142	298	156	386	840	-3.1	-0.29%
106	uture + 50% De	15	1702.66	0.000	0.000	61.7	493.98	6.42	844	702	142	62	237	540	839	-4.4	-0.37%
107	uture + 50% De	16	2625.02	0.070	0.053	74.5	284.89	6.73	844	702	142	144	217	478	839	-4.4	-0.42%
108	uture + 50% De	17	707.88	0.055	0.042	74.1	173.38	6.43	844	702	142	141	217	482	839	-4.4	-0.41%
109	uture + 50% De	18	506.83	0.217	0.165	81.1	135.35	6.12	844	702	142	268	170	402	840	-3.5	-0.33%
110	uture + 50% De	19	618.84	0.311	0.237	83.3	154.22	5.85	844	702	142	332	150	359	841	-2.7	-0.25%
111	uture + 50% De	20	1547.47	0.401	0.305	89.2	123.56	5.48	844	702	142	417	115	310	842	-1.1	-0.06%
112	uture + 50% De	21	509.20	0.269	0.203	89.8	140.40	5.48	844	702	142	348	140	354	841	-2.4	-0.21%
113	uture + 50% De	21.1	327.44	0.201	0.152	77.9	271.75	6.29	844	702	142	237	190	413	840	-3.8	-0.36%
114	uture + 50% De	22	632.59	0.386	0.293	96.8	70.84	5.48	844	702	142	508	63	274	845	1.6	0.24%
115	uture + 50% De	23	803.91	0.262	0.197	91.5	223.21	5.67	844	702	142	355	137	350	841	-2.3	-0.20%
116	uture + 50% De	24	713.77	0.356	0.269	88.5	64.80	5.35	844	702	142	396	119	328	842	-1.4	-0.10%
117	uture + 50% De	25	590.88	0.255	0.191	84.3	212.43	5.74	844	702	142	300	165	375	840	-3.1	-0.29%
118	uture + 50% De	26	522.68	0.337	0.283	90.0	120.32	5.43	844	702	142	388	124	329	841	-2.9	-0.27%
119	uture + 50% De	27	1698.16	0.399	0.310	84.3	256.03	5.23	844	702	142	379	133	330	841	-2.4	-0.21%
120	uture + 50% De	28	600.84	0.416	0.389	82.1	56.02	5.61	844	702	142	393	115	331	839	-4.2	-0.42%

Table F3-1 Clarifica URF water balance summary for Duffins Basin (1986-2000) - Existing Land Use.

Scenario	PRECIP [mm]	RAIN [mm]	SNOW [mm]	RO [mm]	Cperv	Cimp	C [Frac]	GWI [mm]	ET [mm]	Qout [mm]	PRECIP-Qout [mm]	[%]
A1	844	702	142	27	0.03	0.00	0.03	238	576	841	-3	0.1%
A2	844	702	142	72	0.08	0.00	0.08	245	522	839	-5	-0.4%
B1	844	702	142	63	0.07	0.00	0.07	215	561	839	-4	-0.3%
B2	844	702	142	106	0.12	0.00	0.12	217	517	839	-5	-0.4%
B3	844	702	142	186	0.13	0.88	0.22	214	443	842	-1	-0.1%
B4	844	702	142	348	0.12	0.88	0.41	153	340	841	-3	-0.2%
B5	844	702	142	437	0.12	0.88	0.52	126	279	841	-2	-0.2%
B6	844	702	142	582	0.11	0.88	0.69	60	196	838	-5	-0.5%
C1	844	702	142	94	0.11	0.00	0.11	208	537	839	-4	-0.3%
C2	844	702	142	131	0.15	0.00	0.15	207	500	839	-5	-0.4%
C3	844	702	142	226	0.18	0.88	0.27	183	435	844	0	0.1%
C4	844	702	142	386	0.20	0.88	0.46	121	335	842	-1	-0.1%
C5	844	702	142	476	0.22	0.88	0.56	91	276	844	0	0.1%
C6	844	702	142	598	0.19	0.88	0.71	46	194	838	-5	-0.5%
D1	844	702	142	224	0.26	0.00	0.26	73	543	840	-4	-0.3%
D2	844	702	142	268	0.31	0.00	0.31	70	501	839	-4	-0.4%

Hydrologic Soil Group	Land Use Groupings	
A	**1**	rural - undisturbed
B	**2**	rural - agricultural
C	**3**	urban - very low impervious
D	**4**	urban - average impervious
	5	urban - high impervious
	6	urban - very high impervious

Data provided by Clarifica Inc. on October 20, 2002. See Clarifica Inc. (May, 2002) for calculation details.

Table F3-2 Clarifica URF water balance summary for Dufins Basin (1986-2000) - Future Land Use Scenario.

Scenario	PRECIP [mm]	RAIN [mm]	SNOW [mm]	RO [mm]	Cperv	Cimp	C [Frac]	GWI [mm]	ET [mm]	Qout [mm]	PRECIP-Qout [mm]	[%]
A1f	844	702	142	27	0.03	0.00	0.03	241	573	841	-3	0.1%
A2f	844	702	142	72	0.08	0.00	0.08	246	521	839	-4	-0.4%
A4f	844	702	142	285	0.08	0.88	0.34	215	345	845	1	0.2%
B1f	844	702	142	63	0.07	0.00	0.07	217	559	839	-4	-0.3%
B2f	844	702	142	107	0.13	0.00	0.13	215	516	839	-5	-0.4%
B3f	844	702	142	190	0.13	0.88	0.22	211	442	842	-1	0.0%
B4f	844	702	142	347	0.12	0.88	0.41	155	339	841	-3	-0.2%
B5f	844	702	142	438	0.12	0.88	0.52	125	278	841	-2	-0.2%
B6f	844	702	142	582	0.12	0.88	0.69	60	196	838	-5	-0.5%
C1f	844	702	142	94	0.11	0.00	0.11	213	533	839	-4	-0.3%
C2f	844	702	142	133	0.16	0.00	0.16	207	498	839	-5	-0.4%
C4f	844	702	142	385	0.19	0.88	0.45	124	333	842	-1	-0.1%
C5f	844	702	142	474	0.21	0.88	0.56	95	274	844	0	0.1%
C6f	844	702	142	600	0.20	0.88	0.71	45	193	838	-5	-0.5%
D1f	844	702	142	234	0.27	0.00	0.27	66	540	840	-4	-0.3%
D2f	844	702	142	277	0.32	0.00	0.32	64	498	839	-4	-0.4%

Hydrologic Soil Group

A
B
C
D

Land Use Groupings

1 rural - undisturbed
2 rural - agricultural
3 urban - very low impervious
4 urban - average impervious
5 urban - high impervious
6 urban - very high impervious

f - future land use scenario

Data provided by Clarifica Inc. on November 8, 2002. See Clarifica Inc. (May, 2002) for calculation details.

DUFFINS CREEK

HYDROLOGY UPDATE

FINAL REPORT

Prepared for:

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May 2002
Aquafor Beech Reference: 63812

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1.0 INTRODUCTION

Aquafor Beech Limited was retained by the Toronto and Region Conservation Authority (TRCA) to complete an update of the hydrologic model for Duffins Creek. The watershed is approximately 283.1 square kilometres and is situated within parts of Pickering, Ajax, Uxbridge, and Whitchurch-Stouffville, as illustrated in Figure 1.1.

A hydrologic model based on HYMO was developed for Duffins Creek in 1979 (James F. MacLaren Limited, 1979). The 1979 model was subsequently updated using the INTERHYMO/OTTHYMO model in 1991 (Aquafor Beech Ltd.). Since that time, urban development within the watershed has increased. In addition, an extensive GIS database for the Duffins Creek Watershed is now available from TRCA that contains physical, environmental, landuse, and infrastructure-related data. The landuse data is based on 1999 air photographs.

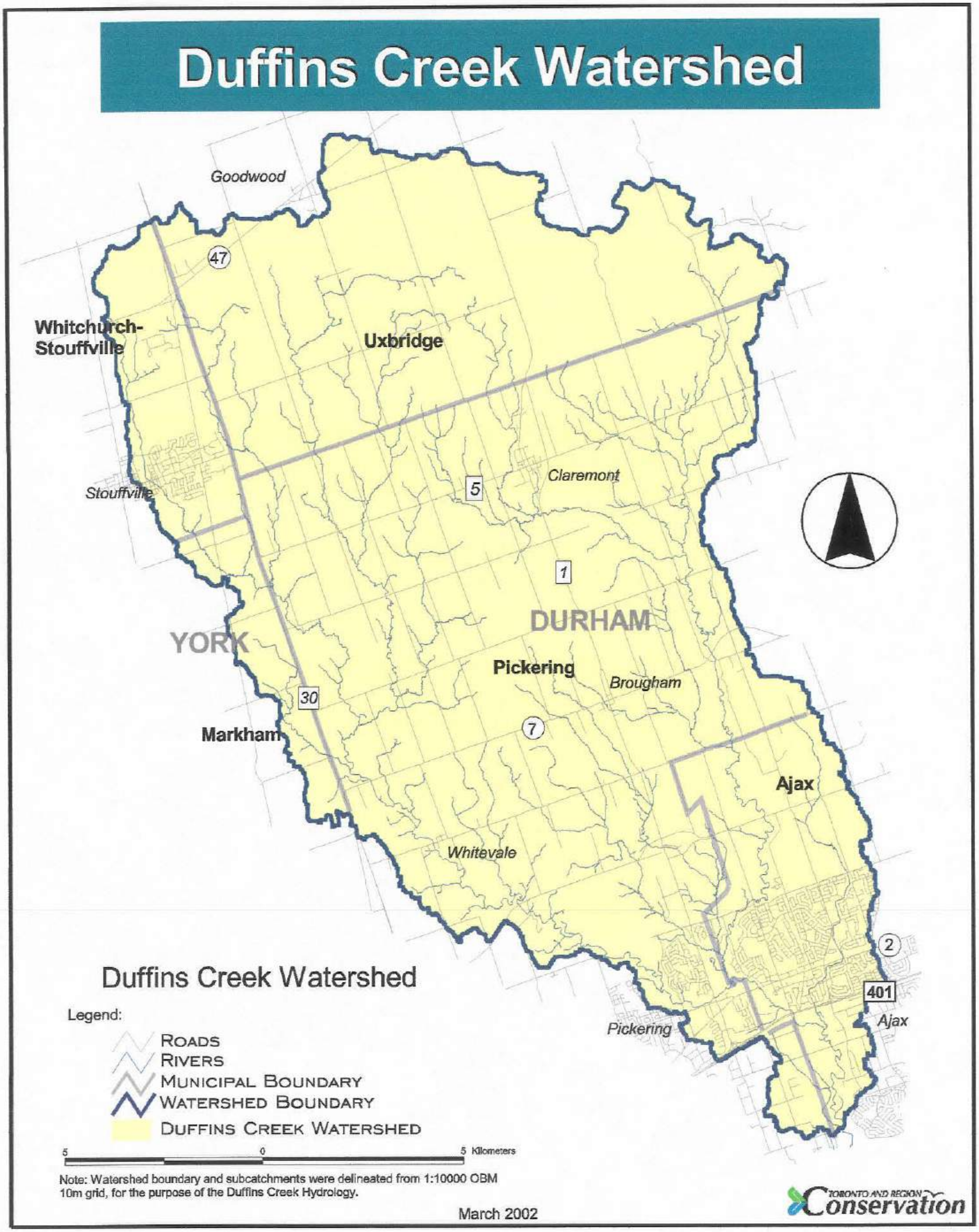


Figure 1.1 *Duffins Creek Watershed*

2.0 HYDROLOGIC MODEL SETUP

2.1 Model Selection

The hydrologic model selected for application in this study was VISUAL OTTHYMO, version 1.06. This is a HYMO-based model, similar to previous "event" models setup and applied in the study area, and is used in a "Windows" operating system environment.

2.2 Model Discretization

As illustrated in Figure 2.1, the Duffins Creek Watershed was divided into approximately 30 subcatchments in order to provide peak flow estimates at key locations throughout the watershed. The subcatchment boundaries are based on a detailed delineation of drainage boundaries from the GIS database, using updated topographic information and a digital elevation model (DEM). This new information resulted in some significant differences to the subcatchment boundaries compared to those used in the 1991 study, particularly in the headwater areas. For consistency, the subcatchment numbering system is similar to that used in the 1991 study.

2.3 Model Parameters

The following techniques and model parameters were applied with the VISUAL OTTHYMO model to simulate rural and urban rainfall-runoff responses:

- the CN* approach was used to determine direct runoff from pervious areas;
- the *Nash* unit hydrograph was applied to simulate runoff response from rural areas;
- the *Standard* unit hydrograph was applied to simulated runoff response from urban areas (this is an updated version of the previous Urbhyd command which incorporates a lag component for the unit hydrograph);
- subcatchment time-to-peak was determined using an equation for basin lag time described by Watt and Chow (1985); and
- hydrographs were routed through channel elements using the *Variable Storage Coefficient* method.

The soils and landuse mapping in the TRCA geographical information system (GIS) database was used to derive the model parameters, including drainage areas, CN* values, percent imperviousness,

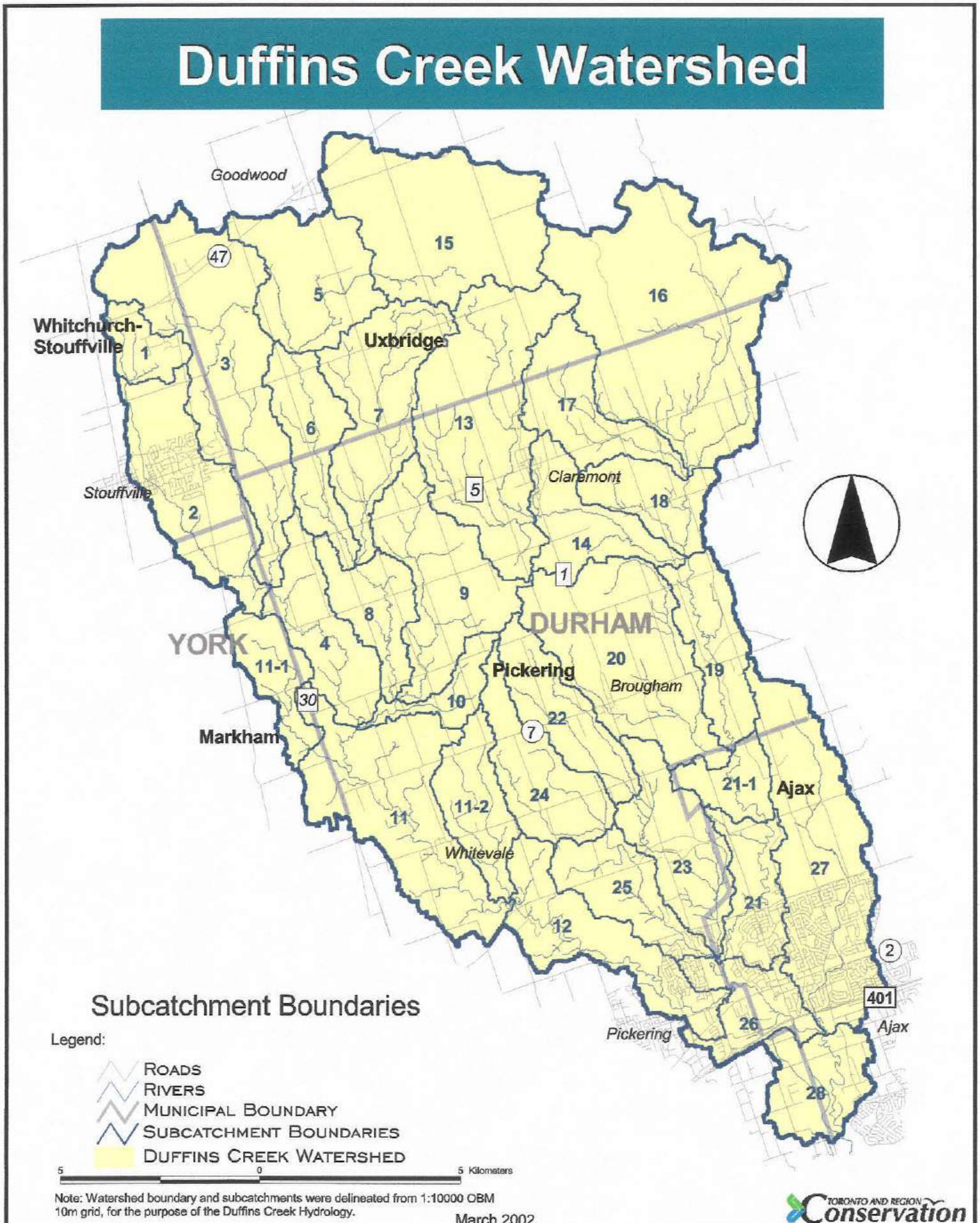


Figure 2.1 *Duffins Creek Hydrologic Model - Subcatchment Boundaries*

basin slopes, and channel slopes. Table 2.1 summarizes the assumed CN values based on soil types and land cover. These were used to derive an initial estimate of the CN* values for each catchment in the hydrologic model. Table 2.2 summarizes the assumed percent impervious values based on landuse. A summary of subcatchment parameters is provided in Appendix A. Soils mapping, landuse maps and land cover maps used to derive the model parameters are also provided in Appendix A.

2.4 Stormwater Management Facilities

Where possible, existing stormwater management facilities were incorporated into the updated hydrologic model. Information including contributing drainage area, percent impervious, and pond rating curves were estimated from a review of files provided by TRCA. Table 2.3 summarizes the stormwater management facilities incorporated into the hydrologic model. A total of sixteen facilities were included in the model.

Table 2.1

Summary of Estimated CN Values by Soil Type and Land Cover

Land Cover	CN			
	A Soils	B Soils	C Soils	D Soils
Forest	36	60	73	79
Agricultural	66	74	82	86
Urban (lawns)	56	71	81	85

Table 2.2

Summary of Estimated Percent Impervious Values by Landuse

Land Use Classification	Percent Impervious
Industrial / Commercial / Institutional	75%
High Density Residential	55%
Medium / Low Density Residential	40%
Estate Residential	15%
Agriculture / Forest	0%

Table 2.3
Summary of Stormwater Management Facilities

TRCA SWM Pond ID	Drainage Basin (Receiving Watercourse)	Drainage Area	Percent Impervious	Level of Control
185.0	2 (Stouffville Creek)	5.8 ha	35%	quantity control to 100-yr
166.0	2 (Stouffville Creek)	52.0 ha	40%	quantity control to 100-yr
295.0	3 (Reesor Creek)	36.0 ha	50%	quantity control to 100-yr
295.1	3 (Reesor Creek)	133.6 ha (81.9 ha urban)	50%	quantity control to 100-yr
263.0	12 (West Duffins Creek)	35.2 ha	40%	quantity control to 2-yr
263.1	12 (West Duffins Creek)	53.1 ha	40%	upstream by-pass (0.27cms) and quantity control to 2-yr
103.0	12 (West Duffins Creek)	5.3 ha	40%	quality control ("first flush")
92.0	21 (East Duffins Creek)	21.8 ha	49%	quality control ("first flush")
93.0	21 (East Duffins Creek)	91.6 ha	40%	quality control ("first flush")
93.1	21 (East Duffins Creek)	9.7 ha	40%	quality control ("first flush")
133.0	23 (Urfe Creek)	21.2 ha	30%	quantity control to 5-yr
93.2	26 (Duffins Creek)	43.3 ha	40%	quality control ("first flush")
279.2	27 (Millers Creek)	24.3 ha	44%	quantity control to 100-yr
207.2	27 (Millers Creek)	49.2 ha	60%	quality control ("first flush")
207.3	27 (Millers Creek)	64.9 ha	53%	quality control ("first flush")
167.0	27 (Millers Creek)	39.6 ha	40%	quantity control to 100-yr

3.0 MODEL CALIBRATION

The hydrologic model was checked through calibration and verification to ensure that the model was representative of the study area. Outlined below are the main steps which were undertaken:

1. Six rainfall-runoff events that occurred in 1999 and 2000, as recorded at the nearby Region of York rain gauge, were used for model calibration and verification. Rainfall depths for these events are summarized in Table 3.1.

2. Streamflow data was collected from six streamflow gauges throughout the Duffins Creek watershed and used in the model calibration. The selected streamflow gauges are illustrated in Figure 3.1 and summarized in Table 3.2.

3. Observed runoff hydrographs were derived from streamflow gauge data by separating baseflows using a procedure provided in Linsley *et al* (1982). Baseflow separation hydrographs are provided in Appendix B.

4. In the calibration process, emphasis was placed first on minimizing the differences between observed and simulated runoff volumes. This involved adjustment of the CN* parameter to match the observed runoff volumes.

5. Following calibration of runoff volumes, emphasis was placed on minimizing the differences between observed and simulated peak flow rates, and matching the general hydrograph timing and shape. This involved adjustment of the subcatchment time-to-peak (Tp) and unit hydrograph shape parameter (n).

6. Results from the calibration process were then used to derive a relationship between the CN* adjustments (step 4) and the amount of precipitation recorded at the rain gauge in the days preceding the storm events. A 10-day antecedent precipitation index (API) was used for each storm (Bruce *et al*). The CN* adjustment for the verification events was then predicted from this relationship.

Illustrated in Figure 3.2 are typical results from the model calibration (11 May 2000 event). As illustrated, good results were obtained with the calibrated model. Provided in Appendix C are the

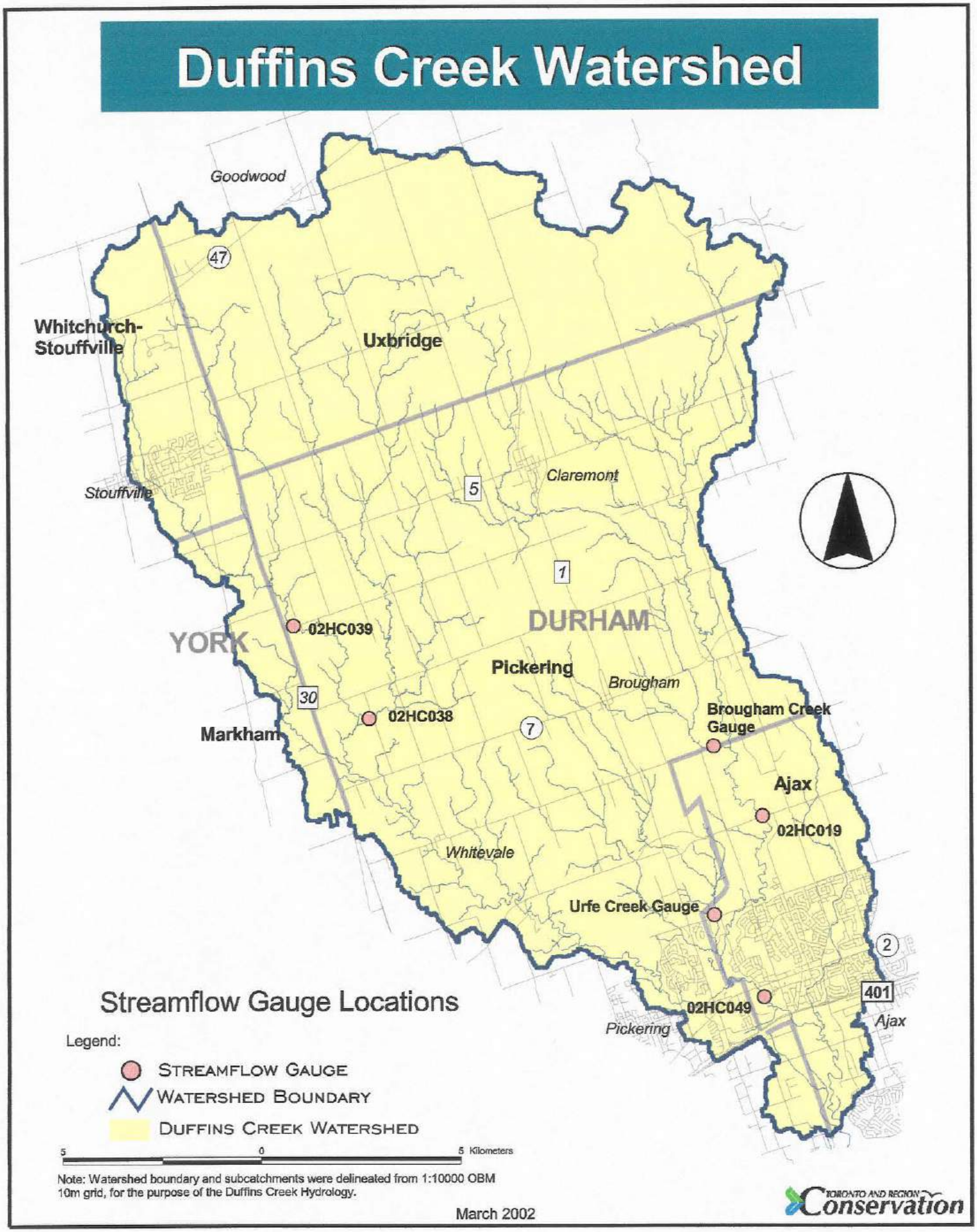


Figure 3.1 *Streamflow Gauge Locations*

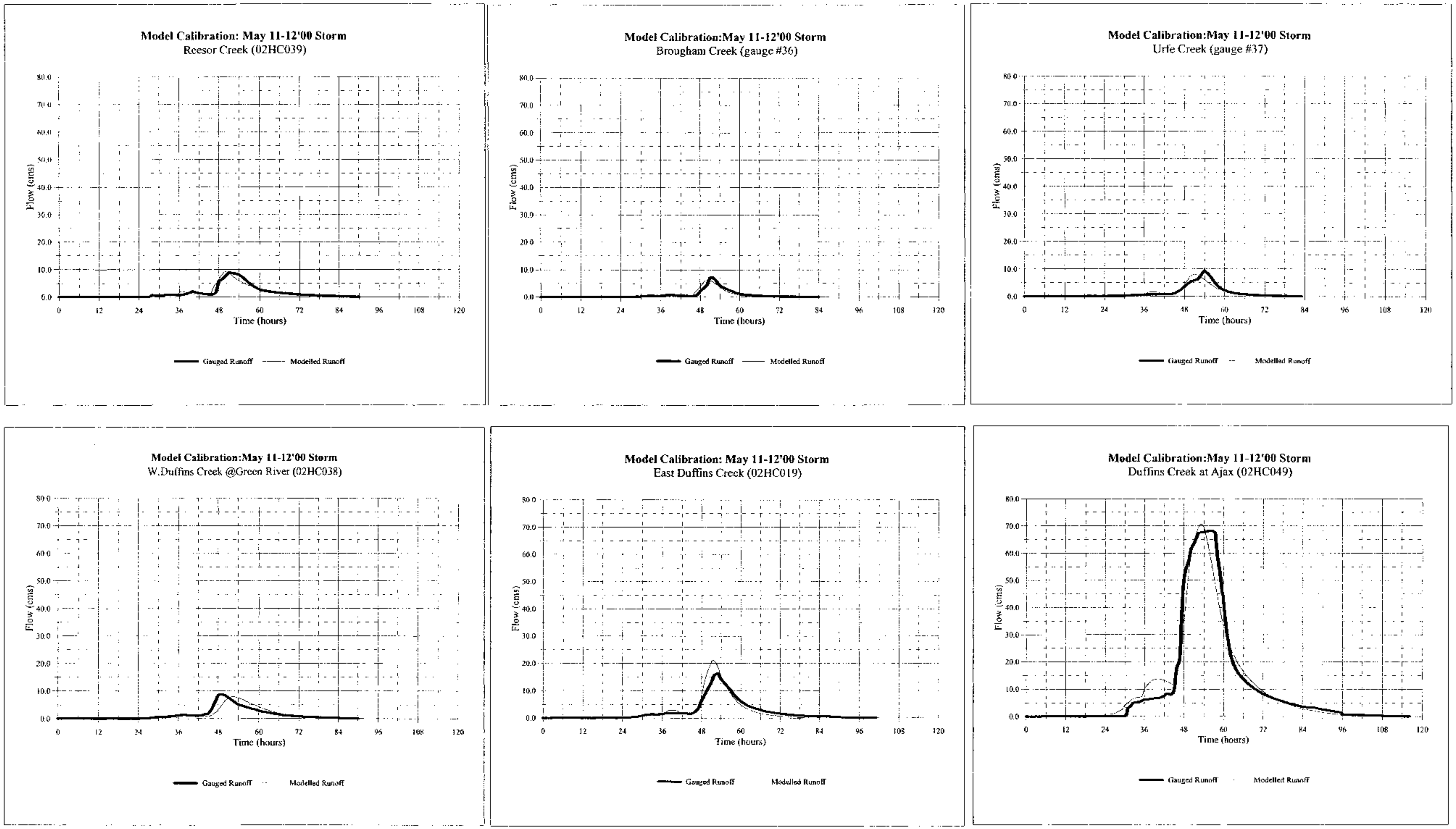
Table 3.1
Summary of Calibration Storm Events

Rainfall Event	Rainfall Depth (Region of York rain gauge)	Calibration / Verification
17 July '99	33.0 mm	calibration event
29 Sept '99	60.2 mm	calibration event
13 Oct '99	45.0 mm	verification event
11 May '00	61.8 mm	calibration event
13 June '00	45.4 mm	calibration event
24 June '00	41.0 mm	verification event

Table 3.2
Summary of Streamflow Gauges

Streamflow Gauge Name	Gauge Number	Drainage Area
Reesor Creek;	WSC 02HC039	32.6 km^2
Brougham Creek	TRCA gauge 36	15.5 km^2
Urfe Creek	TRCA gauge 37	14.2 km^2
West Duffins Creek	WSC 02HC038	61.8 km^2
East Duffins Creek	WSC 02HC019	86.9 km^2
Duffins Creek at Ajax	WSC 02HC049	255 km^2

Figure 3.2: Calibration Results - 11 May 2000 Storm Event



results from all calibration/verification events, and a plot of the CN* adjustment vs. API relationship. Table 3.3 provides a summary of the observed vs. simulated runoff depths and peak flow rates. Several key points from the calibration procedure are outlined below:

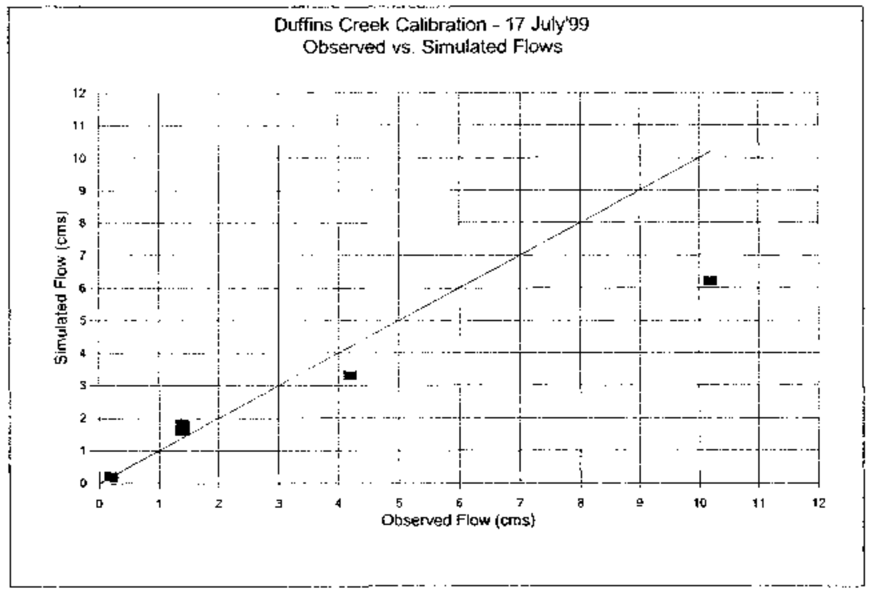
1. Results for the larger "frontal" storm events such as the May and June 2000 events, are more accurate than those for the smaller thunderstorm events such as the July 1999 event.
2. In general, simulated hydrograph characteristics (i.e. volume, peak flows, shape) are reasonable given the variability associated with rainfall data and uncertainty associated with the measurement of streamflow.
3. The calibrated hydrologic model can be considered representative of the watershed.

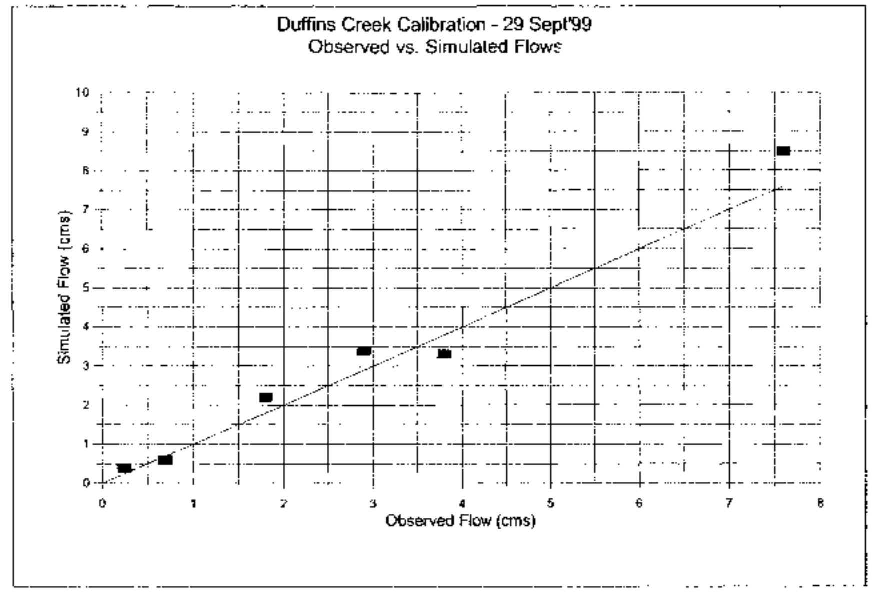
Table 3.3:
Summary of Model Calibration/Verification Results

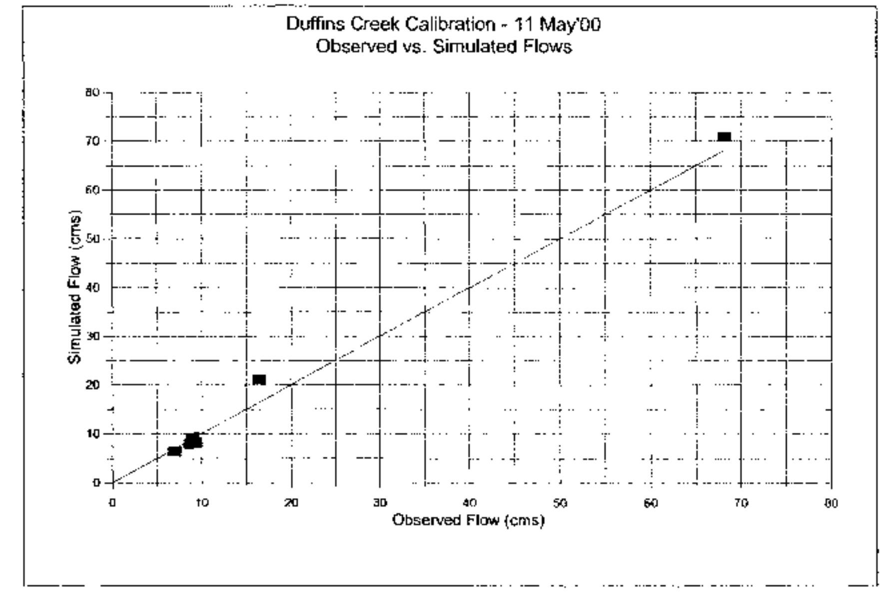
	17 July 1999			29 September 1999			11 May 2000			13 June 2000 (first peak)			13 October 1999*			24 June 2000*		
	Observed	Simulated	Difference	Observed	Simulated	Difference	Observed	Simulated	Difference	Observed	Simulated	Difference	Observed	Simulated	Difference	Observed	Simulated	Difference
Rainfall Depth (mm)	33.0	33.0		60.2	60.2		61.8	61.8		45.4	45.4		45.0	45.0		41.0	41.0	
Runoff Depth (mm)																		
Reesor Creek (gauge 02HC039):	1.16	1.25	7.8%	4.72	4.96	5.1%	14.42	14.14	-1.9%	15.16	15.47	2.0%	5.87	4.59	-21.8%	8.87	8.08	-8.9%
Brougham Creek (gauge #36)	1.61	1.57	-2.5%	1.42	1.44	1.4%	15.02	14.26	-5.1%	n/a	31.99	n/a	n/a - beaver activity			13.77	12.03	-12.6%
Urfe Creek (gauge #37)	n/a - data unreliable			1.16	1.16	0.0%	24.92	23.43	-6.0%	39.34	32.90	-16.4%	2.25	2.25	0.0%	17.36	16.33	-5.9%
West Duffins Creek (gauge 02HC038):	0.23	0.20	-13.0%	2.21	2.27	2.7%	7.50	7.46	-0.5%	13.40	13.90	3.7%	2.67	2.49	-6.7%	5.89	5.77	-2.0%
East Duffins Creek (gauge 02HC019):	1.09	1.09	0.0%	1.72	1.87	8.7%	9.40	9.53	1.4%	22.35	21.16	-5.3%	3.37	2.64	-21.7%	9.34	8.20	-12.2%
Duffins Creek at Ajax (gauge 02HC049):	1.27	1.28	0.8%	2.13	2.30	8.0%	17.14	17.06	-0.5%	24.63	22.63	-8.1%	3.64	4.06	11.5%	12.19	12.40	1.7%
Peak Flow (cms)																		
	0			0			0			0			0			0		
Reesor Creek (gauge 02HC039):	1.4	1.8	28.6%	3.8	3.3	-13.2%	9.0	9.3	3.3%	7.8	6.1	-21.8%	3.2	2.8	-12.5%	6.5	6.9	6.2%
Brougham Creek (gauge #36)	1.4	1.6	14.3%	0.7	0.6	-14.3%	7.0	6.4	-8.6%	9.0	9.0	0.0%	n/a - beaver activity			6.2	6.6	6.5%
Urfe Creek (gauge #37)	n/a - data unreliable			0.3	0.4	52.0%	9.3	8.1	-12.9%	7.2	8.0	11.1%	0.5	0.8	60.0%	5.0	6.9	38.0%
West Duffins Creek (gauge 02HC038):	0.2	0.2	0.0%	1.8	2.2	22.2%	8.8	8.0	-9.1%	10.3	9.1	-11.7%	2.1	2.6	23.8%	7.0	6.9	-1.4%
East Duffins Creek (gauge 02HC019):	4.2	3.3	-21.4%	2.9	3.4	17.2%	16.5	21.1	27.9%	26.3	27.6	4.9%	4.9	5.0	2.9%	18.9	20.6	9.0%
Duffins Creek at Ajax (gauge 02HC049):	10.2	6.2	-39.2%	7.6	8.5	11.8%	68.2	70.8	3.8%	68.9	69.7	1.2%	10.9	14.4	32.1%	54.7	61.3	12.1%

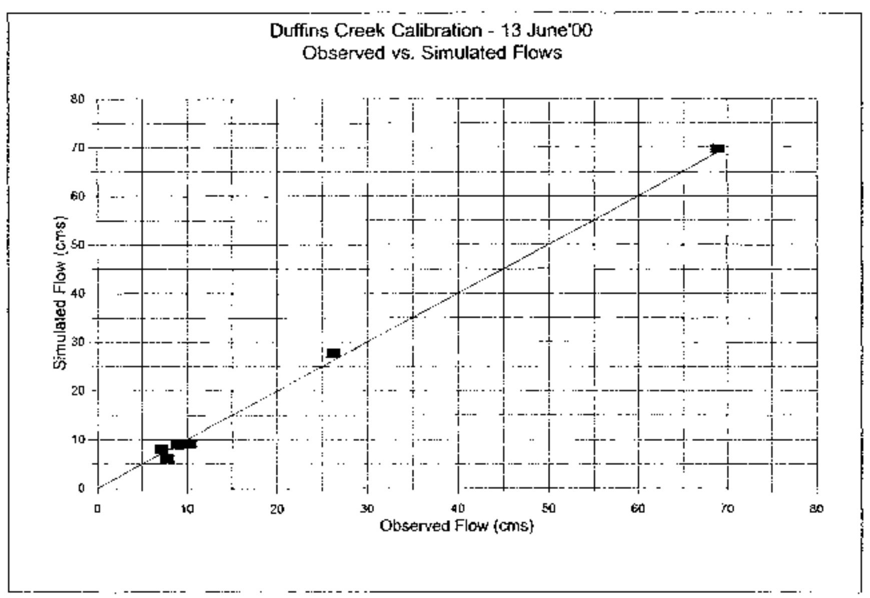
* Verification Event

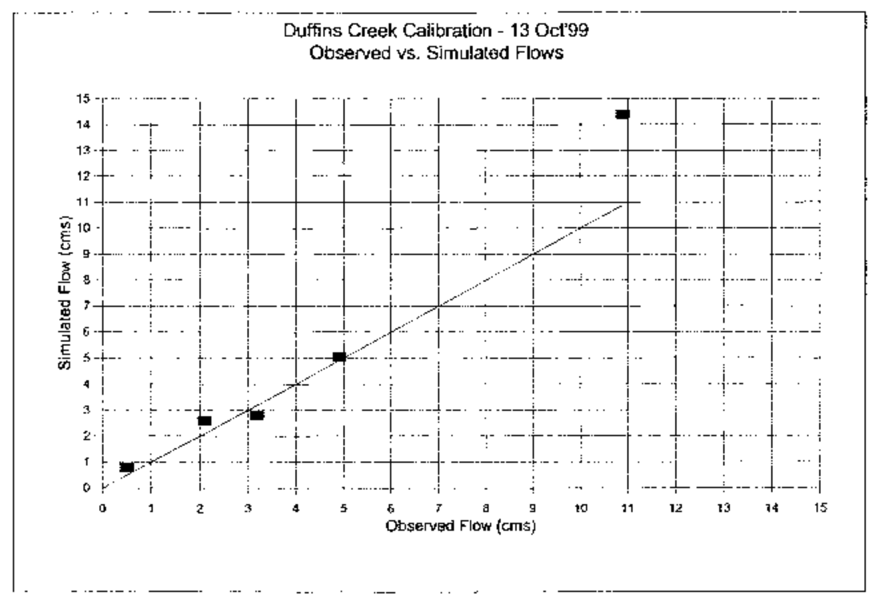
Figure 3.3:
Summary of Observed vs. Simulated Flows

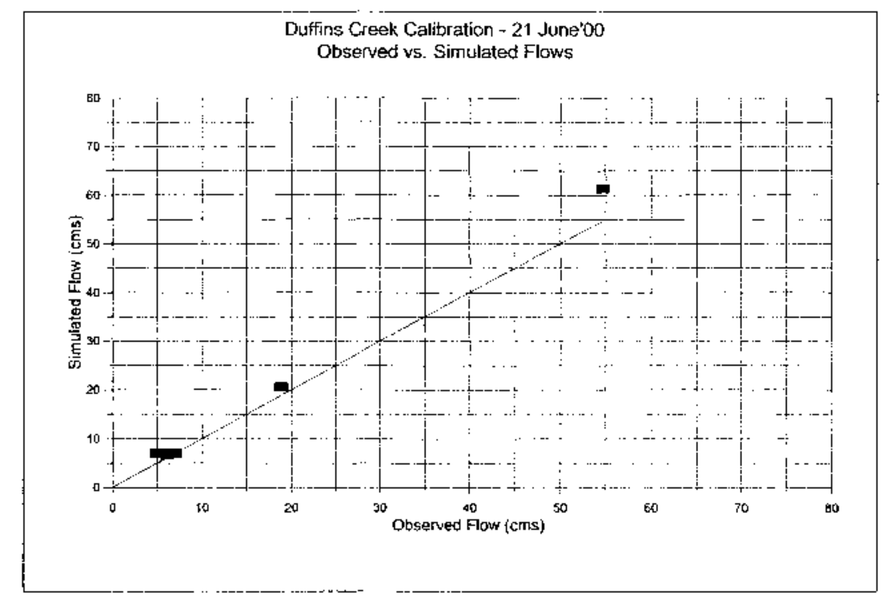












4.0 HYDROLOGIC ASSESSMENT AND DESIGN STORM FLOW ESTIMATES

Peak flows were established at key locations in the study area for the existing and projected future landuse scenarios. A design storm approach was used to estimate the 2, 5, 10, 25, 50, and 100-year peak flows, and the Regulatory Storm. The Regulatory Storm in the study area for floodplain management purposes is based on Hurricane Hazel.

With a design storm approach, a rainfall input (i.e. duration, return period depth, and temporal distribution) is selected and design flows are determined using specified antecedent moisture conditions and a computational technique such as a hydrologic model. It is assumed with this approach that peak flows which are generated are of approximately the same return period as the applied design storm.

4.1 Design Storm Selection

The 12-hour AES design storm was selected for application to the Duffins Creek watershed. The AES distribution was selected over both the U.S. Soil Conservation Service (SCS) and Chicago distributions, as it is more suitable for the study area. Past investigations have indicated that the Chicago distribution is inappropriate for some parts of Canada, and is less than ideal for the rest of the country (Pugsely, 1981). The SCS distribution is based on rainfall data from mountainous regions of the United States, and thus, not considered suitable for the study area. The 12-hour duration was selected as it is representative of the predominant type of storm which will cause flooding on this primarily rural watershed. Further, the 12-hour storm was typically found to be the critical duration in the previous 1991 hydrologic study.

Return period rainfall depths were obtained from Toronto Bloor Street Intensity-Duration-Frequency (IDF) data. Hyetographs for the 2-year through 100-year and Regulatory Storm events are provided in Appendix D.

4.2 Design Storm Flow Estimates - Existing Landuses

The calibrated hydrologic model for Duffins Creek was used as the basis for estimating design storm flow rates. To establish design storm conditions, the "base" CN* values from the calibrated model were adjusted so that peak flow estimates would match the observed flood frequency curves at streamflow gauges. Only minor adjustments from the calibrated model were required:

- West Duffins Creek (including Stouffville, Reesor, and Wixon Creeks): 0% adjustment required (i.e. "base" CN*'s applied)

- East Duffins Creek (including Michell, Brougham, Urfe, and Ganatsekiegon Creeks): +10% adjustment required

- Main Duffins Creek (below East and West Duffins Creeks, including Miller Creek): 0% adjustment required (i.e. "base" CN*'s applied)

Plots comparing the predicted and observed flood frequency curves at four streamflow gauges are provided in Appendix E. As shown, the modeled results can be considered representative of the observed flows at these locations. Insufficient historical data was available to produce flood frequency curves for the other two gauges used in this study (i.e. Urfe Creek and Brougham Creek). The resulting CN* values were assumed to represent AMC II conditions for the purposes of estimating 2-year through 100-year design storm flow rates.

Regional Storm flow estimates were then obtained by converting CN* values from AMC II to AMC III, and application of areal reduction factors to the rainfall depth using the "equivalent circular area method". The routing effects associated with existing stormwater management facilities were not considered for the regional flood estimates.

Peak flow estimates for the existing landuse scenario were obtained at key locations throughout the Duffins Creek Watershed. Summarized in Table 4.1 are the estimated existing design flows at the "flow node" locations illustrated in Figure 4.1. A review of the model results and comparison to the flows from the previous (1991) study is provided in the correspondence in Appendix F.

4.3 Design Storm Flow Estimates - Future Landuses

The hydrologic model was then setup in order to model two additional landuse scenarios associated with future urban development:

- Future Official Plan - includes future urban development committed on Municipal Official Plans; and
- Future Natural Heritage Strategy - includes future urban development, together with

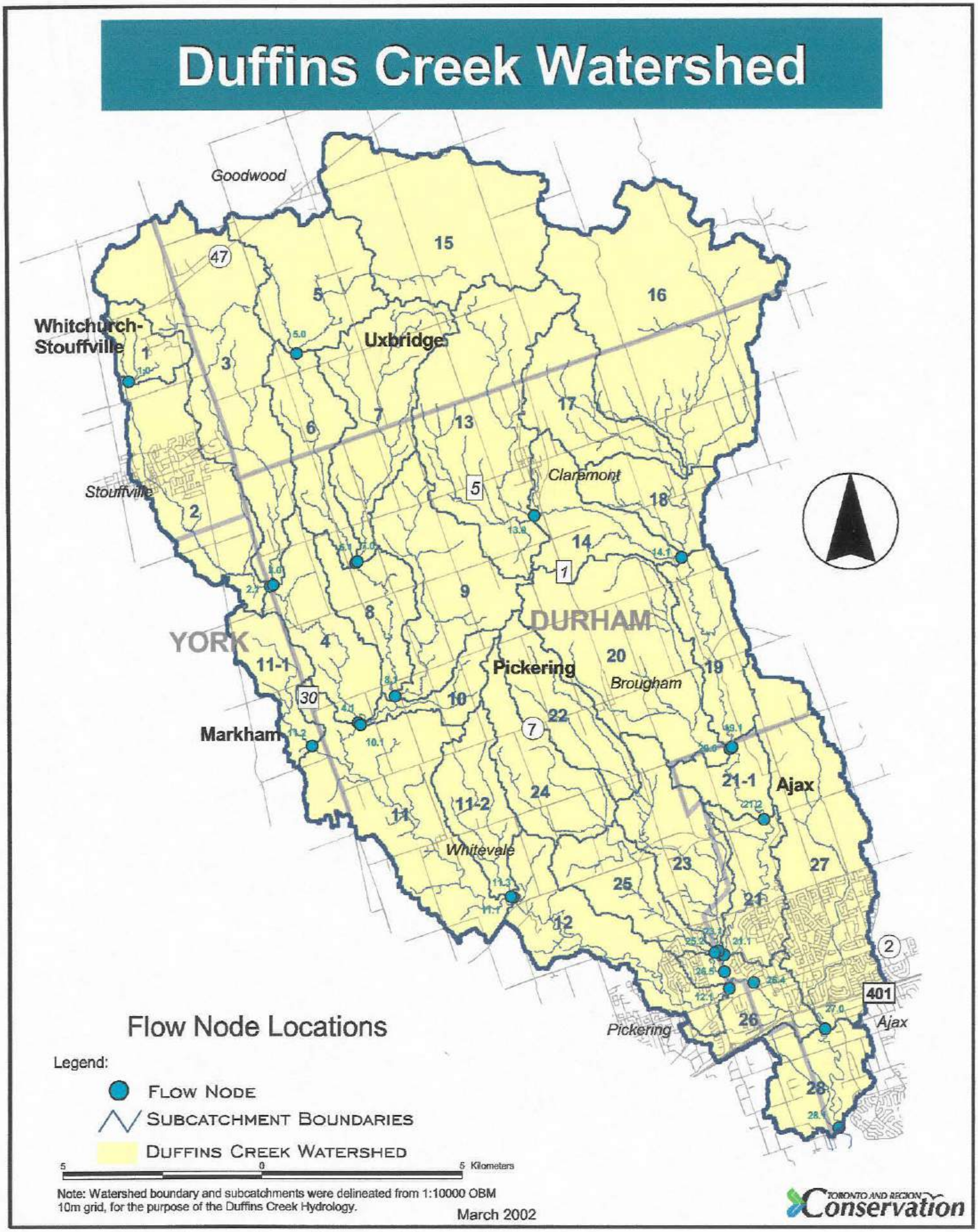


Figure 4.1 *Location of Peak Flow Estimates*

Table 4.1
Summary of Estimated Design Flows

Flow Node	Location	Drainage Area (km2)	Reduction Factor*	Landuse Scenario	Peak Flow Rate (cms)						
					2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	Regional
1.0	Stouffville Creek north of Bethesda Road	2.8	100.0%	Existing	1.5	2.5	3.1	4.1	4.8	5.6	22.3
				Future - Official Plan	1.5	2.5	3.1	4.1	4.8	5.6	22.3
				Future - Natural Heritage	1.4	2.3	2.9	3.8	4.5	5.3	22.0
2.1	Stouffville Creek at Townline Road	13.7	98.2%	Existing	4.8	7.4	9.3	12.0	13.9	16.2	66.4
				Future - Official Plan	7.1	10.9	13.6	17.1	19.9	23.1	83.1
				Future - Natural Heritage	6.7	10.1	12.5	15.5	18.1	21.0	79.6
3.0	Reesor Creek at Townline Road	19.0	97.1%	Existing	3.9	6.2	7.7	9.8	11.4	13.1	59.2
				Future - Official Plan	3.9	6.1	7.7	9.8	11.4	13.1	59.0
				Future - Natural Heritage	3.7	5.8	7.2	9.2	10.7	12.3	56.5
4.1	Reesor Creek at Townline road / north of Green River	39.5	95.4%	Existing	9.2	14.4	18.0	23.0	26.8	30.9	134.8
				Future - Official Plan	10.9	16.6	20.7	26.3	30.9	35.7	146.9
				Future - Natural Heritage	10.3	15.9	19.8	25.2	29.5	33.7	140.2
5.0	West Duffins Creek north of Webb Road at Glasgow	26.0	98.2%	Existing	3.3	5.9	7.7	10.4	12.6	14.9	89.5
				Future - Official Plan	3.3	5.9	7.7	10.4	12.6	14.9	89.5
				Future - Natural Heritage	2.5	4.4	5.8	7.9	9.6	11.4	79.4
6.1	West Duffins Creek south of Ninth Concession Road	32.5	97.1%	Existing	5.0	8.4	10.8	14.3	17.1	20.0	107.6
				Future - Official Plan	5.0	8.4	10.8	14.3	17.1	20.0	107.6
				Future - Natural Heritage	3.9	6.5	8.5	11.2	13.4	15.8	95.3
7.0	Wixon Creek south of Ninth Concession Road	10.8	99.2%	Existing	2.1	3.3	4.2	5.4	6.4	7.4	34.6
				Future - Official Plan	2.1	3.3	4.2	5.4	6.4	7.4	34.6
				Future - Natural Heritage	1.9	3.0	3.8	4.9	5.8	6.8	33.7
8.1	West Duffins Creek south of Seventh Concession Road	48.5	94.8%	Existing	8.1	13.3	17.0	22.3	26.4	30.8	150.4
				Future - Official Plan	8.1	13.3	17.0	22.3	26.4	30.8	150.4
				Future - Natural Heritage	6.8	11.0	14.1	18.6	22.0	25.7	135.6
10.1	West Duffins Creek above confluence with Reesor Creek	61.8	94.2%	Existing	10.9	17.7	22.6	29.4	34.7	40.3	186.2
				Future - Official Plan	10.9	17.7	22.6	29.4	34.7	40.3	186.2
				Future - Natural Heritage	9.6	15.5	19.7	25.6	30.2	35.1	170.6
11.2	Tributary of West Duffins Creek	4.3	100.0%	Existing	1.0	1.6	2.0	2.6	3.0	3.5	15.0
				Future - Official Plan	1.0	1.6	2.0	2.6	3.0	3.5	15.0
				Future - Natural Heritage	1.0	1.6	2.0	2.6	3.0	3.5	15.0
11.3	Whitevale Creek above confluence with West Duffins Creek	5.6	100.0%	Existing	1.3	2.0	2.6	3.3	3.9	4.5	21.1
				Future - Official Plan	2.6	3.8	4.7	6.3	7.4	8.4	26.0
				Future - Natural Heritage	2.6	3.8	4.7	6.3	7.3	8.4	26.0
11.1	West Duffins Creek at Taunton Road / at Clarkes Hollow	126.1	89.4%	Existing	23.9	38.3	48.5	63.0	73.9	85.0	354.4
				Future - Official Plan	24.6	38.8	48.9	63.1	74.0	85.0	352.8
				Future - Natural Heritage	22.8	36.0	45.4	58.7	68.6	79.4	330.9
12.1	West Duffins Creek at Pickering	135.1	89.4%	Existing	24.8	39.9	50.5	65.5	76.9	88.6	368.2
				Future - Official Plan	25.3	40.0	50.4	65.1	76.3	87.6	359.5
				Future - Natural Heritage	23.4	37.0	46.6	60.1	70.5	81.3	334.7

* Areal Reduction Factor Applied to Regional Storm

Table 4.1 (continued ....)
Summary of Estimated Design Flows

Flow Node	Location	Drainage Area (km2)	Reduction Factor*	Landuse Scenario	Peak Flow Rate (cms) 2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	Regional
13.0	Michell Creek at Brock Road	17.4	97.1%	Existing	7.9	12.3	15.3	19.5	22.7	26.1	97.4
				Future - Official Plan	7.9	12.3	15.3	19.5	22.7	26.1	97.4
				Future - Natural Heritage	6.4	10.1	12.7	16.4	19.2	22.2	93.6
14.1	Michell Creek above confluence with East Duffins Creek	23.6	94.8%	Existing	10.5	16.6	20.8	26.8	31.4	35.8	129.5
				Future - Official Plan	10.5	16.6	20.8	26.8	31.4	35.8	132.9
				Future - Natural Heritage	8.7	14.0	17.6	23.0	27.2	31.1	124.1
19.1	East Duffins Creek at Whitevale Road / above Brougham Creek	68.2	94.2%	Existing	24.0	39.0	49.5	64.3	75.8	87.8	346.4
				Future - Official Plan	24.0	39.0	49.5	64.3	75.8	87.8	348.9
				Future - Natural Heritage	19.8	32.6	41.7	54.6	64.7	75.3	328.4
20.0	Brougham Creek south of Whitevale Road	15.5	100.0%	Existing	6.8	10.7	13.3	17.0	19.8	22.8	88.3
				Future - Official Plan	6.8	10.6	13.3	16.9	19.7	22.7	87.4
				Future - Natural Heritage	6.5	10.3	12.8	16.4	19.2	22.0	86.6
21.2	East Duffins Creek at Taunton Road	86.9	89.4%	Existing	31.5	51.3	65.2	83.9	99.0	114.6	421.7
				Future - Official Plan	31.5	51.2	65.0	83.8	98.8	114.4	420.4
				Future - Natural Heritage	26.9	44.1	56.4	73.0	86.5	100.5	399.2
21.1	East Duffins Creek south of Rossland Road / above Urfe Creek	92.0	89.4%	Existing	32.6	53.7	68.2	87.5	103.4	120.0	437.5
				Future - Official Plan	32.2	53.1	67.5	86.6	102.1	118.6	431.7
				Future - Natural Heritage	27.5	45.8	58.7	75.6	89.6	104.3	409.5
23.1	Urfe Creek south of Rossland Road / above East Duffins Creek	14.4	97.1%	Existing	5.1	8.1	10.2	13.2	15.3	17.5	68.0
				Future - Official Plan	10.5	16.2	19.4	24.4	28.2	32.2	84.7
				Future - Natural Heritage	10.4	16.1	19.2	24.2	28.1	32.0	82.8
25.2	Ganatsekiagon Creek east of Brock Road / above East Duffins Creek	12.9	97.1%	Existing	4.4	6.9	8.7	11.1	13.0	14.9	59.4
				Future - Official Plan	11.2	16.1	19.6	24.4	28.2	32.9	83.7
				Future - Natural Heritage	10.9	15.6	19.0	23.6	27.2	31.6	81.8
26.5	East Duffins Creek at Pickering	119.3	89.4%	Existing	42.1	68.7	86.9	111.8	131.5	152.2	553.4
				Future - Official Plan	41.0	67.0	85.7	108.3	127.4	147.7	538.6
				Future - Natural Heritage	35.9	59.2	76.2	96.5	113.8	132.3	507.5
26.4	Duffins Creek at Kingston Road	254.4	89.4%	Existing	65.5	104.1	131.9	171.6	201.8	232.3	895.7
				Future - Official Plan	65.0	103.5	130.7	169.0	198.6	228.4	862.5
				Future - Natural Heritage	57.6	92.3	117.2	151.8	178.2	205.6	799.9
27.0	Millers Creek south of Hwy 401 / above Duffins Creek	17.0	98.2%	Existing	15.6	25.4	31.9	39.8	46.1	52.8	111.8
				Future - Official Plan	20.4	30.0	39.9	50.0	57.8	65.8	133.7
				Future - Natural Heritage	20.4	30.0	39.9	50.0	57.8	65.8	133.7
28.1	Duffins Creek at Lake Ontario	283.1	86.7%	Existing	69.5	110.2	139.1	180.7	212.7	244.8	900.8
				Future - Official Plan	70.2	111.3	140.1	180.1	212.0	243.7	901.4
				Future - Natural Heritage	67.1	99.3	125.3	161.4	189.5	218.0	819.0

* Areal Reduction Factor Applied to Regional Storm

reforestation of the headwaters and creek valleys associated with TRCA's Natural Heritage Strategy.

The TRCA GIS database was again used to derive the hydrologic model parameters associated with the future landuse scenarios listed above (i.e. CN values, percent impervious, etc.). Model parameters associated with future landuses are provided in Appendix A. With respect to the Future Natural Heritage scenario, the roughness coefficients within the channel routing routines were also increased to represent future re-vegetation within the valley corridors. These future landuse scenarios were modeled with no additional stormwater management facilities to control the increased future urban development, and therefore are considered "uncontrolled".

Table 4.1 summarizes the estimated future design flows at the "flow node" locations illustrated in Figure 4.1. A summary of the estimated changes in peak flows from existing rates is provided in Table 4.2. As shown, based on the future Official Plan landuse scenario, the largest flow increases are expected where significant development is planned within small tributaries:

- Stouffville Creek (node 2.1) - increase in urban development from approximately 235 ha to 470 ha (+100%), producing peak flow increases of approximately 45% and 25% for the 100-year flow and Regional Storm flow, respectively;
- Reesor Creek (node 4.1) - increase in urban development from approximately 90 ha to 130 ha (+45%), producing peak flow increases of approximately 15% and 10% for the 100-year flow and Regional Storm flow, respectively;
- Whitevale Creek (node 11.3) - approximately 105 ha of new urban development where there is currently none, producing peak flow increases of approximately 85% and 25% for the 100-year flow and Regional Storm flow, respectively;
- Urfe Creek (node 23.1) - increase in urban development from approximately 20 ha to 465 ha (> 2,000%), producing peak flow increases of approximately 85% and 25% for the 100-year flow and Regional Storm flow, respectively;
- Ganatsekiagon Creek (node 25.2) - increase in urban development from approximately 25 ha to 555 ha (> 2,000%), producing peak flow increases of approximately 120% and 40% for the 100-year flow and Regional Storm flow, respectively; and
- Millers Creek (node 17.0) - increase in urban development from approximately 780 ha to 1,040 ha (+33%), producing peak flow increases of approximately 25% and 20% for the 100-year flow and Regional Storm flow, respectively.

Table 4.2
Summary of Estimated Changes in Design Flows

Flow Node	Location	Drainage Area (km2)	Landuse Scenario	Existing Peak Flow Rates (cms) and Estimated Future Increases(%) 2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	Regional
1.0	Stouffville Creek north of Bethesda Road	2.8	Existing	1.5	2.5	3.1	4.1	4.8	5.6	22.3
			Future - Official Plan	0%	0%	0%	0%	0%	0%	0%
			Future - Natural Heritage	-7%	-8%	-6%	-7%	-6%	-5%	-1%
2.1	Stouffville Creek at Townline Road	13.7	Existing	4.8	7.4	9.3	12.0	13.9	16.2	66.4
			Future - Official Plan	48%	47%	46%	43%	43%	43%	25%
			Future - Natural Heritage	40%	36%	34%	29%	30%	30%	20%
3.0	Reesor Creek at Townline Road	19.0	Existing	3.9	6.2	7.7	9.8	11.4	13.1	59.2
			Future - Official Plan	0%	-2%	0%	0%	0%	0%	0%
			Future - Natural Heritage	-5%	-6%	-6%	-6%	-6%	-6%	-5%
4.1	Reesor Creek at Townline road / north of Green River	39.5	Existing	9.2	14.4	18.0	23.0	26.8	30.9	134.8
			Future - Official Plan	18%	15%	15%	14%	15%	16%	9%
			Future - Natural Heritage	12%	10%	10%	10%	10%	9%	4%
5.0	West Duffins Creek north of Webb Road at Glasgow	26.0	Existing	3.3	5.9	7.7	10.4	12.6	14.9	89.5
			Future - Official Plan	0%	0%	0%	0%	0%	0%	0%
			Future - Natural Heritage	-24%	-25%	-25%	-24%	-24%	-23%	-11%
6.1	West Duffins Creek south of Ninth Concession Road	32.5	Existing	5.0	8.4	10.8	14.3	17.1	20.0	107.6
			Future - Official Plan	0%	0%	0%	0%	0%	0%	0%
			Future - Natural Heritage	-22%	-23%	-21%	-22%	-22%	-21%	-11%
7.0	Wixon Creek south of Ninth Concession Road	10.8	Existing	2.1	3.3	4.2	5.4	6.4	7.4	34.6
			Future - Official Plan	0%	0%	0%	0%	0%	0%	0%
			Future - Natural Heritage	-10%	-9%	-10%	-9%	-9%	-8%	-3%
8.1	West Duffins Creek south of Seventh Concession Road	48.5	Existing	8.1	13.3	17.0	22.3	26.4	30.8	150.4
			Future - Official Plan	0%	0%	0%	0%	0%	0%	0%
			Future - Natural Heritage	-16%	-17%	-17%	-17%	-17%	-17%	-10%
10.1	West Duffins Creek above confluence with Reesor Creek	61.8	Existing	10.9	17.7	22.6	29.4	34.7	40.3	186.2
			Future - Official Plan	0%	0%	0%	0%	0%	0%	0%
			Future - Natural Heritage	-12%	-12%	-13%	-13%	-13%	-13%	-8%
11.2	Tributary of West Duffins Creek	4.3	Existing	1.0	1.6	2.0	2.6	3.0	3.5	15.0
			Future - Official Plan	0%	0%	0%	0%	0%	0%	0%
			Future - Natural Heritage	0%	0%	0%	0%	0%	0%	0%
11.3	Whitevale Creek above confluence with West Duffins Creek	5.6	Existing	1.3	2.0	2.6	3.3	3.9	4.5	21.1
			Future - Official Plan	100%	90%	81%	91%	90%	87%	23%
			Future - Natural Heritage	100%	90%	81%	91%	87%	87%	23%
11.1	West Duffins Creek at Taunton Road / at Clarkes Hollow	126.1	Existing	23.9	38.3	48.5	63.0	73.9	85.0	354.4
			Future - Official Plan	3%	1%	1%	0%	0%	0%	0%
			Future - Natural Heritage	-5%	-6%	-6%	-7%	-7%	-7%	-7%
12.1	West Duffins Creek at Pickering	135.1	Existing	24.8	39.9	50.5	65.5	76.9	88.6	368.2
			Future - Official Plan	2%	0%	0%	-1%	-1%	-1%	-2%
			Future - Natural Heritage	-6%	-7%	-8%	-8%	-8%	-8%	-9%

Table 4.2
Summary of Estimated Changes in Design Flows

Flow Node	Location	Drainage Area (km2)	Landuse Scenario	Existing Peak Flow Rates (cms) and Estimated Future Increases(%)						
				2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	Regional
13.0	Michell Creek at Brock Road	17.4	Existing	7.9	12.3	15.3	19.5	22.7	26.1	97.4
			Future - Official Plan	0%	0%	0%	0%	0%	0%	0%
			Future - Natural Heritage	-19%	-18%	-17%	-16%	-15%	-15%	-4%
14.1	Michell Creek above confluence with East Duffins Creek	23.6	Existing	10.5	16.6	20.8	26.8	31.4	35.8	129.5
			Future - Official Plan	0%	0%	0%	0%	0%	0%	3%
			Future - Natural Heritage	-17%	-16%	-15%	-14%	-13%	-13%	-4%
19.1	East Duffins Creek at Whitevale Road / above Brougham Creek	68.2	Existing	24.0	39.0	49.5	64.3	75.8	87.8	346.4
			Future - Official Plan	0%	0%	0%	0%	0%	0%	1%
			Future - Natural Heritage	-18%	-16%	-16%	-15%	-15%	-14%	-5%
20.0	Brougham Creek south of Whitevale Road	15.5	Existing	6.8	10.7	13.3	17.0	19.8	22.8	88.3
			Future - Official Plan	0%	-1%	0%	-1%	-1%	0%	-1%
			Future - Natural Heritage	-4%	-4%	-4%	-4%	-3%	-4%	-2%
21.2	East Duffins Creek at Taunton Road	86.9	Existing	31.5	51.3	65.2	83.9	99.0	114.6	421.7
			Future - Official Plan	0%	0%	0%	0%	0%	0%	0%
			Future - Natural Heritage	-15%	-14%	-13%	-13%	-13%	-12%	-5%
21.1	East Duffins Creek south of Rossland Road / above Urfe Creek	92.0	Existing	32.6	53.7	68.2	87.5	103.4	120.0	437.5
			Future - Official Plan	-1%	-1%	-1%	-1%	-1%	-1%	-1%
			Future - Natural Heritage	-16%	-15%	-14%	-14%	-13%	-13%	-6%
23.1	Urfe Creek south of Rossland Road / above East Duffins Creek	14.4	Existing	5.1	8.1	10.2	13.2	15.3	17.5	68.0
			Future - Official Plan	106%	100%	90%	85%	84%	84%	25%
			Future - Natural Heritage	104%	99%	88%	83%	84%	83%	22%
25.2	Ganatsekiagon Creek east of Brock Road / above East Duffins Creek	12.9	Existing	4.4	6.9	8.7	11.1	13.0	14.9	59.4
			Future - Official Plan	155%	133%	125%	120%	117%	121%	41%
			Future - Natural Heritage	148%	126%	118%	113%	109%	112%	38%
26.5	East Duffins Creek at Pickering	119.3	Existing	42.1	68.7	86.9	111.8	131.5	152.2	553.4
			Future - Official Plan	-3%	-2%	-1%	-3%	-3%	-3%	-3%
			Future - Natural Heritage	-15%	-14%	-12%	-14%	-13%	-13%	-8%
26.4	Duffins Creek at Kingston Road	254.4	Existing	65.5	104.1	131.9	171.6	201.8	232.3	895.7
			Future - Official Plan	-1%	-1%	-1%	-2%	-2%	-2%	-4%
			Future - Natural Heritage	-12%	-11%	-11%	-12%	-12%	-11%	-11%
27.0	Millers Creek south of Hwy 401 / above Duffins Creek	17.0	Existing	15.8	25.4	31.9	39.8	46.1	52.8	111.8
			Future - Official Plan	29%	18%	25%	26%	25%	25%	20%
			Future - Natural Heritage	29%	18%	25%	26%	25%	25%	20%
28.1	Duffins Creek at Lake Ontario	283.1	Existing	69.5	110.2	139.1	180.7	212.7	244.8	900.8
			Future - Official Plan	1%	1%	1%	0%	0%	0%	0%
			Future - Natural Heritage	-3%	-10%	-10%	-11%	-11%	-11%	-9%

As shown in Table 4.2, negligible changes are predicted in the major tributary reaches under the future Official Plan landuse scenario.

With respect to the future Natural Heritage landuse scenario, peak flow increases are expected to be approximately 0% to 20% less than the increases anticipated under the Official Plan scenario for the 100-year event, and approximately 0% to 10% less than the increases anticipated under the Official Plan scenario for the Regional Storm event. In fact, in many locations the future Natural Heritage scenario results in peak flows which are marginally less than the existing peak flow rates.

5.0 UNIT FLOW DEVELOPMENT

As discussed in the preceding Section, peak flows associated with existing landuses have been established at over 20 flow nodes within the Duffins Creek Watershed. Dependent on the ultimate water management strategy implemented for the watershed, the existing flow rates will represent targets to be maintained with future landuse change. However, development proposals typically represent a significantly smaller drainage area than those associated with the flow nodes. In the absence of specific water management criteria, such as that associated with subwatershed studies or master drainage plans, site stormwater management generally only considers the immediate site and any local external drainage areas. In addition, the methodology and assumptions made in estimating pre-development peak flows will vary from development proponent to development proponent, and therefore result in water management facilities with similar design criteria but varying operational characteristics.

Based on the above, from an implementation perspective the issue has been raised as to whether or not the cumulative impact of "blanket" application of a particular water management strategy will result in the target peak flows at respective downstream flow nodes. The "unit flow" concept has recently been introduced by MTRCA for the Humber River and Upper Don River watersheds to provide a consistent means of pre-development peak flow estimation and ensure target peak flows are met within individual sub-basins.

A similar approach has been undertaken for the Duffins Creek watershed to provide pre-development peak flows which can be determined based on the location in the study area and the drainage area. To do so, unit flow relationships for the Duffins Creek watershed were developed for typical sub-basins.

The calibrated hydrologic model for the existing landuse scenario was modified and applied to determine the unit flow relationships. This was undertaken by progressive discretization of sub-basins into smaller catchments such that relationships could be established for drainage areas varying between approximately 10 hectares and 1000 hectares. Again, model parameters were estimated from TRCA's GIS database. For each subsequent model discretization, peak flows and timing were calibrated to match those of the preceding model at the outlet of the point of interest. This process is shown schematically in Figure 5.1. The calibration process consisted of typically varying the time-to-peak parameter of the Nashyd unit hydrograph to match peak flows and timing.

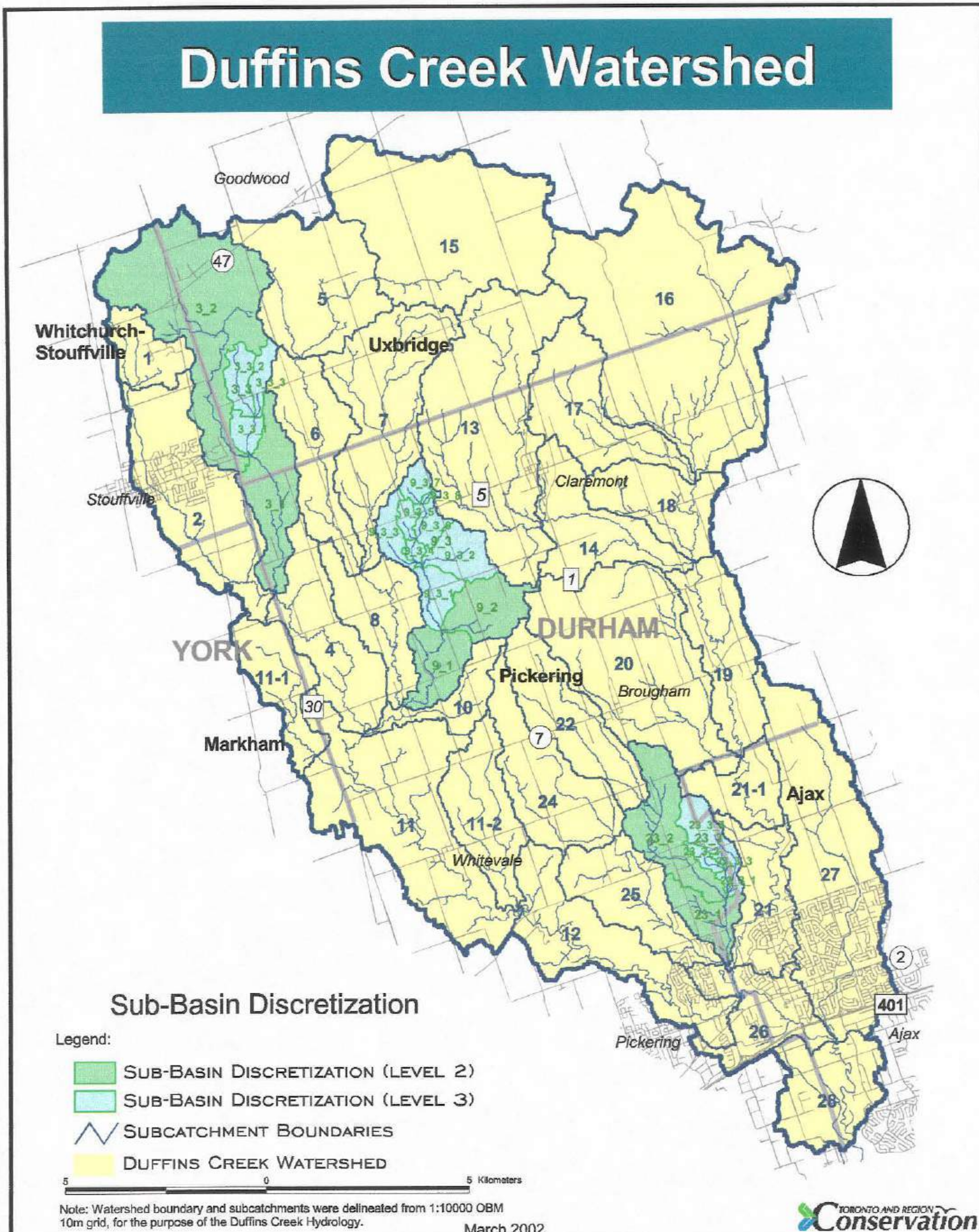


Figure 5.1 *Unit Flow Development - Sub-Basin Discretization*

Three catchments situated throughout the Duffins Creek watershed were selected based on location, soils, and tributary characteristics:

- catchment 3 (Reesor Creek): - upper end of watershed, adjacent to future development in Whitchurch-Stouffville.
  - soils classification: mostly B type soils with some D
- catchment 9 (W.Duffins Tributary): - West Duffins Creek system, middle of watershed, within future Airport Lands
  - soils classification: mostly D type soils with some B
- catchment 23 (Urfe Creek): - East Duffins Creek system, mid-to-lower end of watershed, within future development lands north of Pickering, including the Seaton Lands
  - soils classification: B type soils

The results from the calibrated sub-models were then used to derive regression equations for unit flow rates based on drainage areas within the respective sub-basins. Figures 5.2 to 5.4 illustrate the development of the 2-year and 100-year unit flow relationships for the selected catchments, and Table 5.1 summarizes the unit flow equations. The results from these three representative catchments were then assumed to be applicable to other catchments within the same general tributary system (i.e. Reesor and Stouffville, East Duffins, West Duffins), as summarized in Table 5.2.

Figure 5.2: Unit Flow Development - Catchment 3 (Reesor Creek)

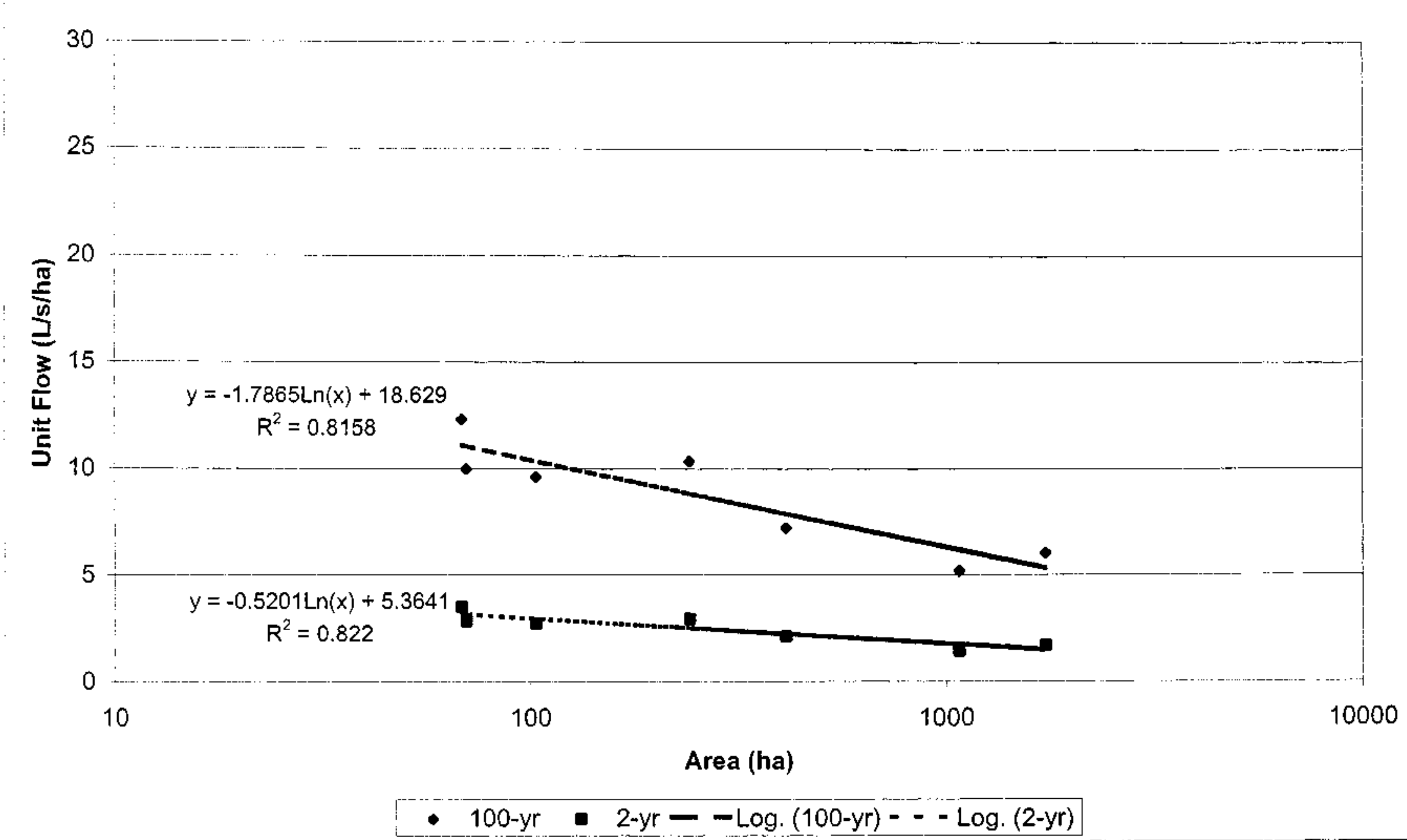


Figure 5.3: Unit Flow Development - Catchment 9 (W. Duffins Tributary)

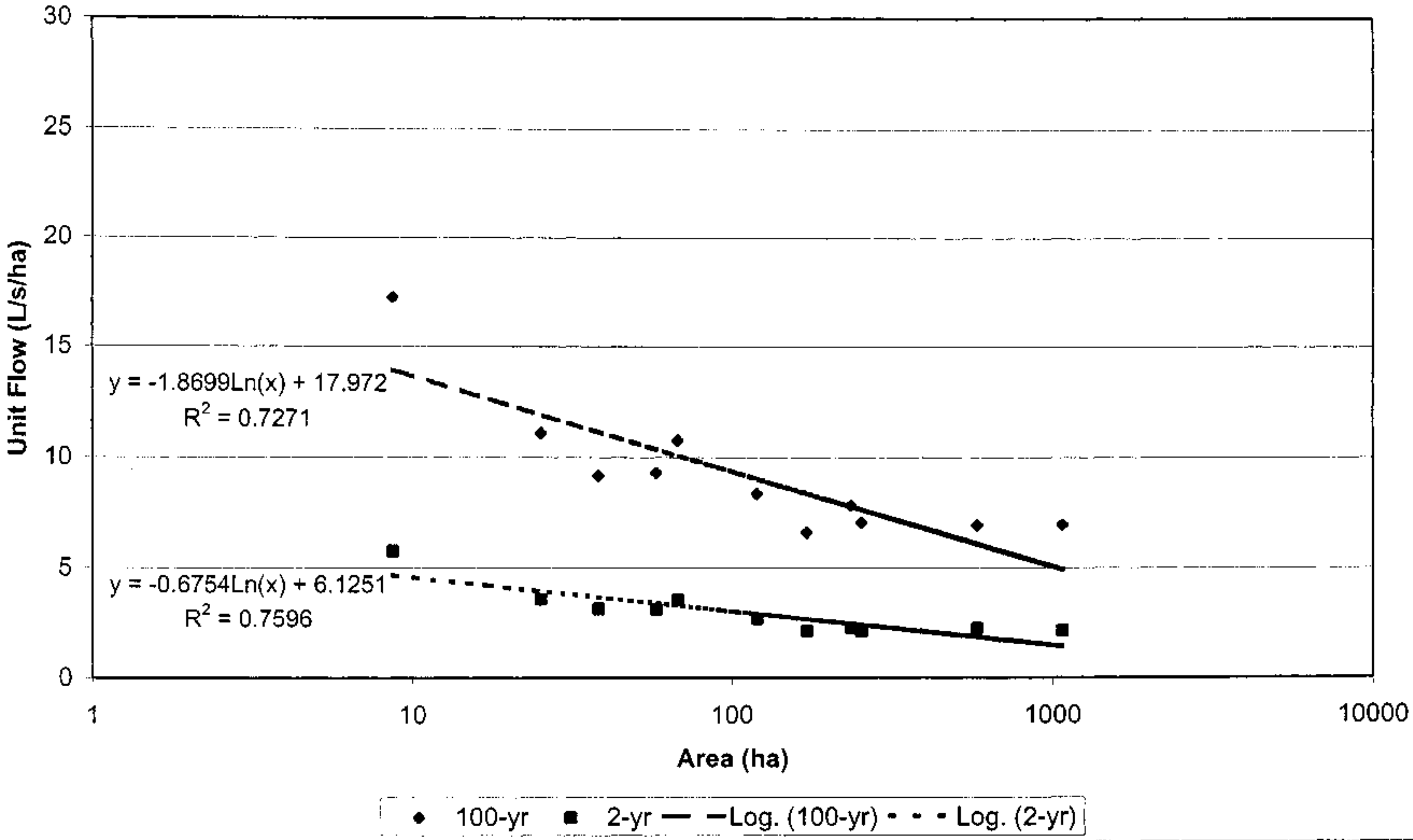


Figure 5.4: Unit Flow Development - Catchment 23 (Urfe Creek)

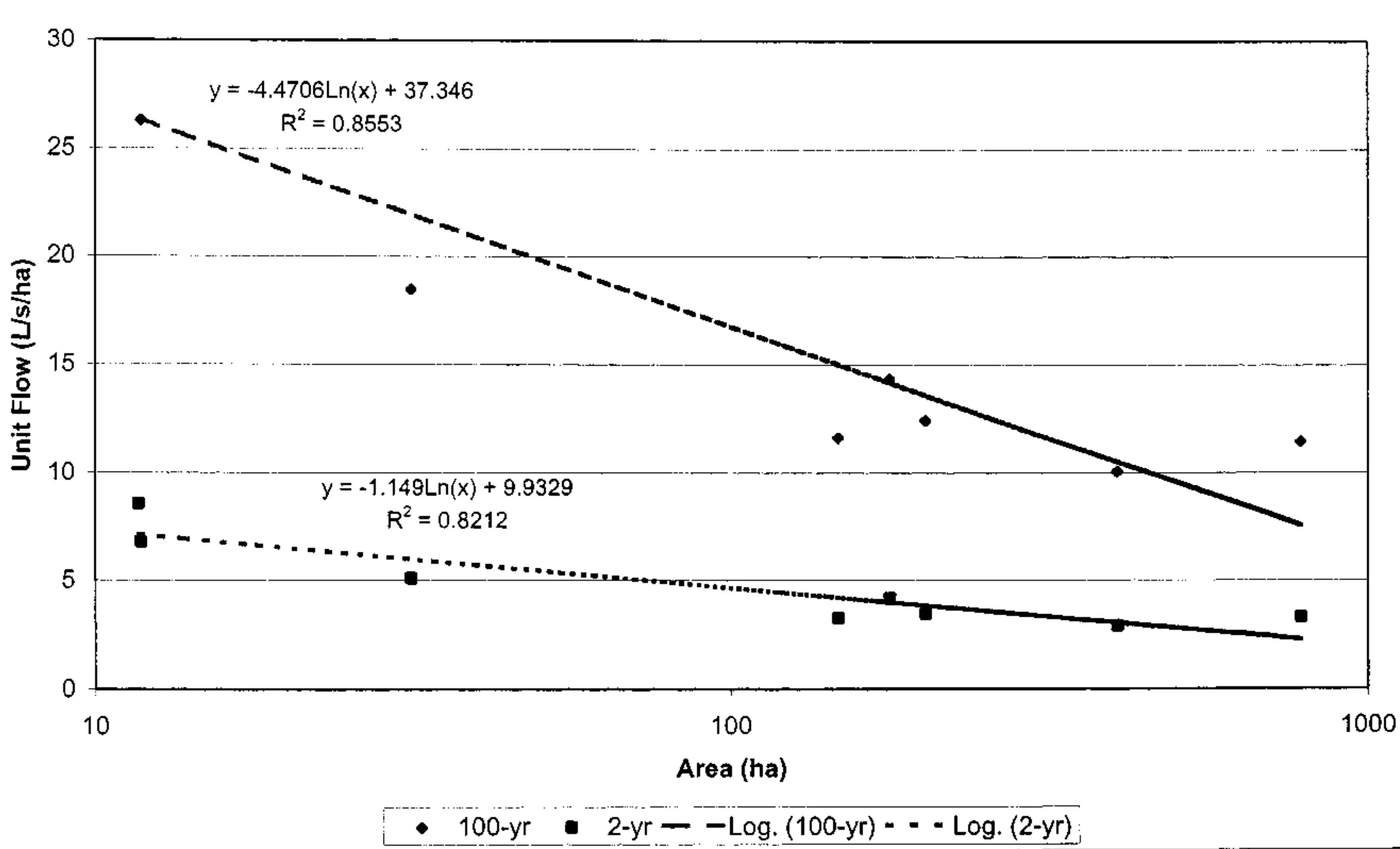


Table 5.1
Summary of Unit Flow Relationships

Return Period	Catchment 3 (Reesor Creek)	Catchment 9 (W.Duffins Creek Trib)	Catchment 23 (Urfe Creek)
2-year	Q_2= 5.364-0.520 ln(A)	Q_2= 6.125-0.675 ln(A)	Q_2= 9.933-1.149 ln(A)
5-year	Q_5= 8.535-0.826 ln(A)	Q_5= 8.601-0.890 ln(A)	Q_5= 16.081-1.873 ln(A)
10-year	Q_{10}= 10.729-1.036 ln(A)	Q_{10}= 11.032-1.168 ln(A)	Q_{10}= 20.440-2.397 ln(A)
25-year	Q_{25}= 13.832-1.334 ln(A)	Q_{25}= 14.199-1.530 ln(A)	Q_{25}= 26.633-3.139 ln(A)
50-year	Q_{50}= 16.132-1.549 ln(A)	Q_{50}= 15.580-1.612 ln(A)	Q_{50}= 32.296-3.867 ln(A)
100-year	Q_{100}= 18.629-1.787 ln(A)	Q_{100}= 17.972-1.870 ln(A)	Q_{100}= 37.346-4.471 ln(A)

Note: - Area (A) in hectares
- Unit Flow (Q_n) in Litres/s/ha

Table 5.2
Application of Unit Flow Equations

Applicable Catchments	Future Urban Development (per Official Plans)	CN*	Catchment Slope	Unit Flows
Reesor & Stouffville Tributaries				
1 (Stouffville Creek)	0 ha	70	3.2%	per Catchment 3
2 (Stouffville Creek)	235 ha	73	2.0%	equations (Table 5.1)
3 (Reesor Creek)	**39 ha**	**70**	**2.8%**	
4 (Reesor Creek)	0 ha	73	2.4%	
West & Lower Duffins System				
5 (W.Duffins Creek)	0 ha	60	4.6%	per Catchment 9
6 (W.Duffins Creek)	0 ha	80	2.7%	equations (Table 5.1)
7 (Wixon Creek)	0 ha	71	3.7%	
8 (W.Duffins Creek)	0 ha	75	2.3%	
9 (W.Duffins Creek Trib.)	**0 ha**	**79**	**1.9%**	
10 (W.Duffins Creek Trib.)	0 ha	74	2.5%	
11 (W. Duffins Creek)	27 ha	73	2.9%	
11.1 (W.Duffins Creek Trib.)	0 ha	76	2.0%	
11.2 (Whitevale Creek)	103 ha	72	2.7%	
12 (W. Duffins Creek)	294 ha	66	4.4%	
15 (W. Duffins Creek)	0 ha	62	3.1%	
26 (Lower Duffins Creek)	0 ha	67	2.6%	
27 (Millers Creek)	258 ha	68	2.4%	
28 (Lower Duffins Creek)	175 ha	68	2.5%	
East Duffins System				
13 (Michell Creek)	0 ha	78	3.2%	per Catchment 23
14 (Michell Creek)	0 ha	77	3.9%	equations (Table 5.1)
16 (E. Duffins Creek)	0 ha	72	5.9%	
17 (E. Duffins Creek)	0 ha	72	4.6%	
18 (E. Duffins Creek)	0 ha	77	4.2%	
19 (E. Duffins Creek)	0 ha	74	3.9%	
20 (Brougham Creek)	28 ha	78	3.1%	
21.1 (E. Duffins Creek)	6 ha	71	4.8%	
21.0 (E. Duffins Creek)	125 ha	77	3.0%	
22 (Urfe Creek)	44 ha	78	3.0%	
23 (Urfe Creek)	**401 ha**	**74**	**3.2%**	
24 (Ganatsekiagon Creek)	213 ha	79	2.6%	
25 (Ganatsekiagon Creek)	318 ha	73	4.4%	

6.0 SUMMARY AND CONCLUSIONS

1. A hydrologic model was setup for the Duffins Creek Watershed using the Visual Otthymo model, version 1.06, with model parameters derived from TRCA's GIS database. The model was calibrated and verified based on a series of rainfall events which occurred in 1999 and 2000.

2. Design flows for the 2-year to 100-year return periods and the Regional Storm were estimated for three scenarios using landuse information from TRCA's GIS database:
   - existing landuses;
   - future landuses as defined in municipal Official Plans; and
   - future natural heritage landuses which includes TRCA's strategy for reforestation within the headwaters and creek valleys.

3. In terms of landuses, approximately 7% of the Duffins Creek Watershed is developed with urban landuses under the existing scenario. The future landuse scenarios, as designated by Official Plans, will increase the level of urban development to approximately 15%.

4. Based on the future Official Plan landuse scenario, large increases in peak flows are anticipated where significant future development is planned within smaller tributaries, including Stouffville, Reesor, Whitevale, Urfe, Ganatsekiagon, and Millers Creeks. Negligible changes are predicted for the major tributary reaches.

5. Based on the future Natural Heritage landuse scenario, peak flow increases are expected to be approximately 0% to 20% less than the increases anticipated under the Official Plan scenario for the 100-year event, and approximately 0% to 10% less than the increases anticipated under the Official Plan scenario for the Regional Storm event. The future Natural Heritage scenario also results in peak flow rates which are marginally less than the existing peak flow rates at many locations.

6. Unit flow relationships were derived for three individual catchments with varying characteristics, located throughout the watershed. Unit flow equations were developed based on drainage area and location within the watershed, and the results of this analysis were then extrapolated to remaining catchments where future development may be planned.

7.0 RECOMMENDATIONS

1. The hydrologic model should be further verified when rainfall and streamflow data becomes available for future storm events which are larger than those used for the calibration.

2. On a routine basis, the model should be updated by development proponents as future development proceeds and future stormwater management facilities are constructed.

3. Based on a comparison of model results for existing and future landuse scenarios, "post-to-pre" flood control (i.e. 2-year to 100-year events) facilities are recommended for developments draining to the following tributaries:

   - Stouffville Creek;
   - Reesor Creek;
   - Whitevale Creek;
   - Urfe Creek;
   - Ganatsekiagon Creek;
   - Millers Creek (north of Taunton Road);
   - Michell Creek;
   - Brougham Creek (including Spring Creek);
   - West Duffins Creek (north of Hwy. 7); and
   - East Duffins Creek (north of Hwy. 7).

   In addition, any proposed commercial infill development draining to Millers Creek (south of Taunton Road) will also require 2-year to 100-year "post-to-pre" control.

4. Based on a comparison of model results for existing and future landuse scenarios, Regional Storm control may be required for the following tributaries:

   - Whitevale Creek;
   - Urfe Creek; and
   - Ganatsekiagon Creek.

   A Regional Storm assessment will be required for proposed developments which drain to the above-mentioned tributaries to determine whether Regional control is required.

5. Should future developments be proposed beyond those assumed in the Official Plan scenario, "post-to-pre" runoff controls may be required, regardless of the location within the watershed, and an assessment will also be required to determine whether Regional Storm controls will be necessary for such developments.

Respectfully submitted,

AQUAFOR BEECH LIMITED

Greg R. Frew, P.Eng.

REFERENCES

Aquafor Engineering Limited. July, 1991. Duffins Creek Watershed Study, Phase 1: Hydrology. Final Report for Metropolitan Toronto and Region Conservation Authority.

Aquafor Beech Limited. November, 1997. Humber River Watershed Hydrology/Hydraulics and Stormwater Management Study. Final Report prepared for the Toronto and Region Conservation Authority.

Bruce, J.P. and Clark, R.H., Introduction to Hydrometeorology. The Commonwealth and International Library of Science Technology Engineering and Liberal Studies.

Hogg, W.D. 1980. Time Distribution of Short Duration Rainfall in Canada. Proceedings of the Canadian Hydrology Symposium: 80, NRCC, Ottawa, Ontario.

James F. MacLaren Limited. 1979. Hydrologic Model Study for the Humber, Don and Rouge Rivers, Highland, Duffin, Petticoat and Carruthers Creeks. Report prepared for the MTRCA.

Linsley, R.K., and Kohler, M., and Paulhus, J.L. Hydrology for Engineers. 1982.

Ontario Ministry of the Natural Resources. 1987. Flood Plain Management in Ontario: Technical Guidelines. Conservation Authorities and Water management Branch.

Paul Wisner and Associates Inc. 1989. Interhymo/Otthymo 89 Users Manual. Ottawa, Ontario.

Pugsley, W.I. (Ed.). 1981. Flood Hydrology Guide for Canada: Hydrometeorological Design Techniques. CL 13-81, AES, Environment Canada, Downsview, Ontario.

Environment Canada. 2001. HYDAT Surface Water and Sediment Data - Version 99-2.00. Water Survey of Canada.

Watt, W.E. and K.C.A. Chow. 1985. A General Expression for Basin Lag Time. Canadian Journal of Civil Engineering, 12(2): 294-300.

Greenland Engineering Group. Visual Otthymo Version 1.0 for Windows 95/NT. Users Manual.

APPENDIX A:

Hydrologic Model Parameters, Soils and Landuse Mapping

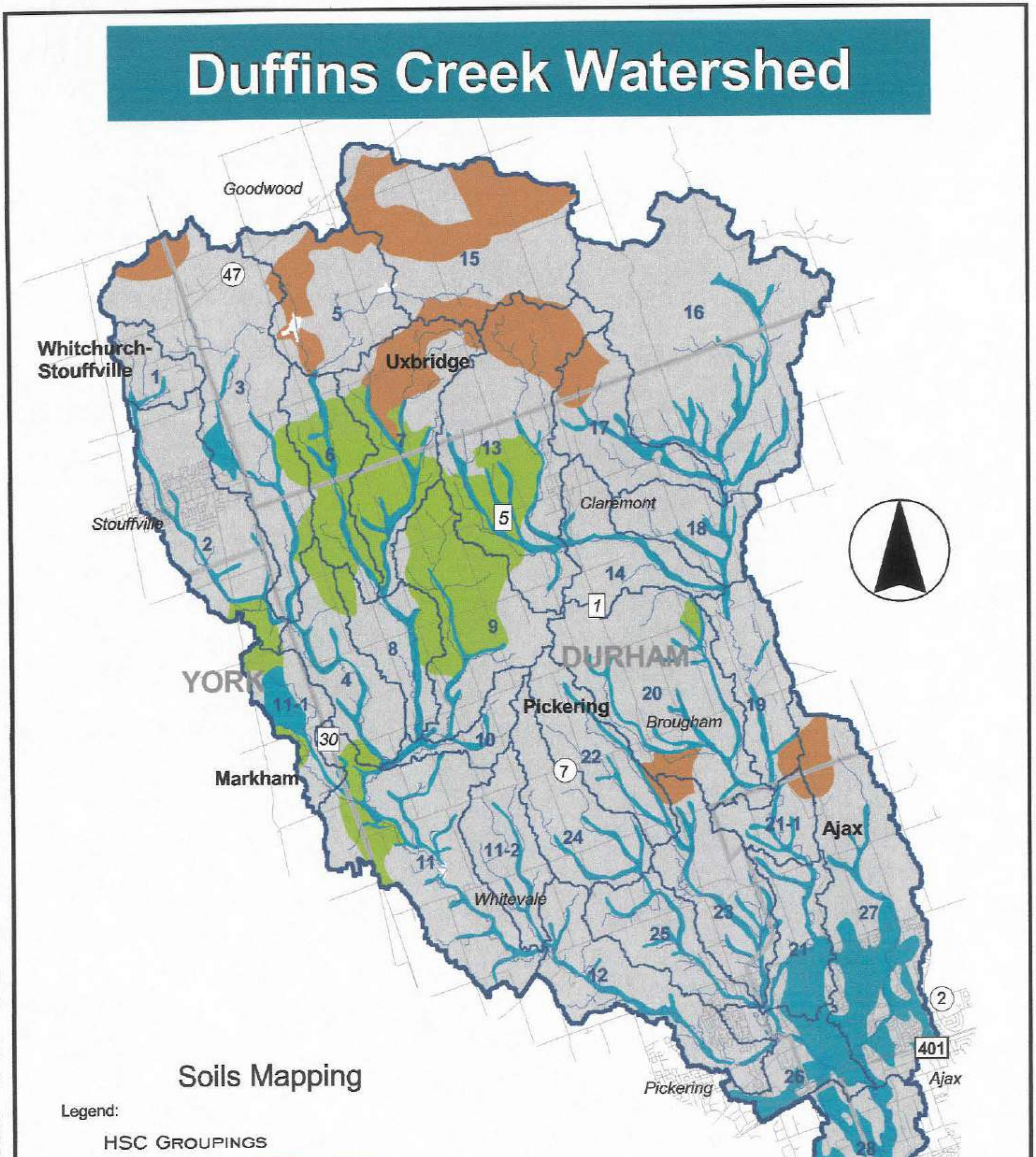


Figure A.1 *Soils Mapping*

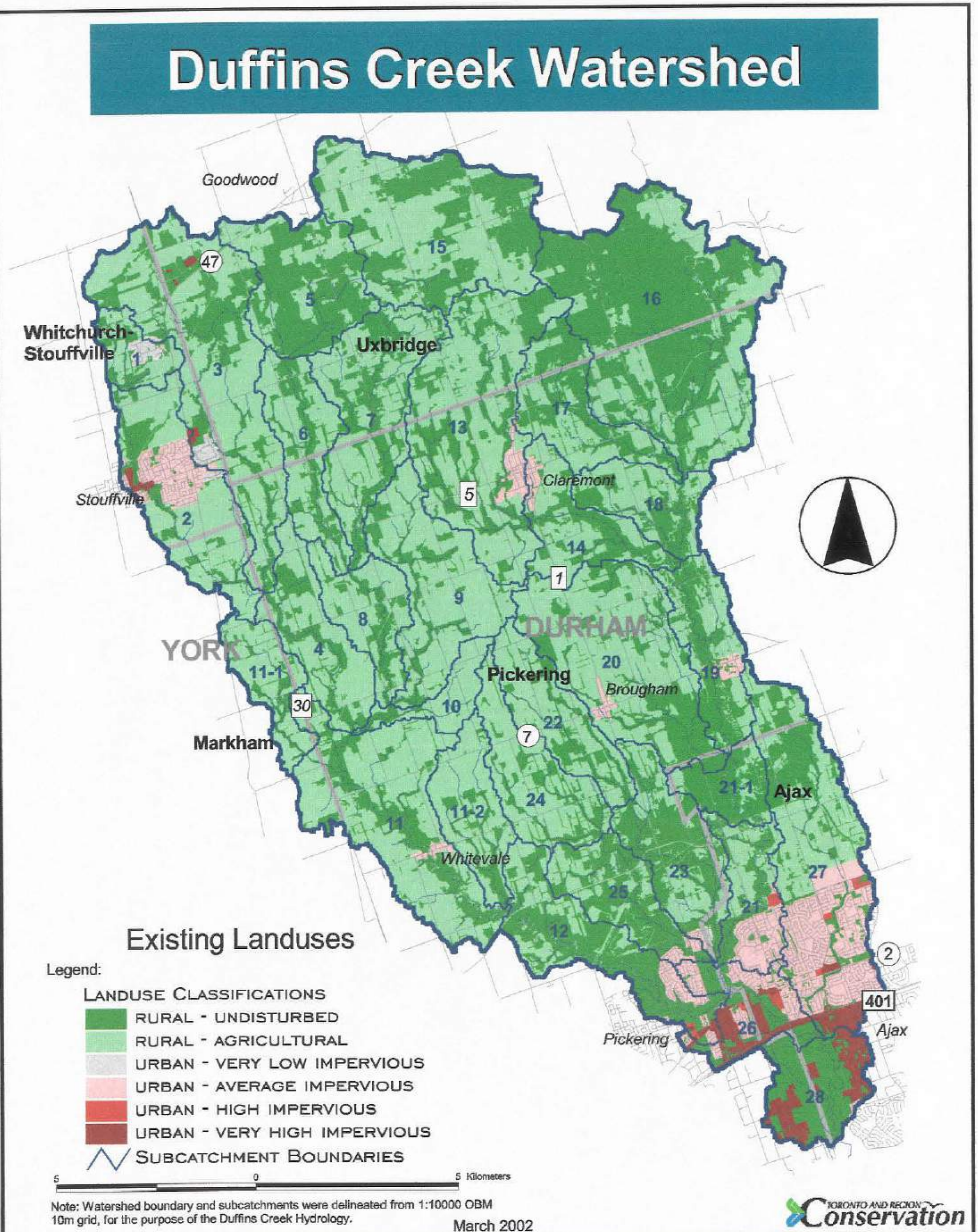


Figure A.2 *Existing Landuses*

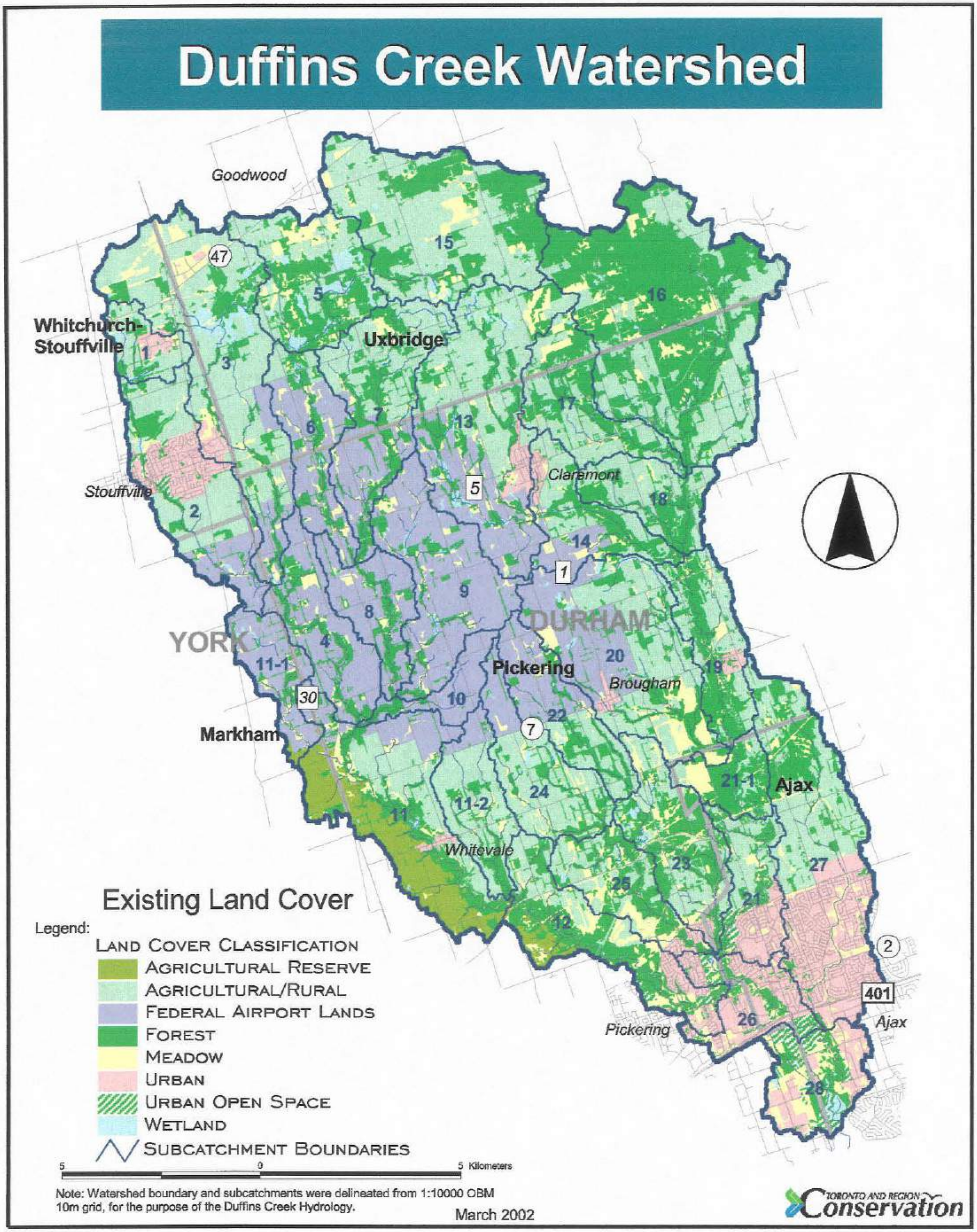


Figure A.3 *Existing Land Cover*

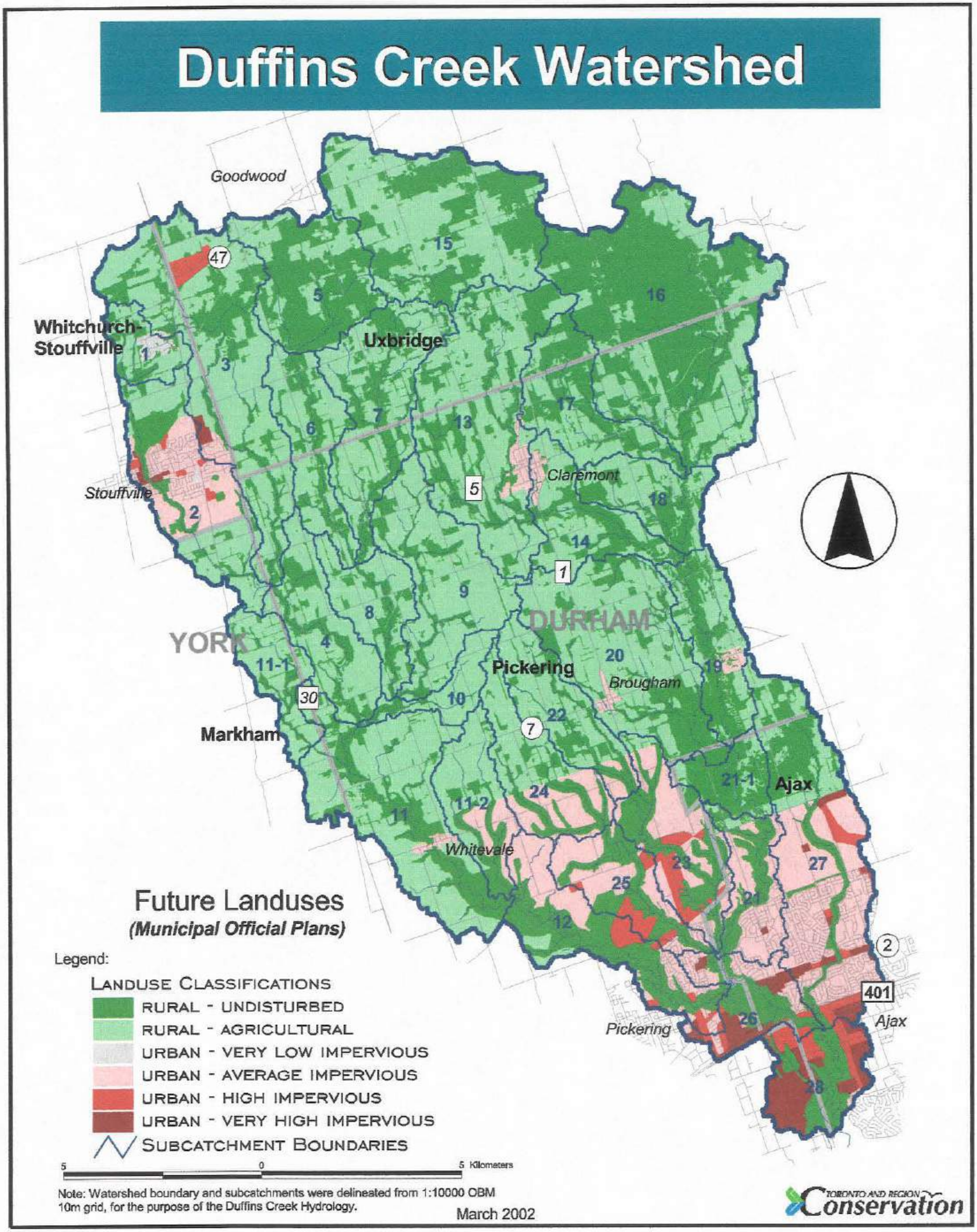


Figure A.4 *Future Landuses - (Municipal Official Plans)*

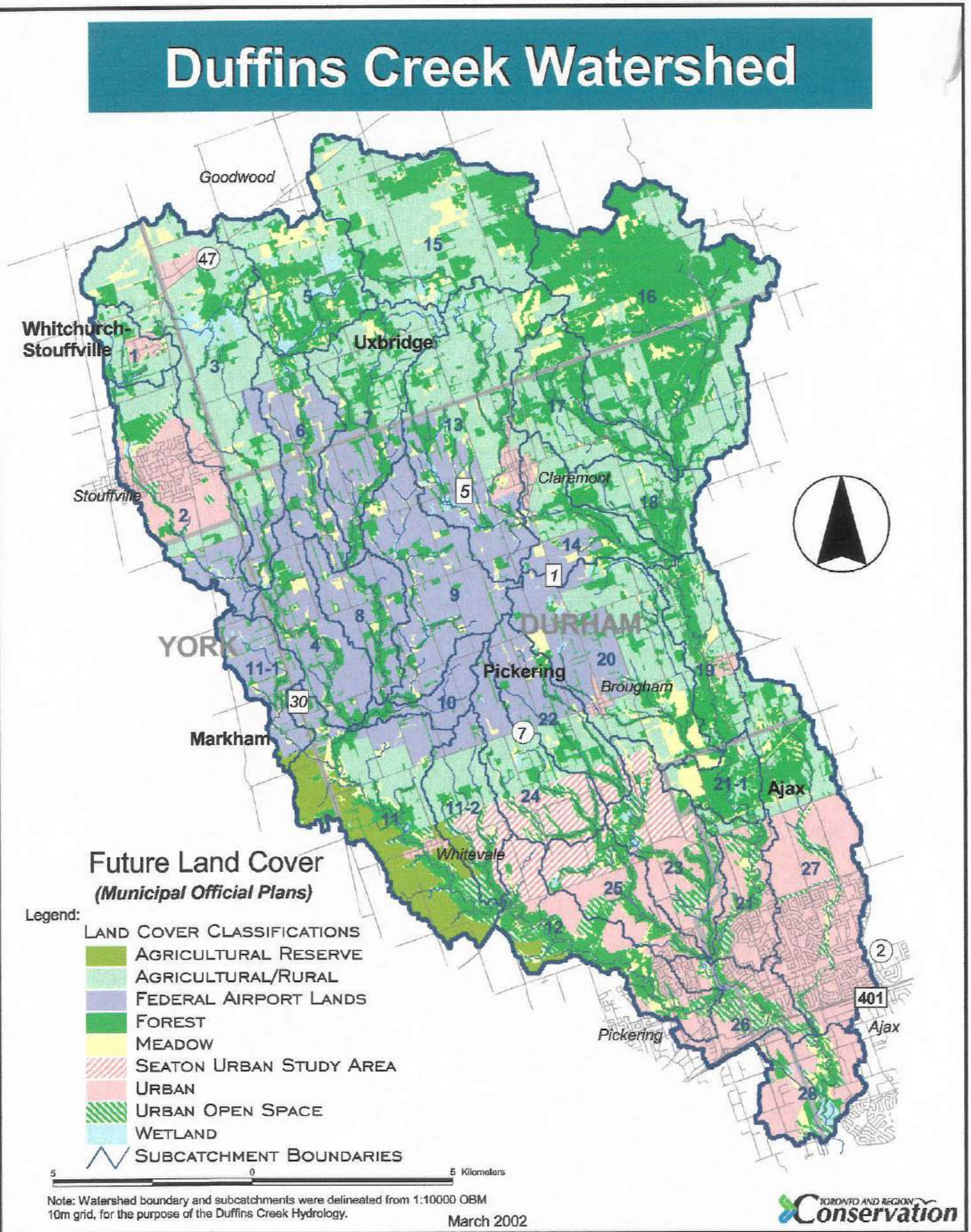


Figure A.5 *Future Land Cover - (Municipal Official Plans)*

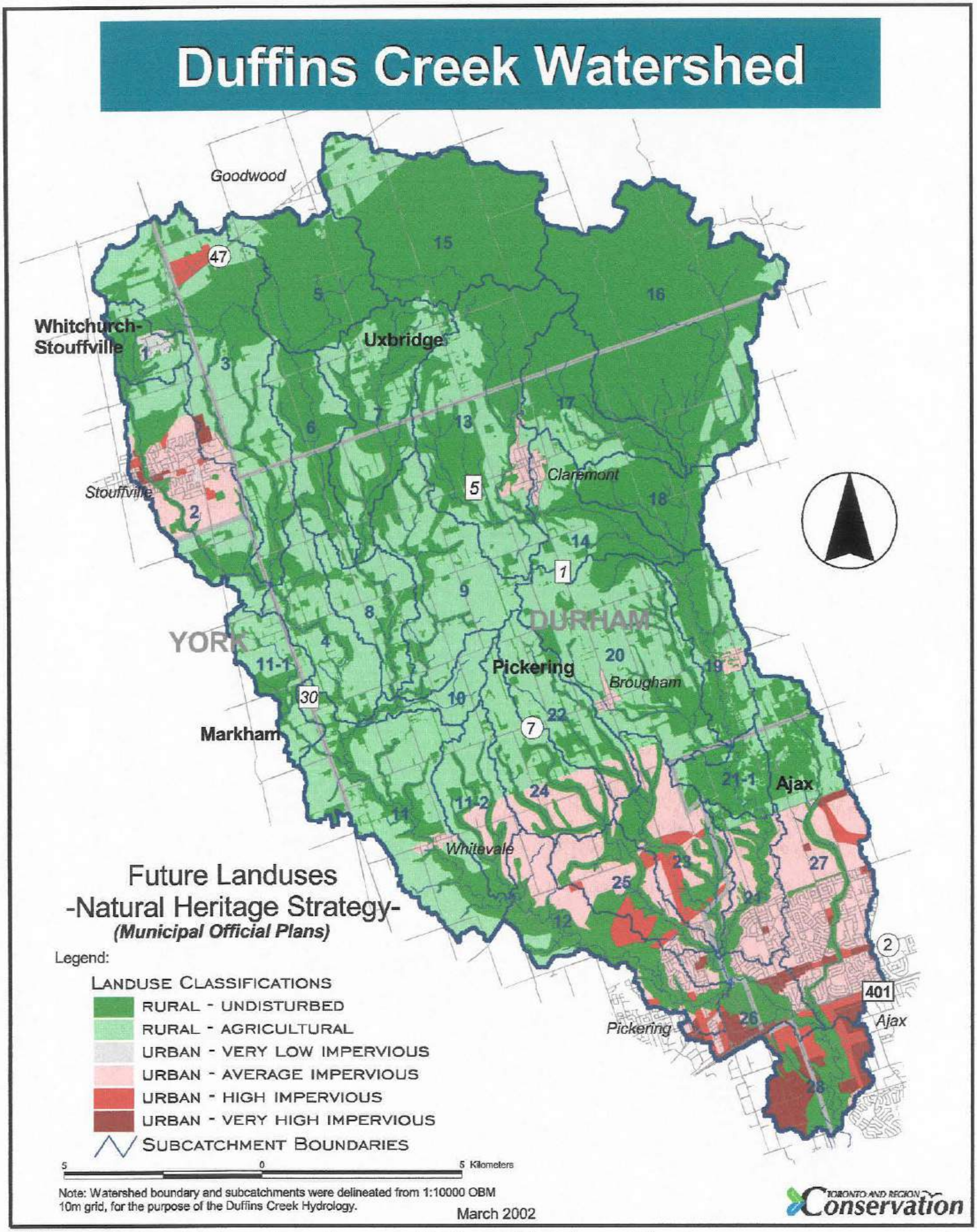


Figure A.6 *Future Landuses - Natural Heritage Strategy (Municipal Official Plans)*

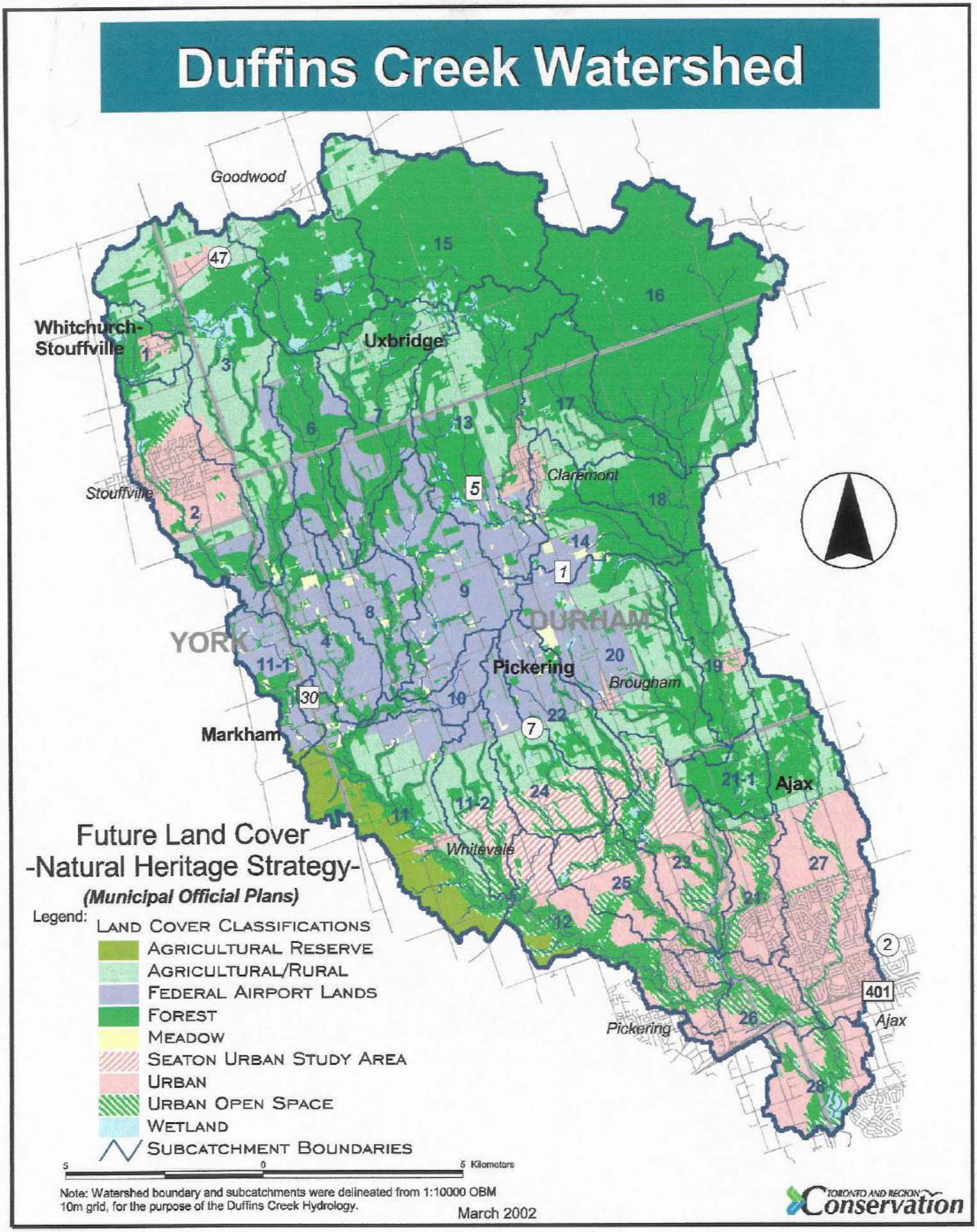


Figure A.7 *Future Land Cover - Natural Heritage Strategy (Municipal Official Plans)*

EXISTING LANDUSE SCENARIO

Note: Design Storm Parameters are based on calibrated values, but include a +10% adjustment for CN's within the East Branch of Duffins Creek (catchments 13 to 25)
Note: Existing Land Use (Digitized from 1999 ortho-photograhy) coupled with TRCA Natural Heritage terrestial data

RURAL COMPONENT PARAMETERS

SUB-BASIN	SWM POND #	TOTAL AREA (hectares)		RURAL AREA (hectares)	SUB-BASIN SLOPE (mean)	STREAM SLOPE (%)	MAX STREAM LENGTH (metres)	UNADJUSTED CN_RURAL (from GIS)	DESIGN CN_RURAL AMC II	DESIGN CN_RURAL AMC III	IA_rural (mm)	"n"	Tp (hrs)
1.0		281.6		239.8	3.19	2.31	2,462	70	70	86	5.0	1.5	0.91
2.0		1,027.4		847.3	1.99	1.87	8,569	73	73	87	5.0	1.5	2.94
2.01	185.0	5.8		0.0									
2.02	166.0	52.0		0.0									
3.0		1,728.4		1,728.4	2.77	2.21	13,313	70	70	86	5.0	1.5	3.65
3.01	295.0	36.0		0.0									
3.02	295.1	133.6		81.9				70	70	86	5.0	1.5	4.87
4.0		681.6		681.6	2.40	2.60	9,021	73	73	87	5.0	1.5	3.79
5.0		920.6		901.3	4.67	2.28	6,118	60	60	78	10.0	1.5	2.14
6.0		644.0		644.0	2.77	2.62	7,291	80	80	92	5.0	1.5	3.03
7.0		1,082.1		1,082.1	3.66	3.21	9,312	71	71	86	5.0	1.5	3.29
8.0		516.5		516.5	2.34	2.15	7,225	75	75	89	5.0	1.5	3.21
9.0		1,073.1		1,073.1	1.87	2.08	8,819	79	79	91	5.0	1.5	4.11
10.0		262.7		262.7	2.45	2.45	5,860	74	74	88	5.0	1.5	2.67
11.0		1,512.7		1,512.7	2.86	3.76	11,705	73	73	88	5.0	1.5	4.35
11.1		425.0		425.0	2.00	1.64	6,329	76	76	89	5.0	1.5	3.08
11.2		555.9		555.9	2.70	2.90	6,377	72	72	87	5.0	1.5	2.75
12.0		841.5	**	793.4	4.39	2.80	11,607	66	66	83	5.0	1.5	3.64
12.01	263.0	35.2		0.0									
12.02	263.1	53.1	**	0.0									
12.03	103.0	5.3		0.0									
13.0		1,736.5		1,668.6	3.20	2.83	8,575	71	78	91	5.0	2.0	2.44
14.0		622.5		586.2	3.97	3.11	7,603	70	77	90	5.0	2.0	2.04
15.0		1,702.7		1,701.7	3.11	2.38	6,539	62	62	80	10.0	1.5	2.65
16.0		2,625.0		2,625.0	5.95	3.97	10,038	66	72	87	10.0	2.0	2.88
17.0		707.9		705.1	4.61	3.32	7,116	66	72	87	5.0	2.0	2.43
18.0		506.8		506.8	4.19	2.78	4,471	70	77	90	5.0	2.0	1.31
19.0		618.8		586.0	3.90	2.20	6,767	67	74	88	5.0	2.0	1.87
20.0		1,547.5		1,547.5	3.11	2.93	8,985	71	78	91	5.0	2.0	2.56
21.0		386.1		341.7	3.04	3.27	7,256	70	77	90	5.0	2.0	2.91
21.01	92.0	21.8		0.0									
21.02	93.0	91.6		0.0									
21.03	93.1	9.7		0.0									
21.1		327.4		327.4	4.82	3.31	4,192	65	71	86	5.0	2.0	1.18
22.0		632.6		632.6	2.97	3.88	6,995	71	78	91	5.0	2.0	2.85
23.0		792.7	*	784.0	3.24	3.44	7,958	67	74	88	5.0	2.0	3.05
23.01	133.0	21.2	*	0.0									
24.0		713.8		713.8	2.55	2.32	7,831	72	79	91	5.0	2.0	3.31
25.0		580.9	*	558.4	4.38	4.04	8,256	67	73	88	5.0	2.0	2.79
25.01	107.0	(NOTE: no rating curve available, therefore, this SWM Pond not added to the model											
26.0		439.4	**	198.4	2.61	2.32	5,653	67	67	84	5.0	1.5	2.53
26.01	93.2	43.3		0.0									
27.0		1,520.2	***	917.5	2.39	3.47	13,500	68	68	84	5.0	1.5	5.22
27.01	279.2	24.3	***	0.0									
27.02	207.2	49.2	***	0.0									
27.03	207.3	64.9	***	0.0									
27.04	167.0	39.6	***	0.0									
28.0		600.8		408.9	2.51	2.37	4,162	68	68	84	5.0	1.5	2.02
	TOTALS =	28,301.2		26,155.4									
	APPROX. URBAN COMPONENT =				7%								

URBAN COMPONENT PARAMETERS

SUB-BASIN	URBAN AREA (hectares)	UNADJUSTED CN_URBAN (from GIS)	DESIGN CN_URBAN AMC II	DESIGN CN_URBAN AMC III	IA_perv (mm)	DPI (IA_imp) (mm)	% IMPERVIOUS (%)	IMPERVIOUS LENGTH (m)	PERVIOUS LENGTH	IMPERVIOUS n	PERVIOUS n
1.0	41.73	71	71	86	5.0	2.0	15.00	527	40	0.013	0.250
2.0	179.86	72	72	87	5.0	2.0	41.65	1,095	40	0.013	0.250
2.01	5.80	72	72	87	5.0	2.0	35.00	197	40	0.013	0.250
2.02	52.00	72	72	87	5.0	2.0	40.00	589	40	0.013	0.250
3.0											
3.01	36.00	74	74	88	5.0	2.0	50.00	490	40	0.013	0.250
3.02	51.70	74	74	88	5.0	2.0	50.00	587	40	0.013	0.250
4.0											
5.0											
6.0											
7.0											
8.0											
9.0											
10.0											
11.0											
11.1											
11.2											
12.0	48.08	71	71	86	5.0	2.0	46.70	566	40	0.013	0.250
12.01	35.20	71	71	86	5.0	2.0	40.00	484	40	0.013	0.250
12.02	53.10	71	71	86	5.0	2.0	40.00	595	40	0.013	0.250
12.03	5.30	71	71	86	5.0	2.0	40.00	188	40	0.013	0.250
13.0	67.89	71	78	91	5.0	2.0	40.01	673	40	0.013	0.250
14.0	36.32	73	80	92	5.0	2.0	40.01	492	40	0.013	0.250
15.0											
16.0											
17.0	2.74	71	78	91	5.0	2.0	40.15	135	40	0.013	0.250
18.0											
19.0	32.87	71	78	91	5.0	2.0	40.01	468	40	0.013	0.250
20.0											
21.0	44.36	79	87	95	5.0	2.0	40.80	544	40	0.013	0.250
21.01	21.80	79	87	95	5.0	2.0	49.00	381	40	0.013	0.250
21.02	91.60	79	87	95	5.0	2.0	40.00	781	40	0.013	0.250
21.03	9.70	79	87	95	5.0	2.0	40.00	254	40	0.013	0.250
21.1											
22.0											
23.0											
23.01	21.20	71	78	91	5.0	2.0	30.20	376	40	0.013	0.250
24.0											
25.0	22.52	72	79	91	5.0	2.0	40.01	387	40	0.013	0.250
25.01	(NOTE: no rating curve available, therefore, this SWM Pond not added to the model										
26.0	241.01	76	76	89	5.0	2.0	54.26	1,268	40	0.013	0.250
26.01	43.30	76	76	89	5.0	2.0	40.00	537	40	0.013	0.250
27.0	602.65	77	77	90	5.0	2.0	45.01	2,004	40	0.013	0.250
27.01	24.30	77	77	90	5.0	2.0	44.00	402	40	0.013	0.250
27.02	49.20	77	77	90	5.0	2.0	60.00	573	40	0.013	0.250
27.03	64.90	77	77	90	5.0	2.0	53.00	658	40	0.013	0.250
27.04	39.60	77	77	90	5.0	2.0	40.00	514	40	0.013	0.250
28.0	191.92	75	75	89	5.0	2.0	73.75	1,131	40	0.013	0.250
TOTALS	2,116.7										

* Note: diversion of approx. 10 ha from basin 25 to basin 23 associated with SWM Pond 133.0
** Note: diversion of approx. 40 ha from basin 26 to basin 12 associated with SWM Pond 263.1
*** Note: areas draining to SWM Ponds 279.2, 207.2, and 207.3 within catchment 27 (Millers Creek) were represented as rural in the existing landuse maps. But the maps are based on 1999 data.
Therefore, the rural area within catchment 27 was reduced by the sum of the drainage areas to these ponds, and the total urban area increases as a result.

FUTURE OFFICIAL PLAN LANDUSE SCENARIO

Note: Design Storm Parameters are based on calibrated values, but include a +10% adjustment for CN's within the East Branch of Duffins Creek (catchments 13 to 25)
Note: Municipal OP combined with TRCA Natural Heritage terrestial data

RURAL COMPONENT PARAMETERS

SUB-BASIN	SWM POND #	TOTAL AREA (hectares)		RURAL AREA (hectares)	SUB-BASIN SLOPE (mean)	STREAM SLOPE (%)	MAX STREAM LENGTH (metres)	UNADJUSTED CN_RURAL (from GIS)	DESIGN CN_RURAL AMC II	DESIGN CN_RURAL AMC III	IA_rural (mm)	"n"	Tp (hrs)
1.0		281.55		239.82	3.19	2.31	2461.63	70	70	86	5.0	1.5	0.91
2.0		1027.39		611.90	1.99	1.87	8569.43	72	72	87	5.0	1.5	2.94
2.01	185.0	5.8		0.0									
2.02	166.0	52.0		0.0									
3.0		1728.39		1688.40	2.77	2.21	13312.59	70	70	86	5.0	1.5	3.65
3.01	295.0	36.0		0.0									
3.02	295.1	133.6		81.9				70	70	86	5.0	1.5	4.87
4.0		681.59		681.59	2.40	2.60	9020.81	73	73	87	5.0	1.5	3.79
5.0		920.64		901.27	4.67	2.28	6117.88	60	60	78	10.0	1.5	2.14
6.0		643.98		643.98	2.77	2.62	7290.50	80	80	92	5.0	1.5	3.03
7.0		1082.14		1082.14	3.66	3.21	9312.17	71	71	86	5.0	1.5	3.29
8.0		516.51		516.51	2.34	2.15	7224.51	75	75	89	5.0	1.5	3.21
9.0		1073.12		1073.12	1.87	2.08	8818.60	79	79	91	5.0	1.5	4.11
10.0		262.69		262.69	2.45	2.45	5860.20	74	74	88	5.0	1.5	2.67
11.0		1512.70		1479.18	2.86	3.76	11704.94	72	72	87	5.0	1.5	4.35
11.1		425.03		425.03	2.00	1.64	6328.67	76	76	89	5.0	1.5	3.08
11.2		555.88		452.87	2.70	2.90	6376.87	71	71	86	5.0	1.5	2.75
12.0		841.5	**	499.81	4.39	2.80	11606.98	64	64	82	5.0	1.5	3.64
12.01	263.0	35.2		0.0									
12.02	263.1	53.1	**	0.0									
12.03	103.0	5.3		0.0									
13.0		1736.50		1668.61	3.20	2.83	8575.17	71	78	91	5.0	2.0	2.44
14.0		622.51		586.19	3.97	3.11	7602.81	70	77	90	5.0	2.0	2.04
15.0		1702.66		1701.65	3.11	2.38	6538.58	62	62	80	10.0	1.5	2.65
16.0		2625.02		2625.02	5.95	3.97	10037.96	66	72	87	10.0	2.0	2.88
17.0		707.88		705.14	4.61	3.32	7115.76	66	72	87	5.0	2.0	2.43
18.0		506.83		506.83	4.19	2.78	4471.31	70	77	90	5.0	2.0	1.31
19.0		618.84		586.06	3.90	2.20	6766.58	67	74	88	5.0	2.0	1.87
20.0		1547.47		1519.90	3.11	2.93	8985.06	71	78	91	5.0	2.0	2.56
21.0		386.10		217.26	3.04	3.27	7255.99	66	73	88	5.0	2.0	2.91
21.01	92.0	21.8		0.0									
21.02	93.0	91.6		0.0									
21.03	93.1	9.7		0.0									
21.1		327.44		321.67	4.82	3.31	4191.80	65	71	86	5.0	2.0	1.18
22.0		632.59		588.73	2.97	3.88	6994.84	71	78	91	5.0	2.0	2.85
23.0		792.7	*	391.59	3.24	3.44	7957.53	64	71	86	5.0	2.0	3.05
23.01	133.0	21.2	*	0.0									
24.0		713.77		500.73	2.55	2.32	7831.31	70	77	90	5.0	2.0	3.31
25.0		580.9	*	240.85	4.38	4.04	8255.52	64	70	86	5.0	2.0	2.79
25.01	107.0	(NOTE: no rating curve available, therefore, this SWM Pond not added to the model											
26.0		439.4	**	208.32	2.61	2.32	5652.99	67	67	84	5.0	1.5	2.53
26.01	93.2	43.3		0.0									
27.0		1,520.2		659.61	2.39	3.47	13499.94	65	65	82	5.0	1.5	5.22
27.01	279.2	24.3		0.0									
27.02	207.2	49.2		0.0									
27.03	207.3	64.9		0.0									
27.04	167.0	39.6		0.0									
28.0		600.84		230.97	2.51	2.37	4161.54	69	69	85	5.0	1.5	2.02
	TOTALS =	28,301.2		23,899.3									
	APPROX. URBAN COMPONENT =				15%								

URBAN COMPONENT PARAMETERS

SUB-BASIN	URBAN AREA (hectares)	JNADJUSTEI CN_URBAN (from GIS)	DESIGN CN_URBAN AMC II	DESIGN CN_URBAN AMC III	IA_perv (mm)	DPI (IA_imp) (mm)	% IMPERVIOU: (%)	IMPERVIOU! LENGTH (m)	PERVIOUS LENGTH	MPERVIOU: n	PERVIOUS n
1.0	41.73	71	71	86	5.0	2.0	15.00	527	40	0.013	0.250
2.0	415.30	71	71	86	5.0	2.0	41.83	1,664	40	0.013	0.250
2.01	5.80	72	72	87	5.0	2.0	35.00	197	40	0.013	0.250
2.02	52.00	72	72	87	5.0	2.0	40.00	589	40	0.013	0.250
3.0	39.09	73	73	87	5.0	2.0	51.10	510	40	0.013	0.250
3.01	36.00	74	74	88	5.0	2.0	50.00	490	40	0.013	0.250
3.02	51.70	74	74	88	5.0	2.0	50.00	587	40	0.013	0.250
11.0	27.02	71	71	86	5.0	2.0	40.00	424	40	0.013	0.250
11.2	103.01	71	71	86	5.0	2.0	40.00	829	40	0.013	0.250
12.0	341.64	71	71	86	5.0	2.0	43.44	1,509	40	0.013	0.250
12.01	35.20	71	71	86	5.0	2.0	40.00	484	40	0.013	0.250
12.02	53.10	71	71	86	5.0	2.0	40.00	595	40	0.013	0.250
12.03	5.30	71	71	86	5.0	2.0	40.00	188	40	0.013	0.250
13.0	67.89	71	78	91	5.0	2.0	40.00	673	40	0.013	0.250
14.0	36.32	73	80	92	5.0	2.0	40.00	492	40	0.013	0.250
17.0	2.74	71	78	91	5.0	2.0	40.00	135	40	0.013	0.250
19.0	32.78	71	78	91	5.0	2.0	40.00	467	40	0.013	0.250
20.0	27.57	73	80	92	5.0	2.0	40.00	429	40	0.013	0.250
21.0	168.84	76	84	94	5.0	2.0	40.33	1,061	40	0.013	0.250
21.01	21.80	79	87	95	5.0	2.0	49.00	381	40	0.013	0.250
21.02	91.60	79	87	95	5.0	2.0	40.00	781	40	0.013	0.250
21.03	9.70	79	87	95	5.0	2.0	40.00	254	40	0.013	0.250
21.1	5.77	71	78	91	5.0	2.0	40.00	196	40	0.013	0.250
22.0	43.89	70	78	91	5.0	2.0	40.00	541	40	0.013	0.250
23.0	401.16	71	78	91	5.0	2.0	43.36	1,635	40	0.013	0.250
23.01	21.20	71	78	91	5.0	2.0	30.20	376	40	0.013	0.250
24.0	213.04	71	78	91	5.0	2.0	40.00	1,192	40	0.013	0.250
25.0	340.03	71	78	91	5.0	2.0	43.06	1,506	40	0.013	0.250
25.01	(NOTE: no rating curve available, therefore, this SWM Pond not added to the model										
26.0	231.06	77	77	90	5.0	2.0	54.05	1,241	40	0.013	0.250
26.01	43.30	76	76	89	5.0	2.0	40.00	537	40	0.013	0.250
27.0	860.55	75	75	89	5.0	2.0	44.26	2,395	40	0.013	0.250
27.01	24.30	77	77	90	5.0	2.0	44.00	402	40	0.013	0.250
27.02	49.20	77	77	90	5.0	2.0	60.00	573	40	0.013	0.250
27.03	64.90	77	77	90	5.0	2.0	53.00	658	40	0.013	0.250
27.04	39.60	77	77	90	5.0	2.0	40.00	514	40	0.013	0.250
28.0	366.83	75	75	89	5.0	2.0	68.16	1,564	40	0.013	0.250
TOTALS	4,371.0										

* Note: diversion of approx. 10 ha from basin 25 to basin 23 associated with SWM Pond 133.0
** Note: diversion of approx. 40 ha from basin 26 to basin 12 associated with SWM Pond 263.1

FUTURE NATURAL HERITAGE LANDUSE SCENARIC

Note: Design Storm Parameters are based on calibrated values, but include a +10% adjustment for CN's within the East Branch of Duffins Creek (catchments 13 to 25)
Note: Municipal OP combined with TRCA Natural Heritage terrestial data (modelled condtions)

RURAL COMPONENT PARAMETERS:

SUB-BASIN	SWM POND #	TOTAL AREA (hectares)	RURAL AREA (hectares)	SUB-BASIN SLOPE (mean)	STREAM SLOPE (%)	MAX STREAM LENGTH (metres)	UNADJUSTED CN_RURAL (from GIS)	DESIGN CN_RURAL AMC II	DESIGN CN_RURAL AMC III	IA_rural (mm)	"n"	Tp (hrs)
1.0		281.55	239.82	3.19	2.31	2461.63	67	67	84	5.0	1.5	0.91
2.0		1027.39	611.90	1.99	1.87	8569.43	71	71	86	5.0	1.5	2.94
2.01	185.0	5.8	0.0									
2.02	166.0	52.0	0.0									
3.0		1728.39	1688.40	2.77	2.21	13312.59	68	68	84	5.0	1.5	3.65
3.01	295.0	36.0	0.0									
3.02	295.1	133.6	81.9				70	70	86	5.0	1.5	4.87
4.0		681.59	681.59	2.40	2.60	9020.81	73	73	87	5.0	1.5	3.79
5.0		920.64	901.27	4.67	2.28	6117.88	55	55	75	10.0	1.5	2.14
6.0		643.98	643.98	2.77	2.62	7290.50	77	77	90	5.0	1.5	3.03
7.0		1082.14	1082.14	3.66	3.21	9312.17	68	68	84	5.0	1.5	3.29
8.0		516.51	516.51	2.34	2.15	7224.51	75	75	89	5.0	1.5	3.21
9.0		1073.12	1073.12	1.87	2.08	8818.60	79	79	91	5.0	1.5	4.11
10.0		262.69	262.69	2.45	2.45	5860.20	74	74	88	5.0	1.5	2.67
11.0		1512.70	1479.18	2.86	3.76	11704.94	72	72	87	5.0	1.5	4.35
11.1		425.03	425.03	2.00	1.64	6328.67	76	76	89	5.0	1.5	3.08
11.2		555.88	452.87	2.70	2.90	6376.87	70	70	86	5.0	1.5	2.75
12.0		841.5 **	499.81	4.39	2.80	11606.98	64	64	82	5.0	1.5	3.64
12.01	263.0	35.2	0.0									
12.02	263.1	53.1 **	0.0									
12.03	103.0	5.3	0.0									
13.0		1736.50	1668.61	3.20	2.83	8575.17	66	72	87	5.0	2.0	2.44
14.0		622.51	586.19	3.97	3.11	7602.81	68	75	89	5.0	2.0	2.04
15.0		1702.66	1701.65	3.11	2.38	6538.58	52	52	72	10.0	1.5	2.65
16.0		2625.02	2625.02	5.95	3.97	10037.96	63	69	85	10.0	2.0	2.88
17.0		707.88	705.14	4.61	3.32	7115.76	61	67	84	5.0	2.0	2.43
18.0		506.83	506.83	4.19	2.78	4471.31	64	70	86	5.0	2.0	1.31
19.0		618.84	585.97	3.90	2.20	6766.58	66	72	87	5.0	2.0	1.87
20.0		1547.47	1519.90	3.11	2.93	8985.06	70	77	90	5.0	2.0	2.56
21.0		386.10	217.26	3.04	3.27	7255.99	66	73	88	5.0	2.0	2.91
21.01	92.0	21.8	0.0									
21.02	93.0	91.6	0.0									
21.03	93.1	9.7	0.0									
21.1		327.44	321.67	4.82	3.31	4191.80	65	71	86	5.0	2.0	1.18
22.0		632.59	588.73	2.97	3.88	6994.84	70	77	90	5.0	2.0	2.85
23.0		792.7 *	391.59	3.24	3.44	7957.53	64	71	86	5.0	2.0	3.05
23.01	133.0	21.2 *	0.0									
24.0		713.77	500.73	2.55	2.32	7831.31	70	77	90	5.0	2.0	3.31
25.0		580.9 *	240.85	4.38	4.04	8255.52	64	70	86	5.0	2.0	2.79
25.01	107.0	(NOTE: no rating curve available, therefore, this SWM Pond not added to the model										
26.0		439.4 **	208.32	2.61	2.32	5652.99	67	67	84	5.0	1.5	2.53
26.01	93.2	43.3	0.0									
27.0		1,520.2	659.61	2.39	3.47	13499.94	65	65	82	5.0	1.5	5.22
27.01	279.2	24.3	0.0									
27.02	207.2	49.2	0.0									
27.03	207.3	64.9	0.0									
27.04	167.0	39.6	0.0									
28.0		600.84	230.97	2.51	2.37	4161.54	69	69	85	5.0	1.5	2.02
	TOTALS =	28,301.2	23,899.3									
	APPROX. URBAN COMPONENT =			15%								

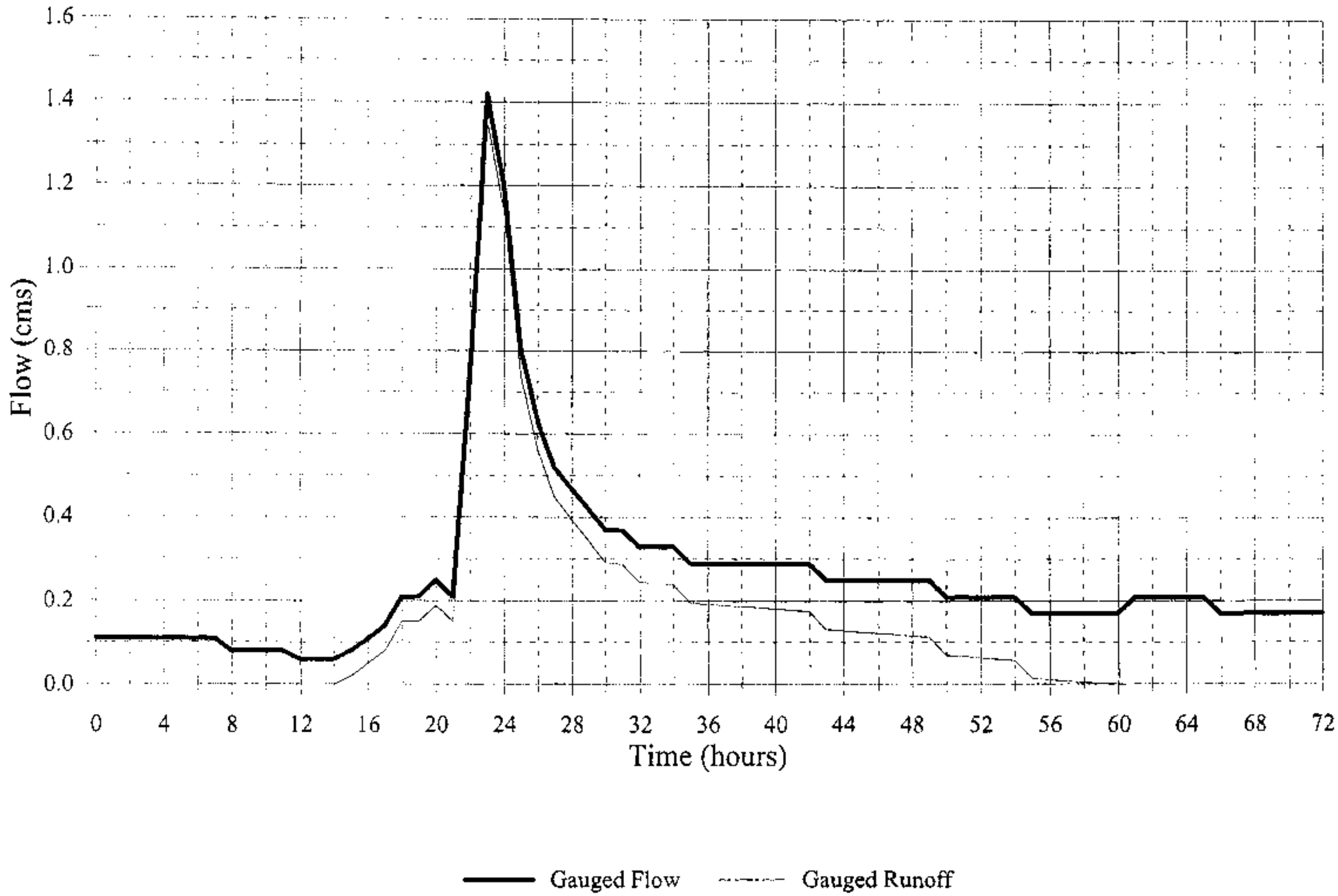
URBAN COMPONENT PARAMETERS:

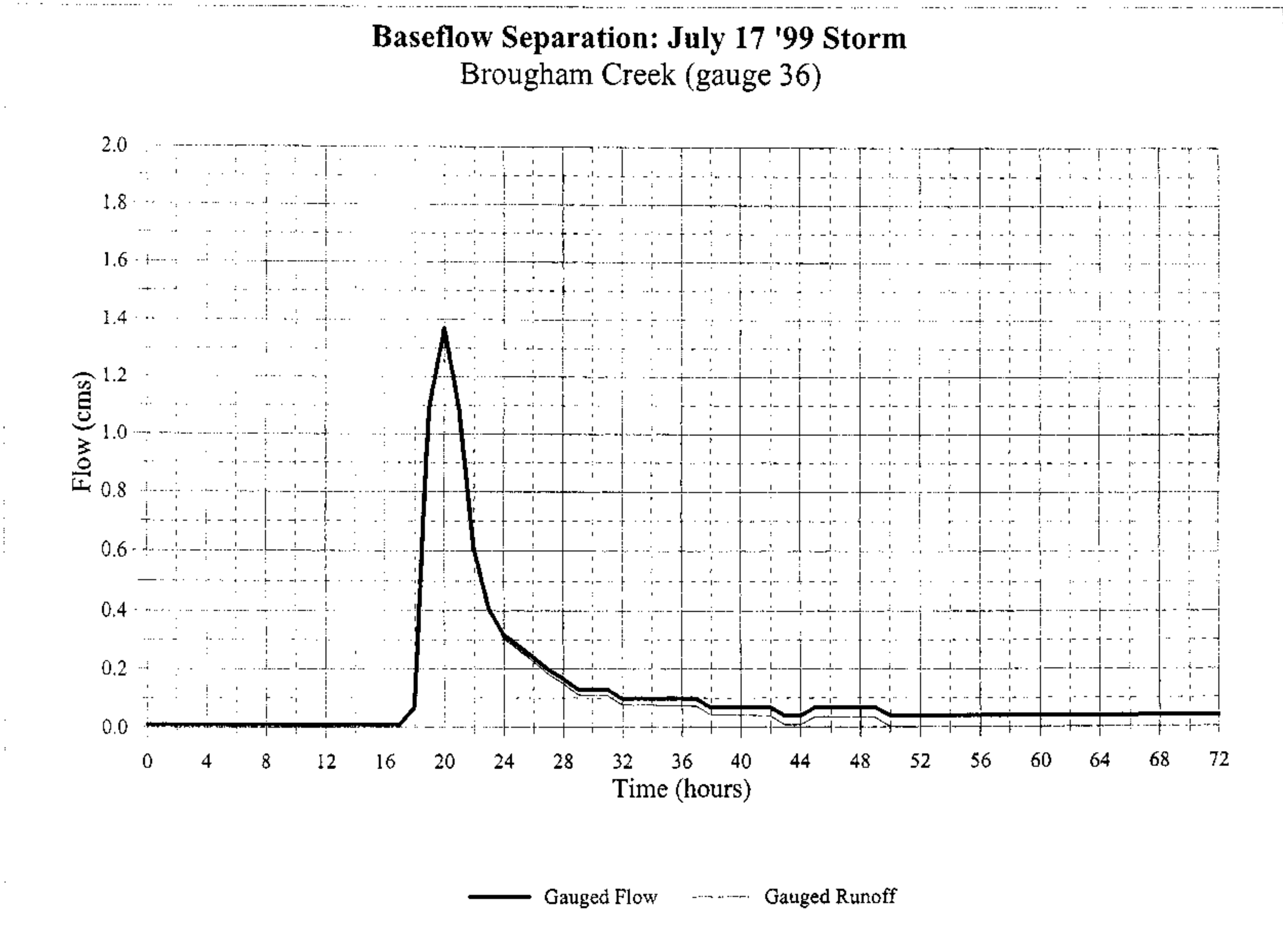
SUB-BASIN	URBAN AREA (hectares)	JNADJUSTEL CN_URBAN (from GIS)	DESIGN CN_URBAN AMC II	DESIGN CN_URBAN AMC III	IA_perv (mm)	DPI (IA_imp) (mm)	% IMPERVIOUS (%)	IMPERVIOUS LENGTH (m)	PERVIOUS LENGTH	IMPERVIOUS n	PERVIOUS n
1.0	41.73	71	71	86	5.0	2.0	15.00	527	40	0.013	0.250
2.0	415.30	71	71	86	5.0	2.0	41.83	1,664	40	0.013	0.250
2.01	5.80	72	72	87	5.0	2.0	35.00	197	40	0.013	0.250
2.02	52.00	72	72	87	5.0	2.0	40.00	589	40	0.013	0.250
3.0	39.09	73	73	87	5.0	2.0	51.10	510	40	0.013	0.250
3.01	36.00	74	74	88	5.0	2.0	50.00	490	40	0.013	0.250
3.02	51.70	74	74	88	5.0	2.0	50.00	587	40	0.013	0.250
11.0	27.02	71	71	86	5.0	2.0	40.00	424	40	0.013	0.250
11.2	103.01	71	71	86	5.0	2.0	40.00	829	40	0.013	0.250
12.0	341.64	71	71	86	5.0	2.0	43.44	1,509	40	0.013	0.250
12.01	35.20	71	71	86	5.0	2.0	40.00	484	40	0.013	0.250
12.02	53.10	71	71	86	5.0	2.0	40.00	595	40	0.013	0.250
12.03	5.30	71	71	86	5.0	2.0	40.00	188	40	0.013	0.250
13.0	67.89	71	78	91	5.0	2.0	40.00	673	40	0.013	0.250
14.0	36.32	73	80	92	5.0	2.0	40.00	492	40	0.013	0.250
17.0	2.74	71	78	91	5.0	2.0	40.00	135	40	0.013	0.250
19.0	32.87	71	78	91	5.0	2.0	40.00	468	40	0.013	0.250
20.0	27.57	73	80	92	5.0	2.0	40.00	429	40	0.013	0.250
21.0	168.84	76	84	94	5.0	2.0	40.33	1,061	40	0.013	0.250
21.01	21.80	79	87	95	5.0	2.0	49.00	381	40	0.013	0.250
21.02	91.60	79	87	95	5.0	2.0	40.00	781	40	0.013	0.250
21.03	9.70	79	87	95	5.0	2.0	40.00	254	40	0.013	0.250
21.1	5.77	71	78	91	5.0	2.0	40.00	196	40	0.013	0.250
22.0	43.89	70	78	91	5.0	2.0	40.00	541	40	0.013	0.250
23.0	401.16	71	78	91	5.0	2.0	43.36	1,635	40	0.013	0.250
23.01	21.20	71	78	91	5.0	2.0	30.20	376	40	0.013	0.250
24.0	213.04	71	78	91	5.0	2.0	40.00	1,192	40	0.013	0.250
25.0	340.03	71	78	91	5.0	2.0	43.06	1,506	40	0.013	0.250
25.01	(NOTE: no rating curve available, therefore, this SWM Pond not added to the model										
26.0	231.06	77	77	90	5.0	2.0	54.05	1,241	40	0.013	0.250
26.01	43.30	76	76	89	5.0	2.0	40.00	537	40	0.013	0.250
27.0	860.55	75	75	89	5.0	2.0	44.26	2,395	40	0.013	0.250
27.01	24.30	77	77	90	5.0	2.0	44.00	402	40	0.013	0.250
27.02	49.20	77	77	90	5.0	2.0	60.00	573	40	0.013	0.250
27.03	64.90	77	77	90	5.0	2.0	53.00	658	40	0.013	0.250
27.04	39.60	77	77	90	5.0	2.0	40.00	514	40	0.013	0.250
28.0	366.83	75	75	89	5.0	2.0	68.16	1,564	40	0.013	0.250
TOTALS	4,371.1										

* Note: diversion of approx. 10 ha from basin 25 to basin 23 associated with SWM Pond 133.0
** Note: diversion of approx. 40 ha from basin 26 to basin 12 associated with SWM Pond 263.1

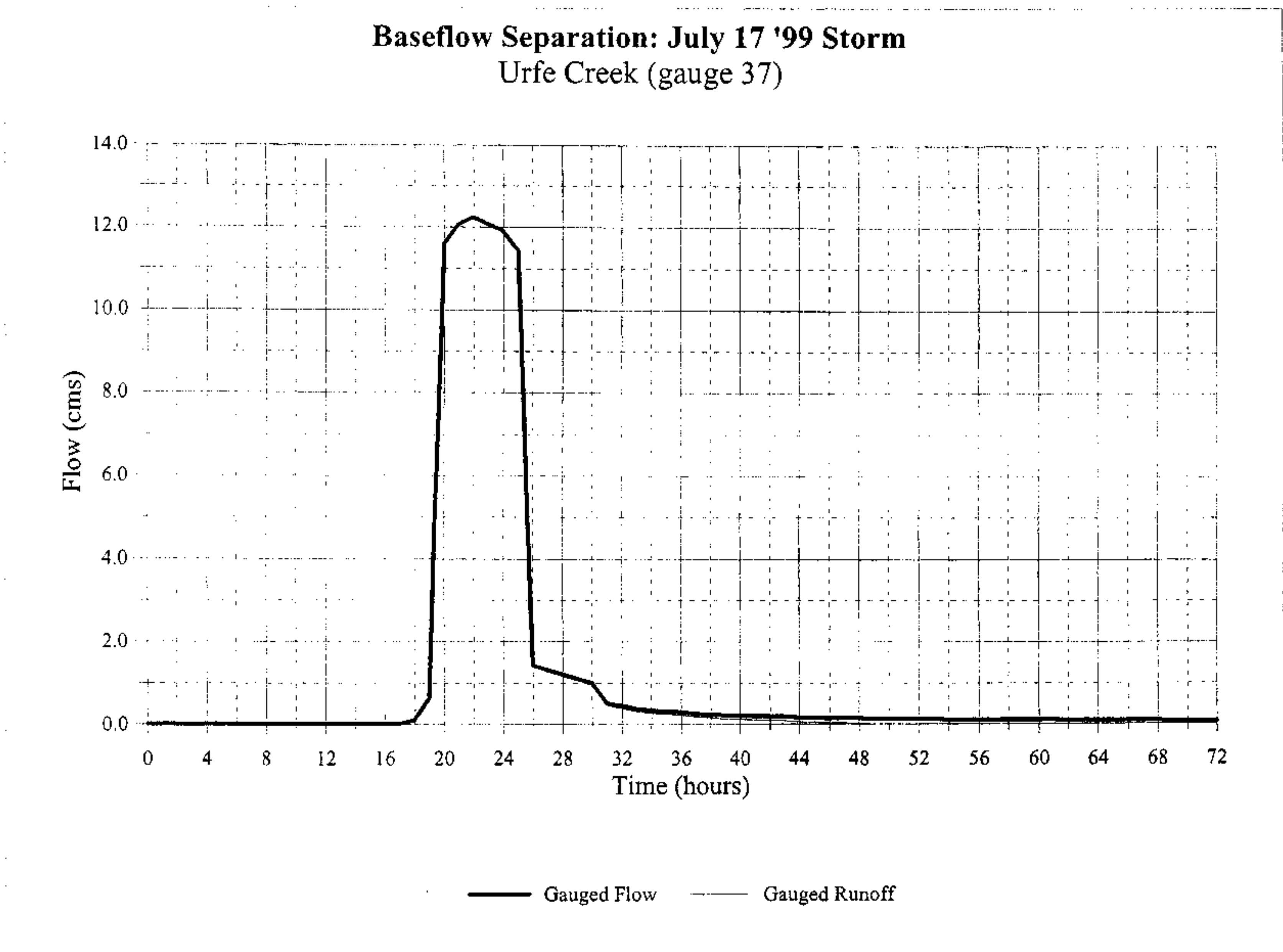
APPENDIX B:
Hydrograph Separation for Calibration Events

Baseflow Separation: July 17 '99 Storm
Reesor Creek (02HC039)

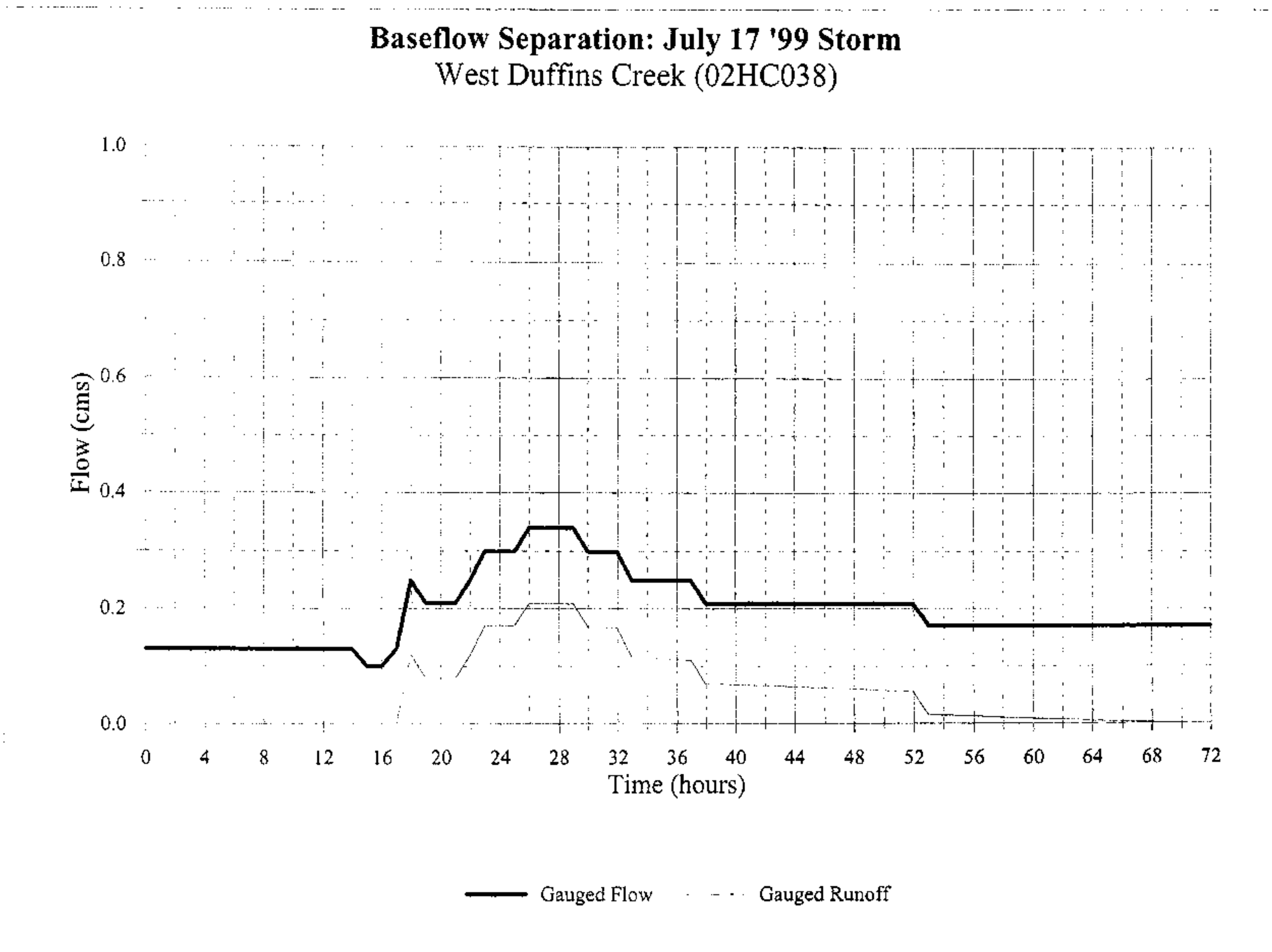


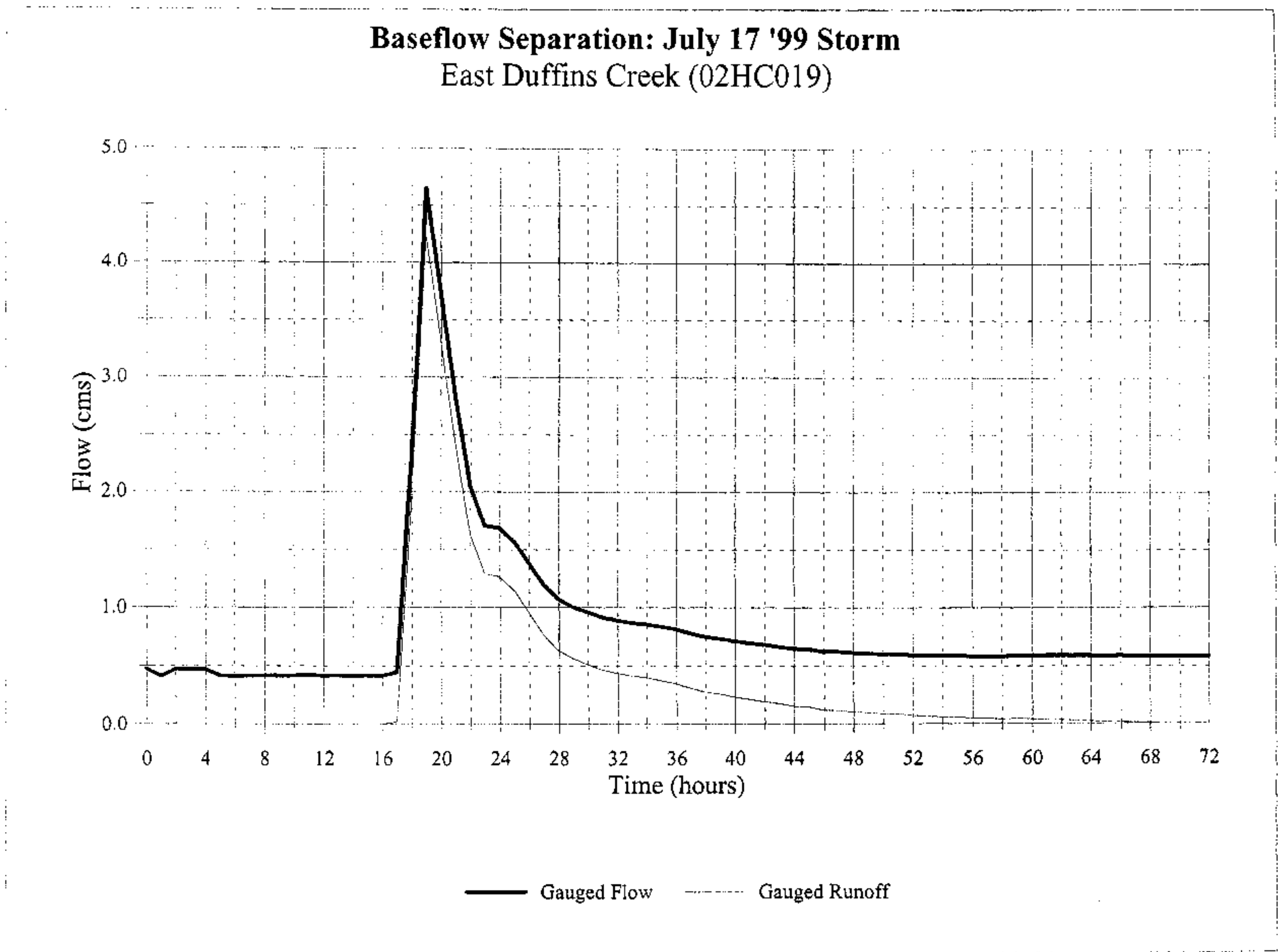


Baseflow Separation: July 17 '99 Storm
Brougham Creek (gauge 36)
Flow (cms)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60
64
68
72
Time (hours)
Gauged Flow
Gauged Runoff

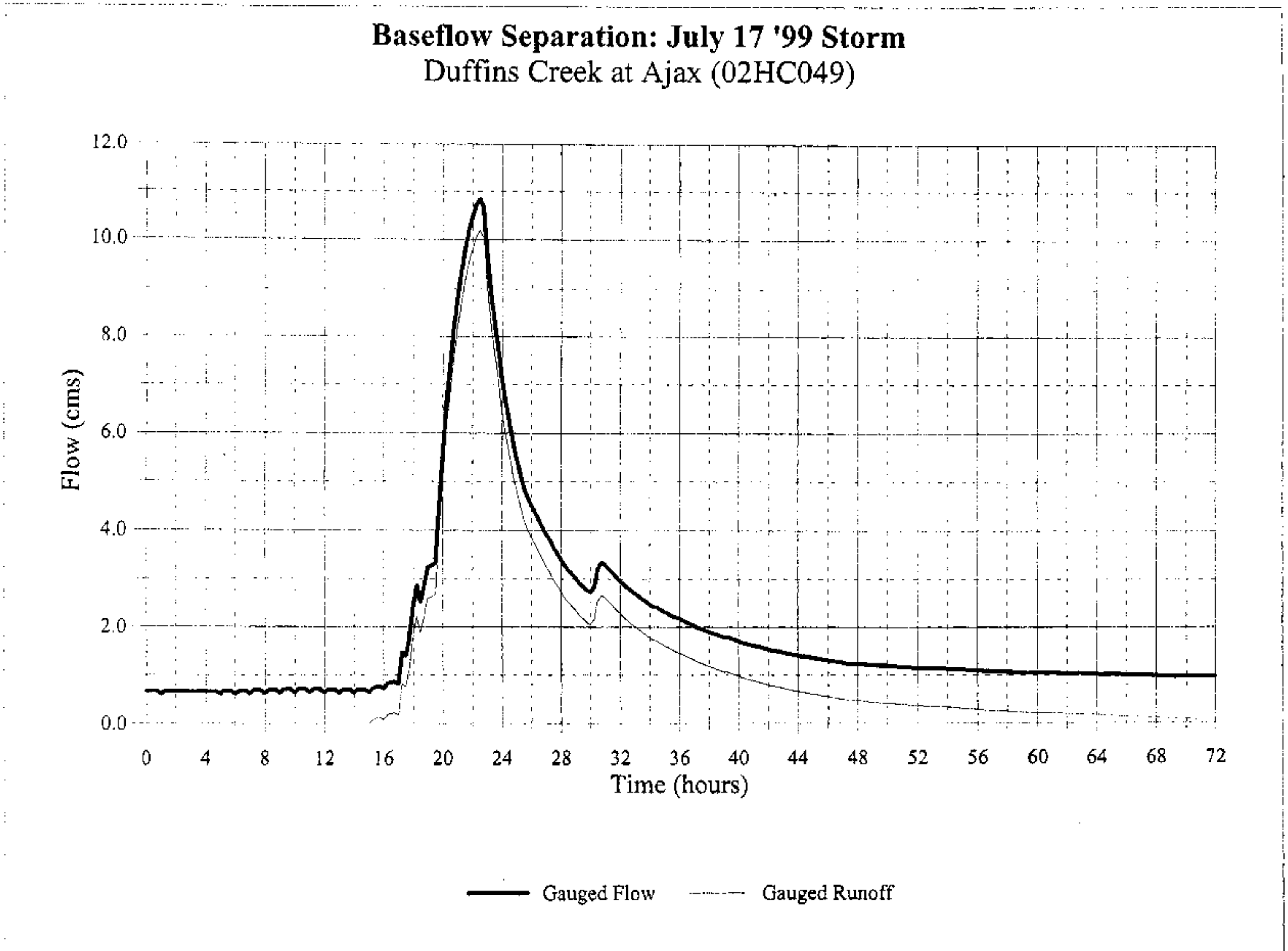


Baseflow Separation: July 17 '99 Storm
Urfe Creek (gauge 37)
Flow (cms)
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60
64
68
72
Time (hours)
Gauged Flow
Gauged Runoff

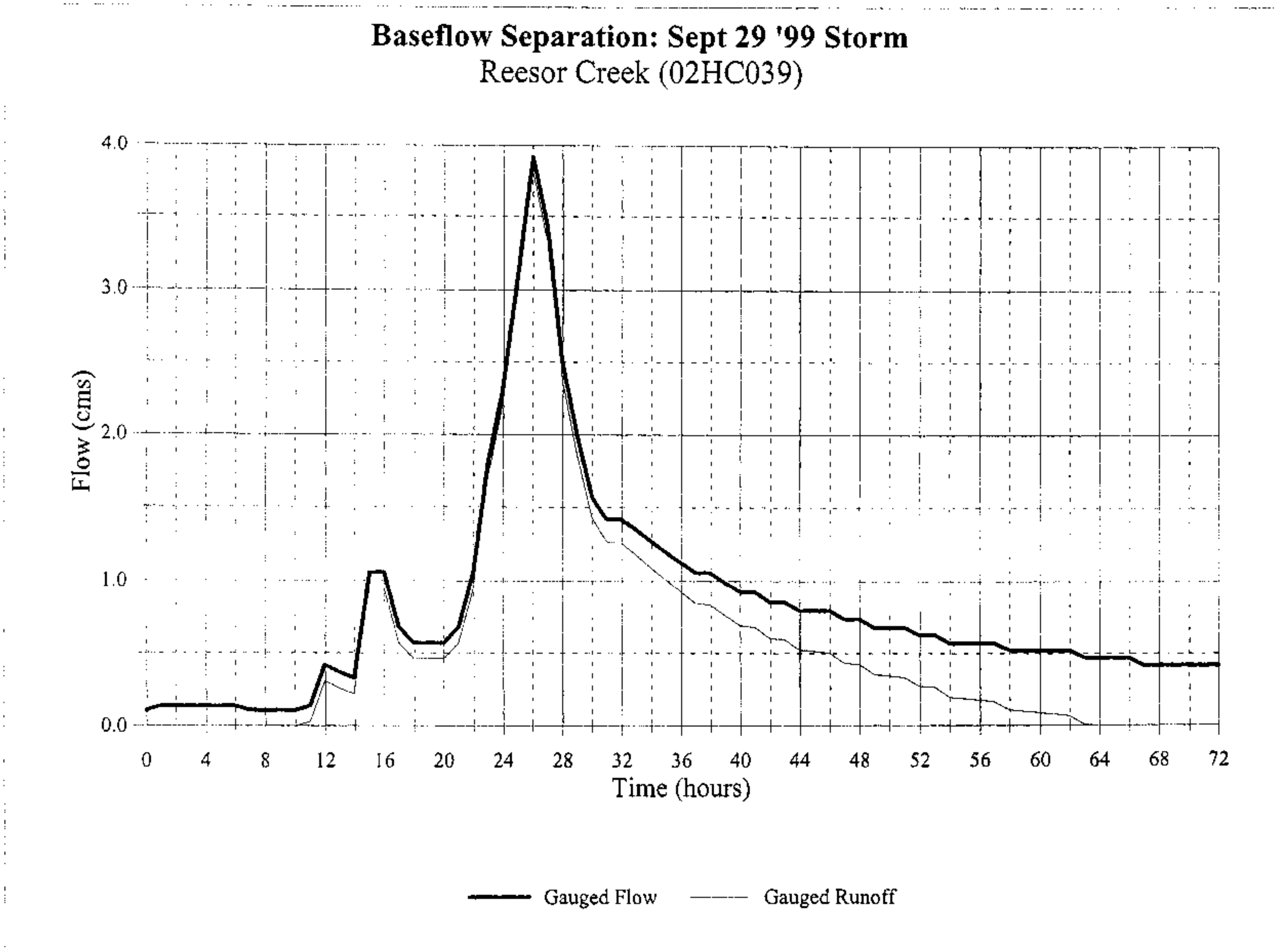

Baseflow Separation: July 17 '99 Storm
West Duffins Creek (02HC038)
Flow (cms)
1.0
0.8
0.6
0.4
0.2
0.0
0
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60
64
68
72
Time (hours)
Gauged Flow
Gauged Runoff



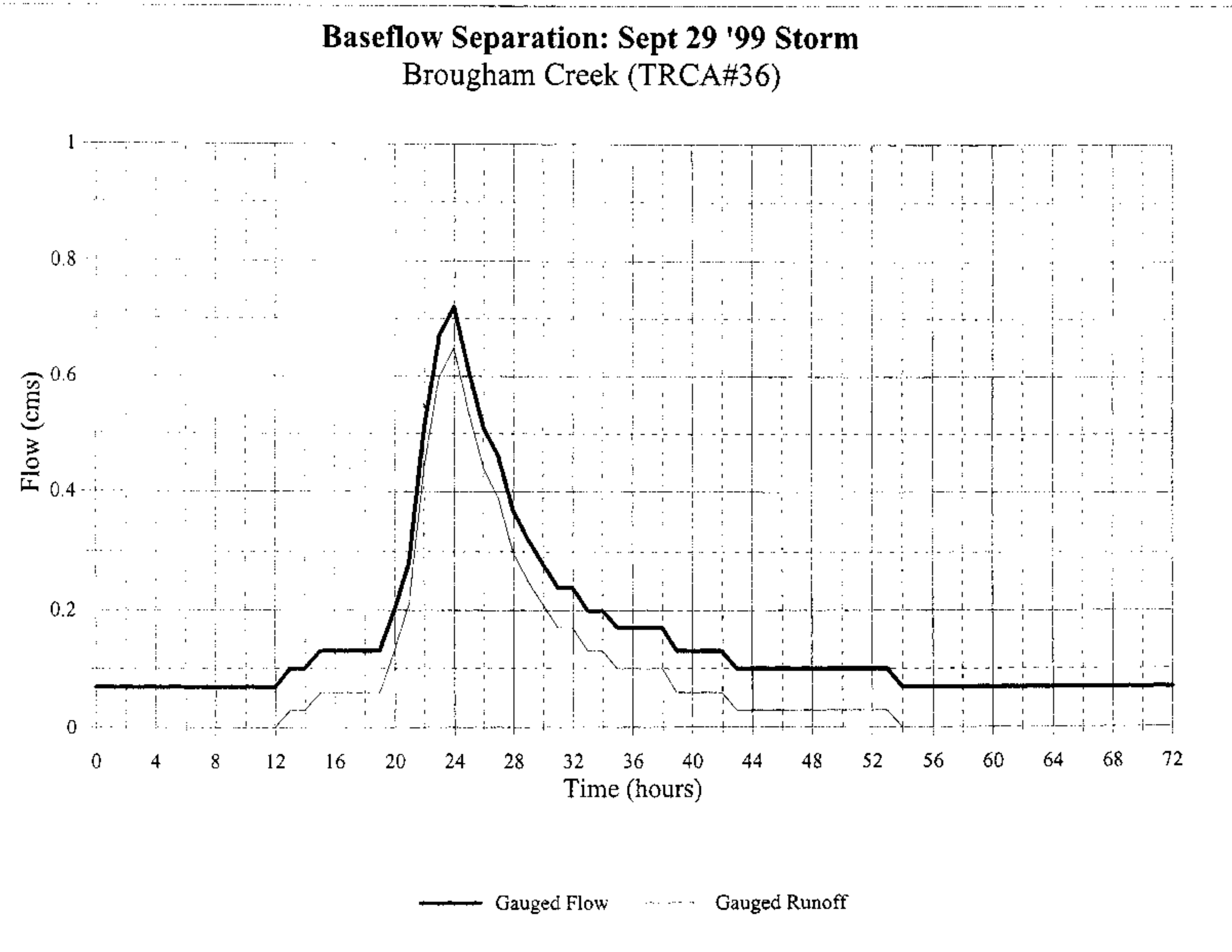
Baseflow Separation: July 17 '99 Storm
East Duffins Creek (02HC019)
5.0
4.0
3.0
2.0
1.0
0.0
Flow (cms)
0
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60
64
68
72
Time (hours)
Gauged Flow
Gauged Runoff

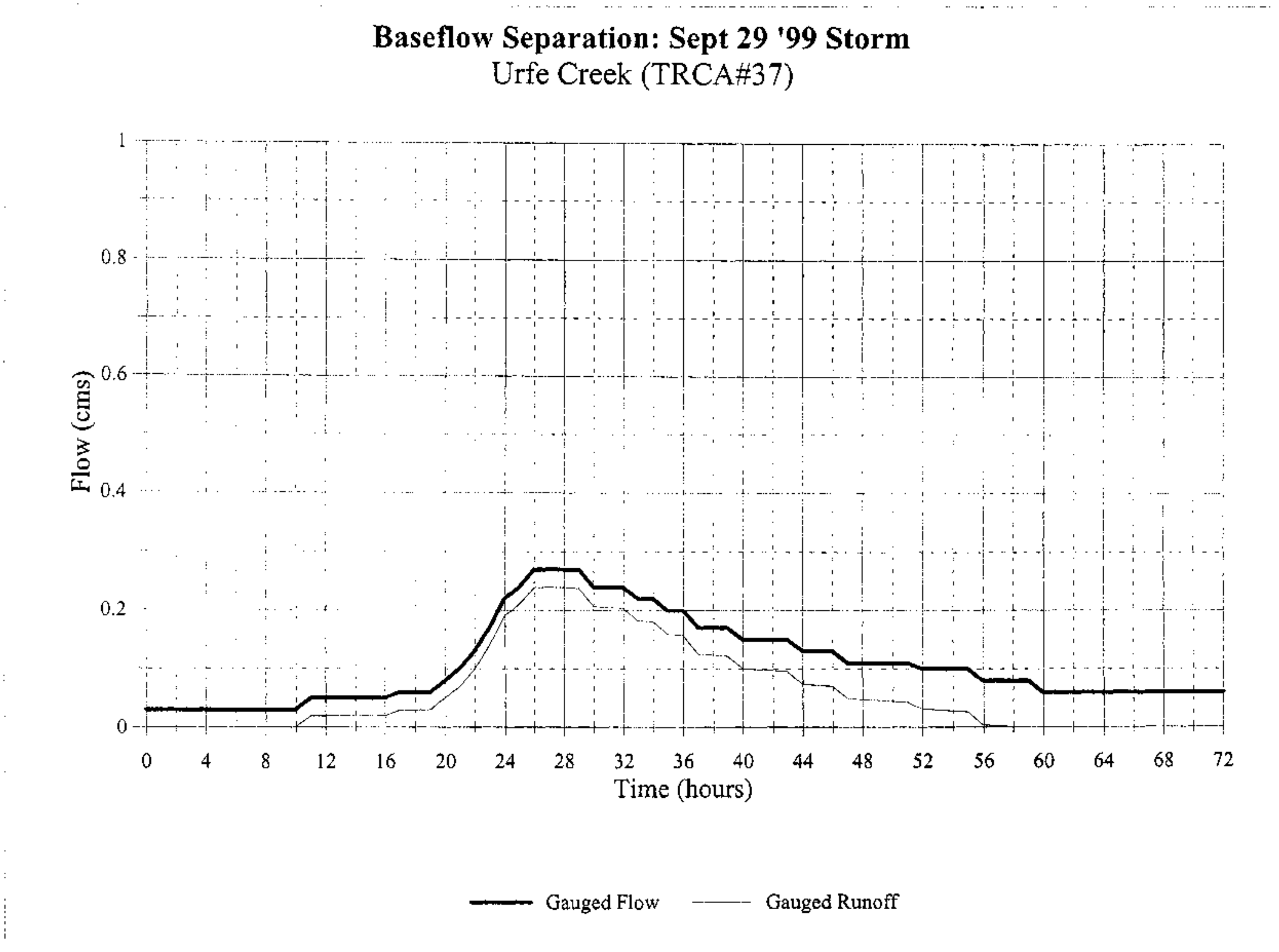


Baseflow Separation: July 17 '99 Storm
Duffins Creek at Ajax (02HC049)
Flow (cms)
0.0
2.0
4.0
6.0
8.0
10.0
12.0
Time (hours)
0
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60
64
68
72
Gauged Flow
Gauged Runoff



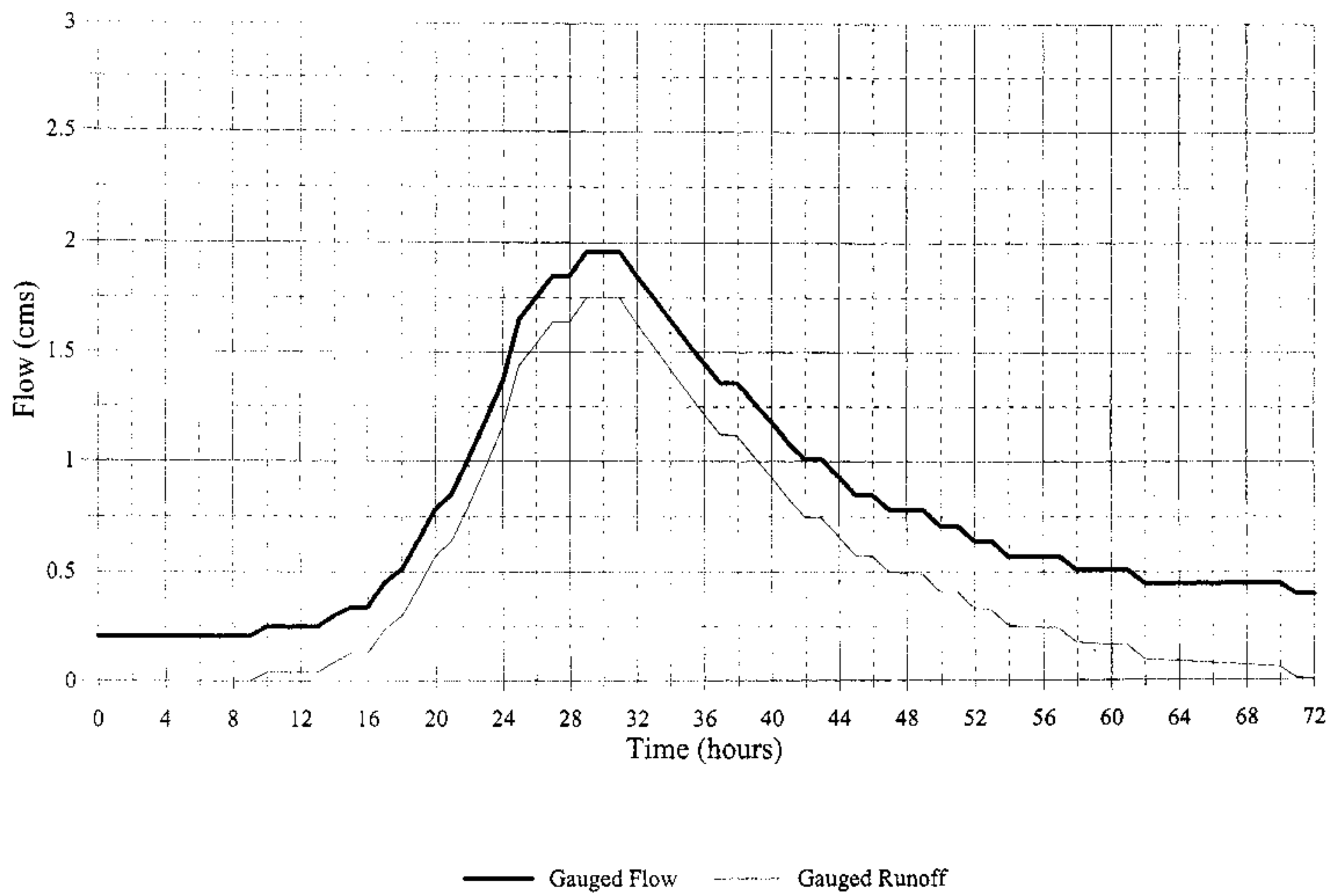
Baseflow Separation: Sept 29 '99 Storm
Reesor Creek (02HC039)
4.0
3.0
2.0
1.0
0.0
Flow (cms)
0
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60
64
68
72
Time (hours)
Gauged Flow
Gauged Runoff

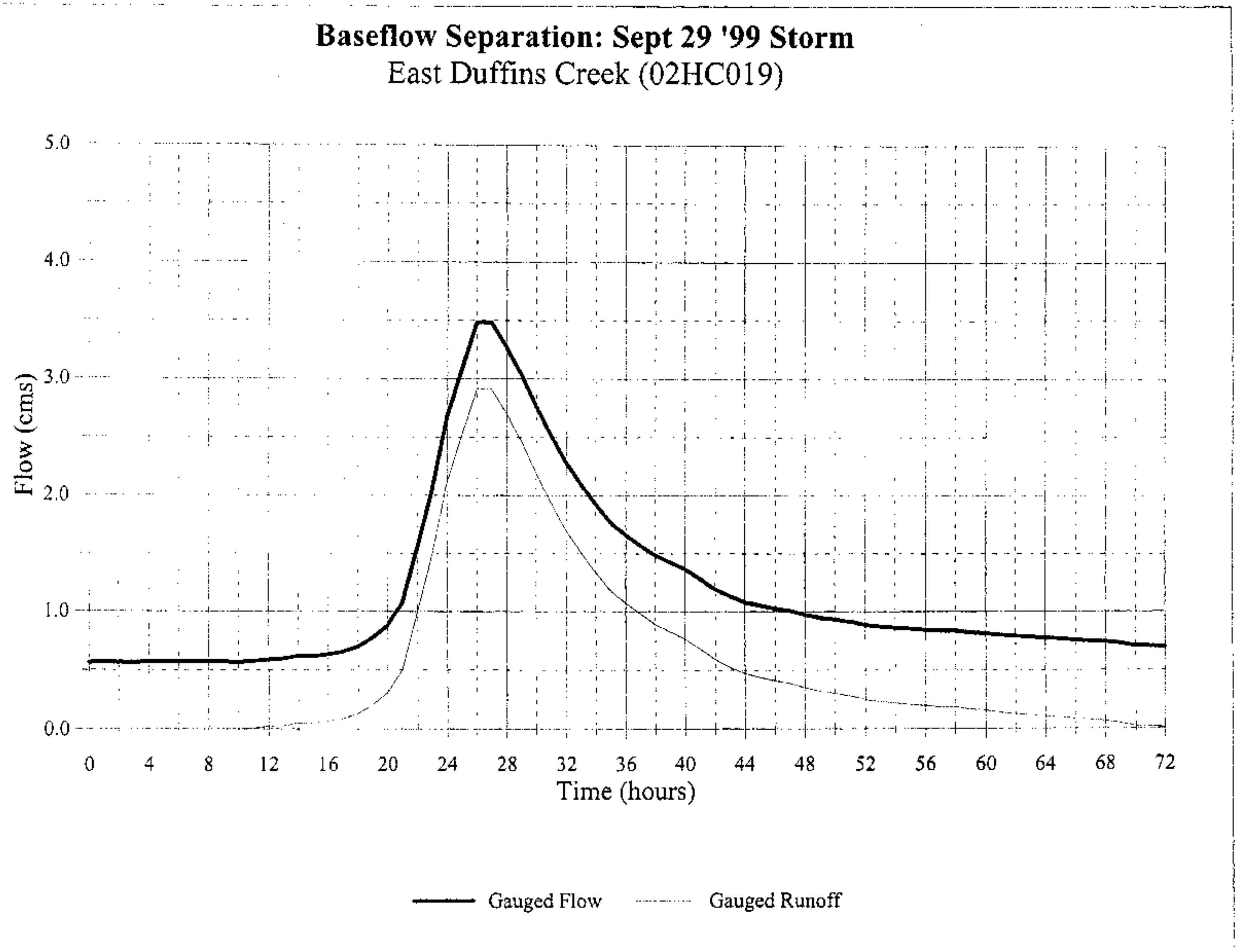

Baseflow Separation: Sept 29 '99 Storm
Brougham Creek (TRCA#36)
Flow (cms)
1
0.8
0.6
0.4
0.2
0
0
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60
64
68
72
Time (hours)
Gauged Flow
Gauged Runoff



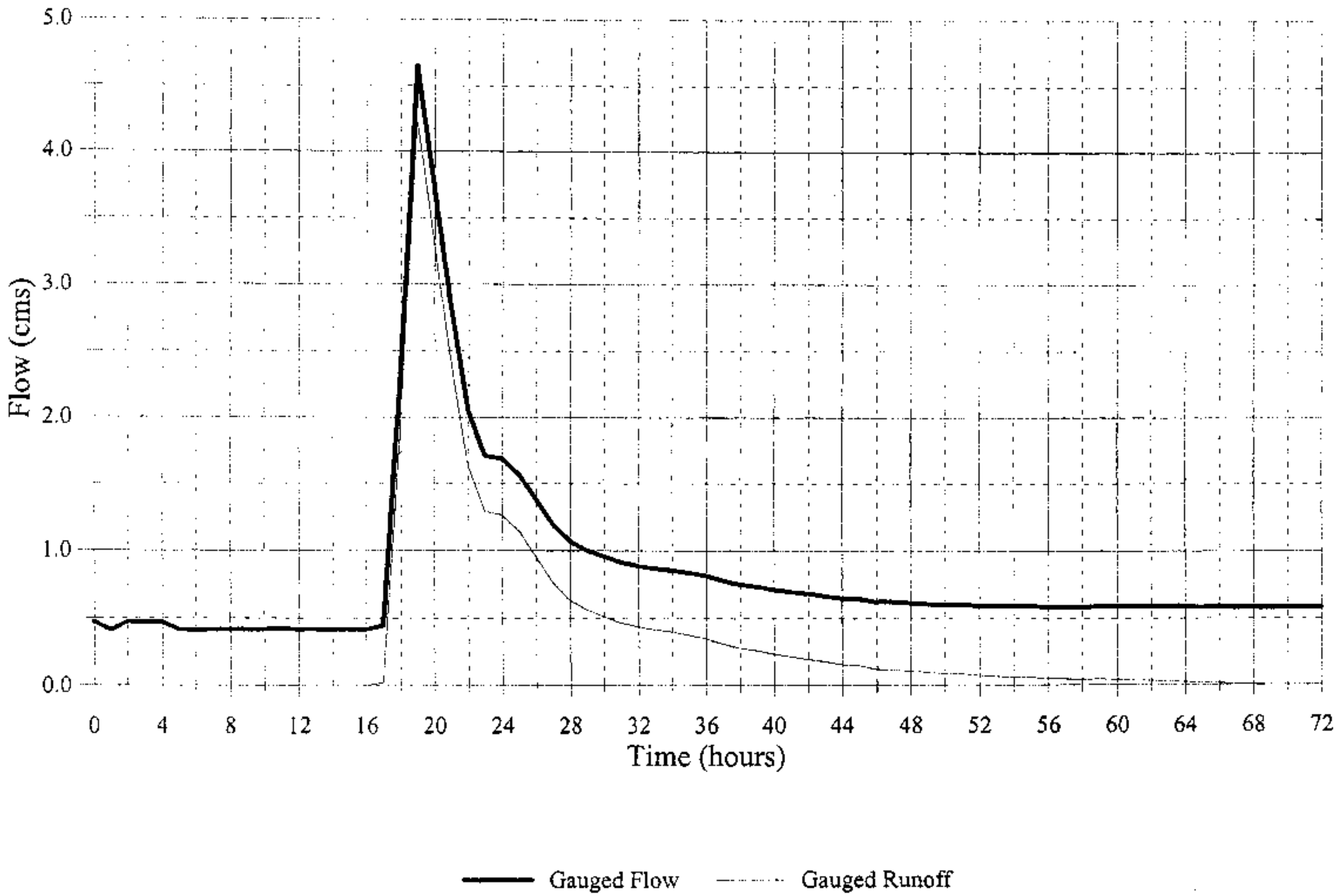
Baseflow Separation: Sept 29 '99 Storm
Urfe Creek (TRCA#37)
Flow (cms)
1
0.8
0.6
0.4
0.2
0
0
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60
64
68
72
Time (hours)
Gauged Flow
Gauged Runoff

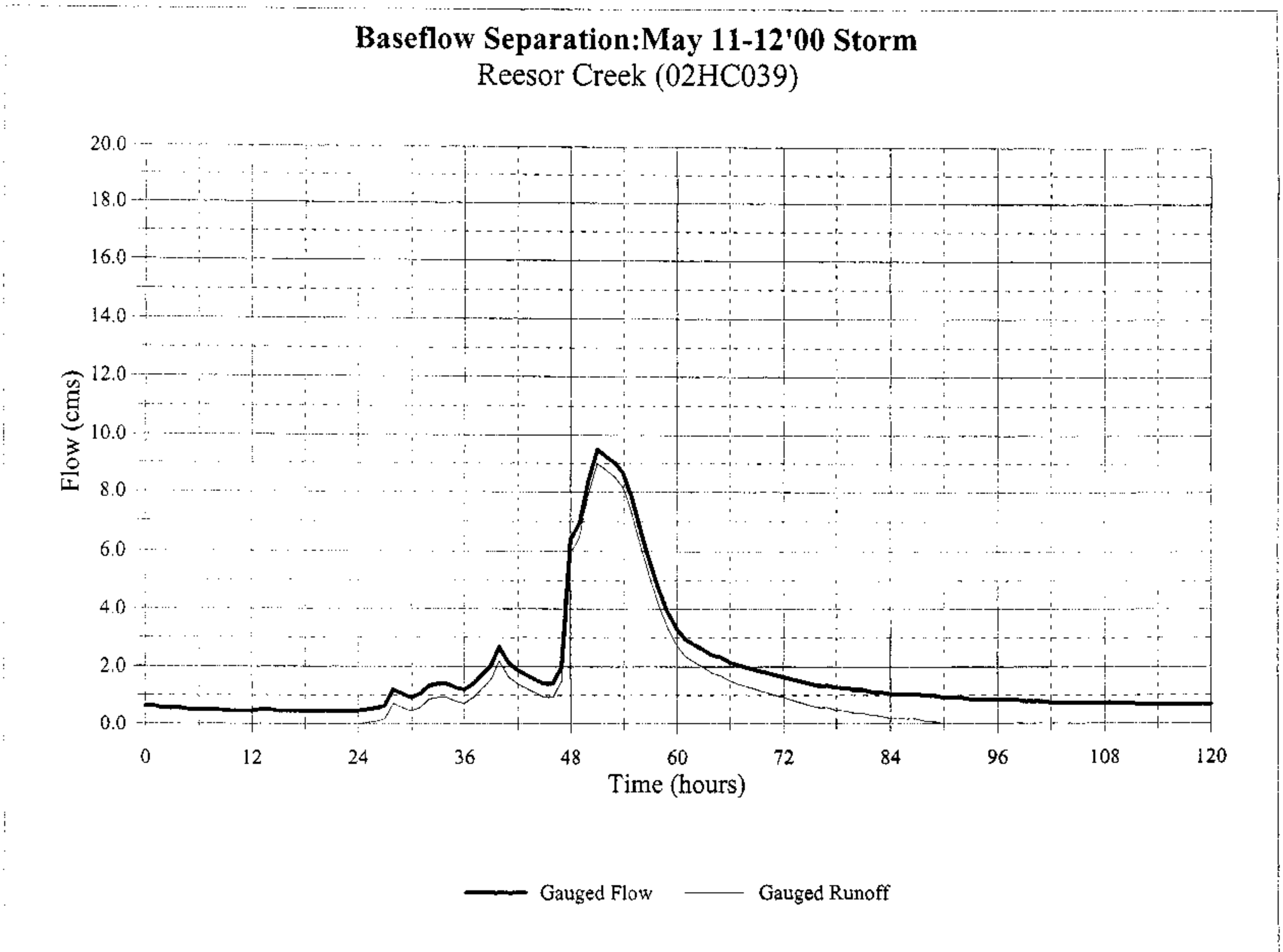
Baseflow Separation: Sept 29 '99 Storm
West Duffins Creek (02HC038)




Baseflow Separation: Sept 29 '99 Storm
East Duffins Creek (02HC019)
Flow (cms)
5.0
4.0
3.0
2.0
1.0
0.0
0
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60
64
68
72
Time (hours)
Gauged Flow
Gauged Runoff

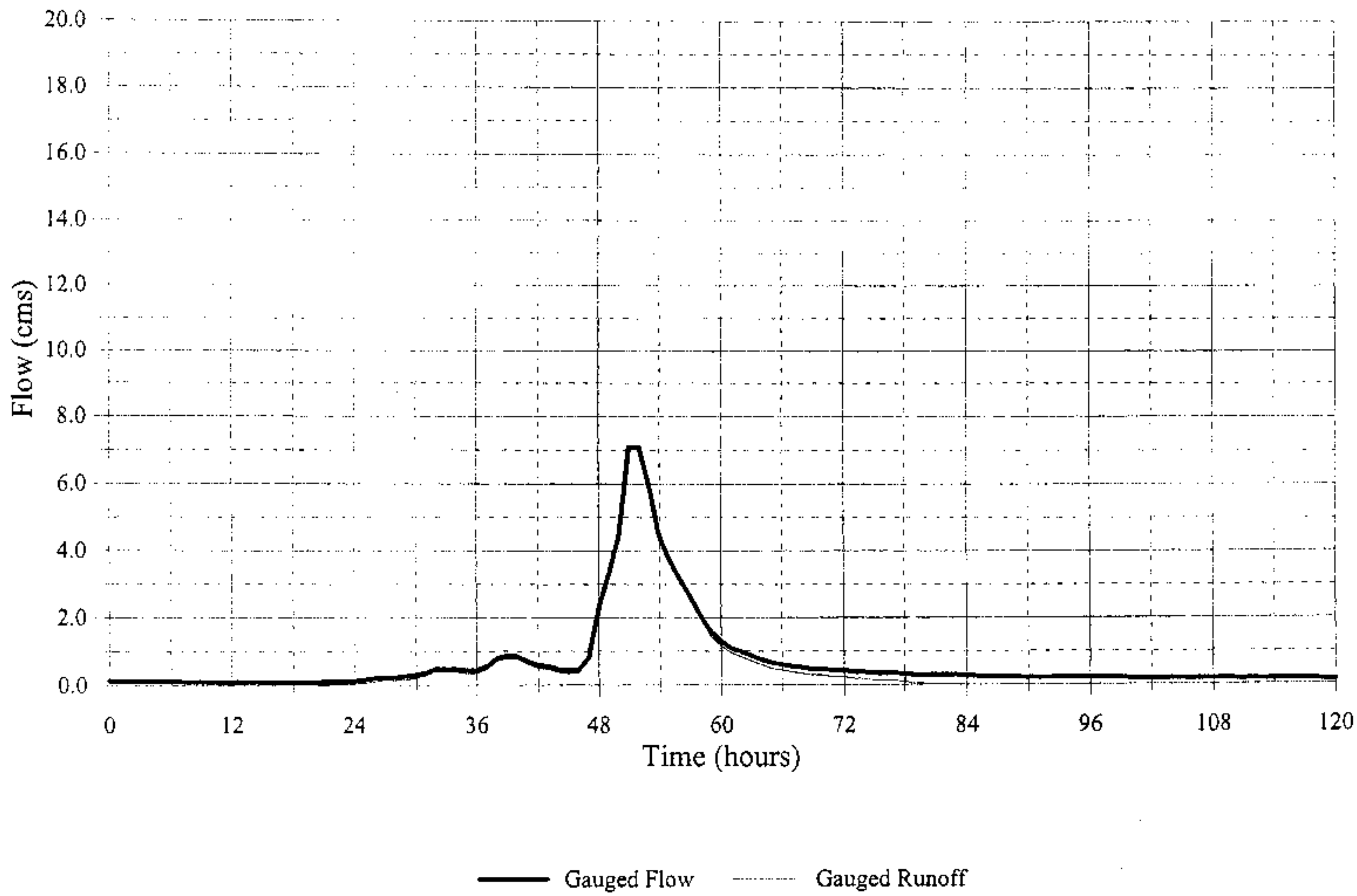
Baseflow Separation: July 17 '99 Storm
East Duffins Creek (02HC019)

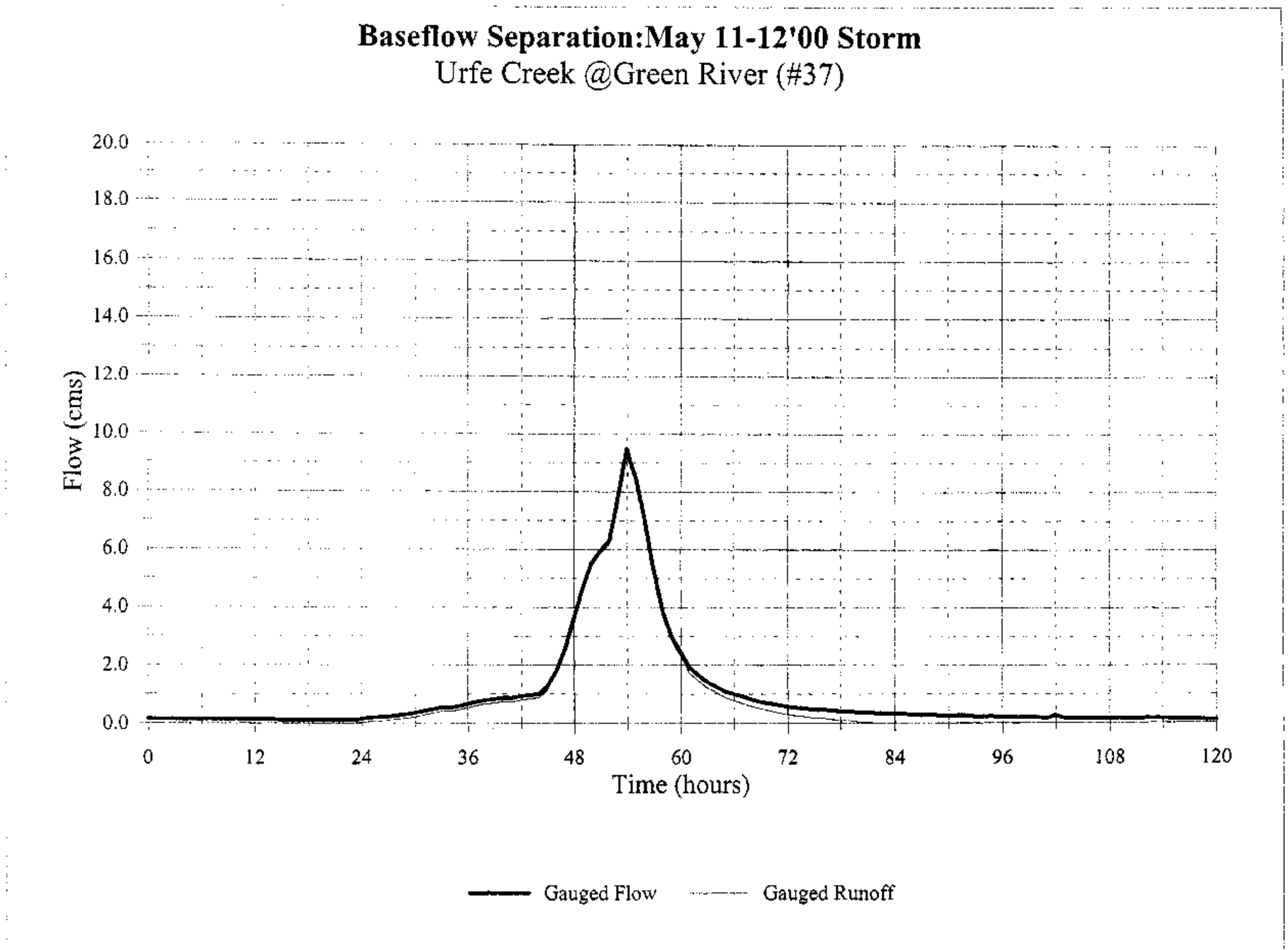




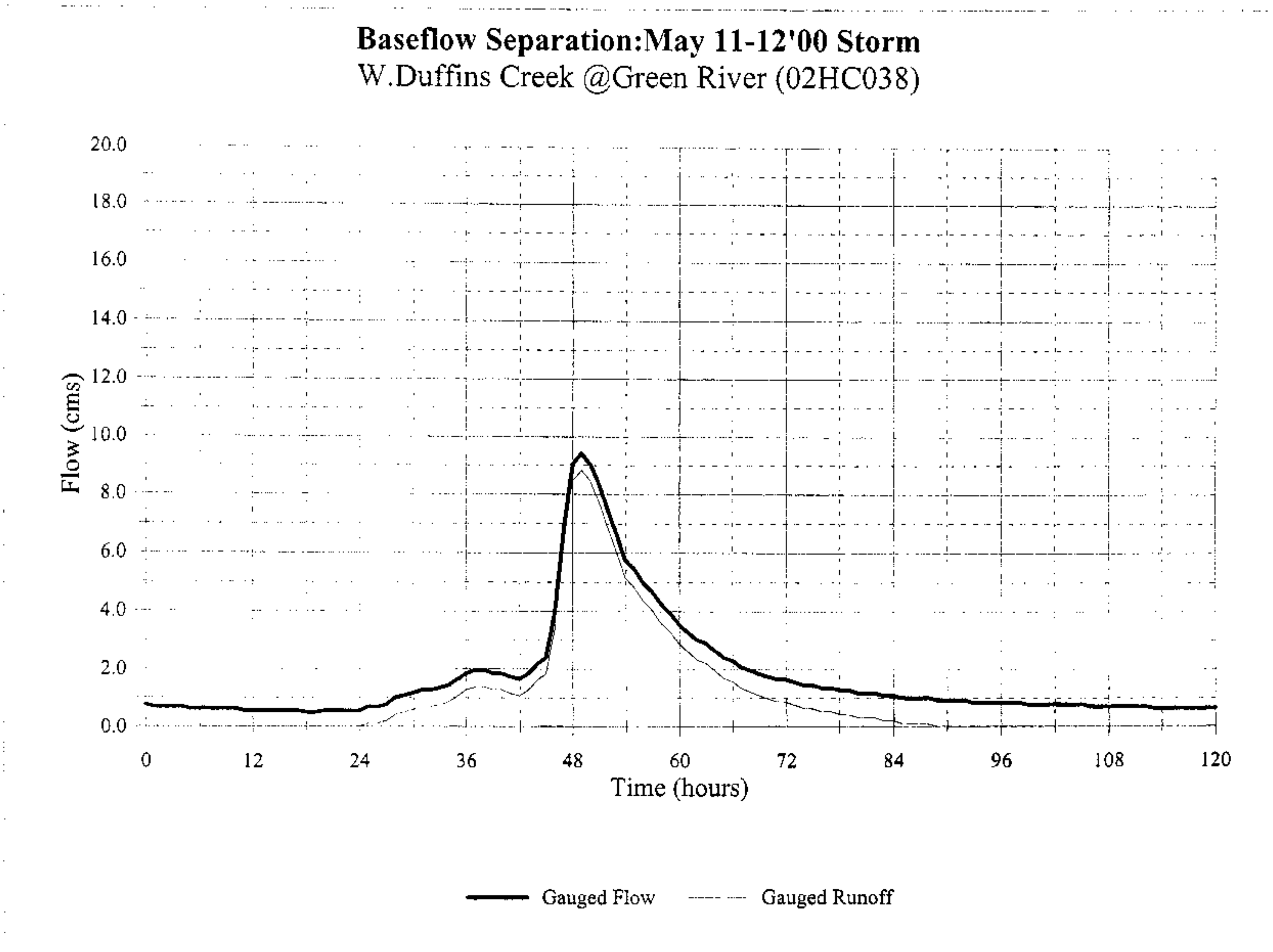
Baseflow Separation:May 11-12'00 Storm
Reesor Creek (02HC039)
Flow (cms)
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0
12
24
36
48
60
72
84
96
108
120
Time (hours)
Gauged Flow
Gauged Runoff

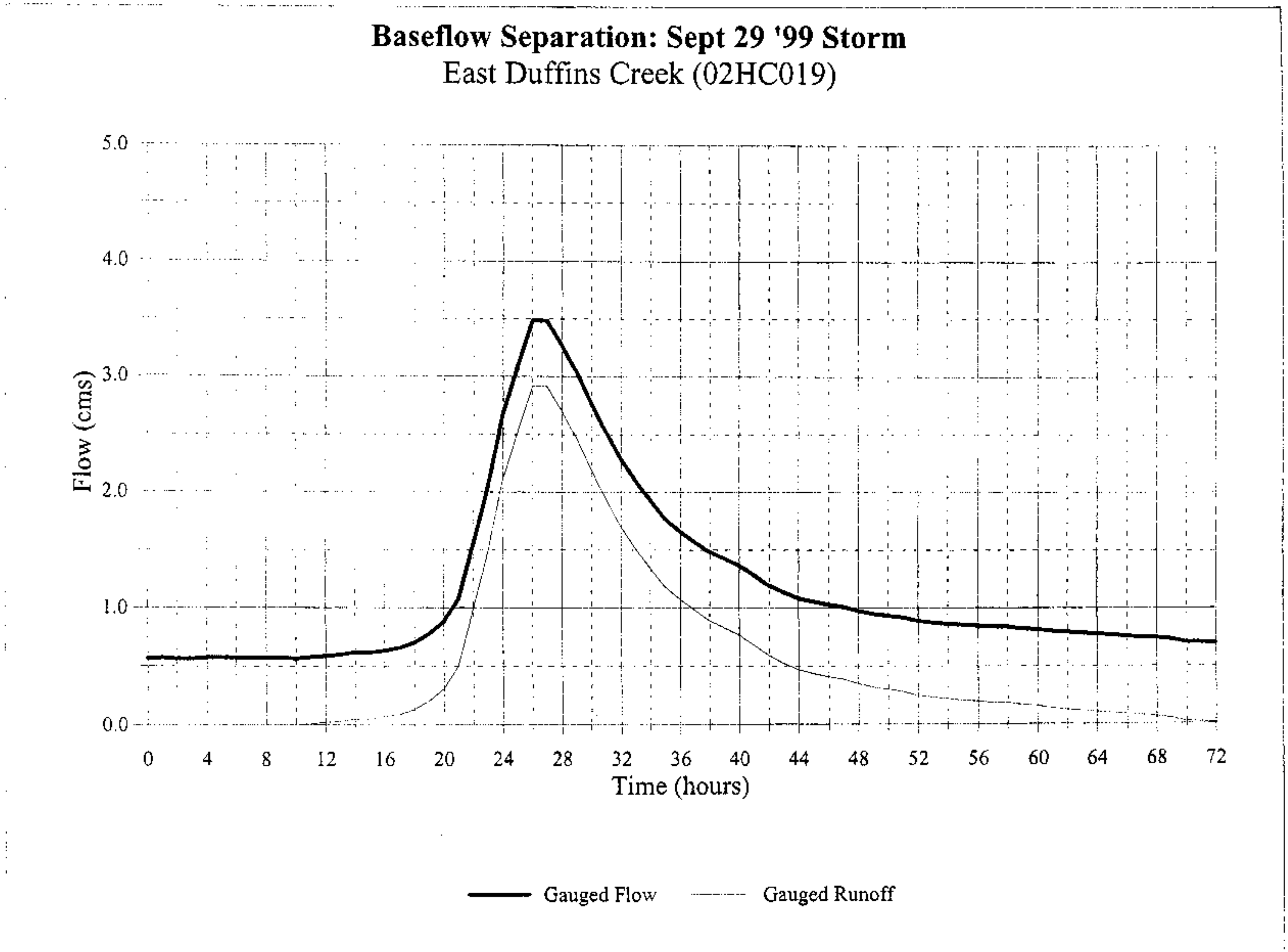
Baseflow Separation:May 11-12'00 Storm
Brougham Creek @Green River (#36)





Baseflow Separation:May 11-12'00 Storm
Urfe Creek @Green River (#37)
Flow (cms)
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0
12
24
36
48
60
72
84
96
108
120
Time (hours)
Gauged Flow
Gauged Runoff

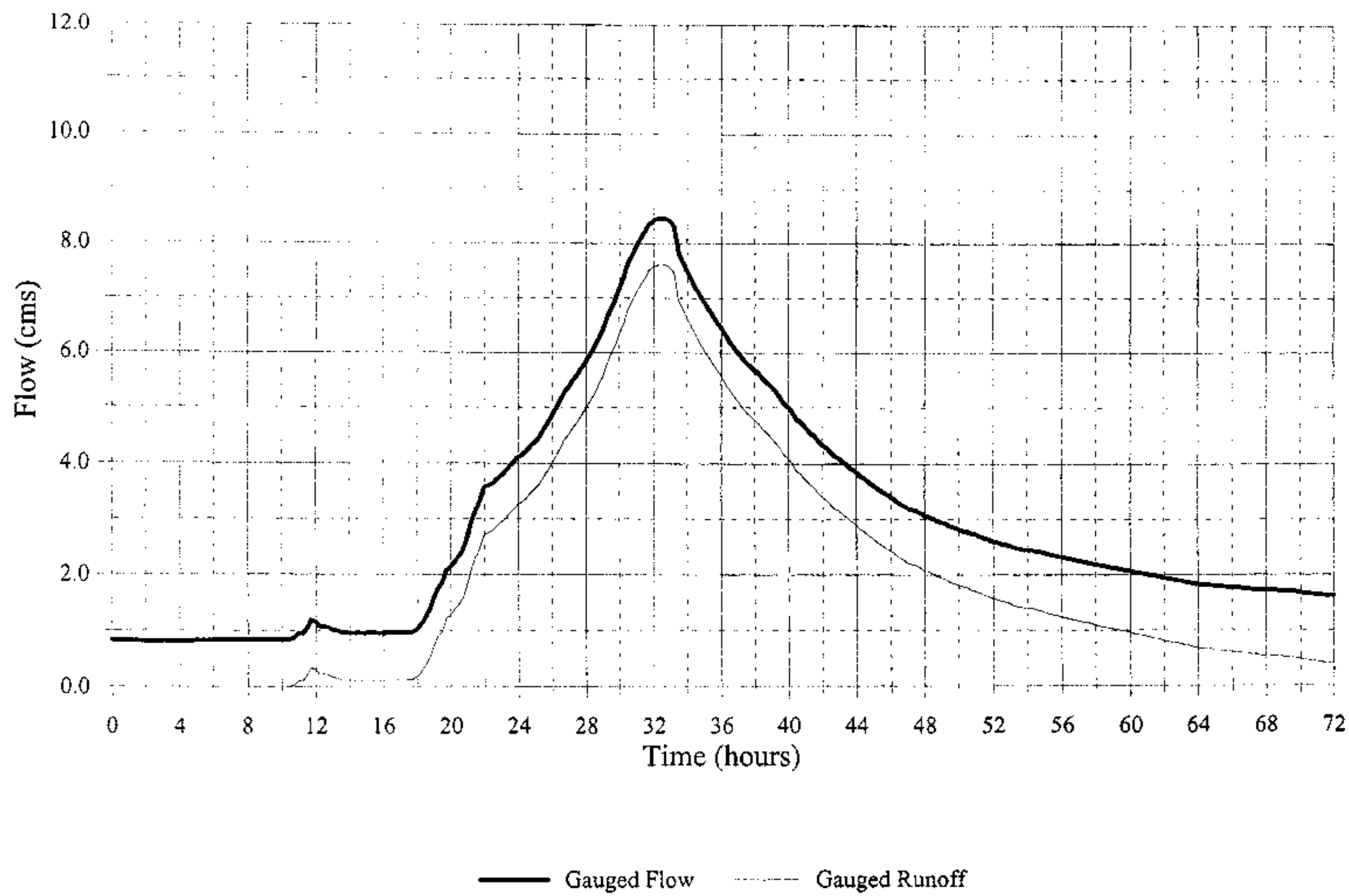

Baseflow Separation:May 11-12'00 Storm
W.Duffins Creek @Green River (02HC038)
Flow (cms)
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0
12
24
36
48
60
72
84
96
108
120
Time (hours)
Gauged Flow
Gauged Runoff

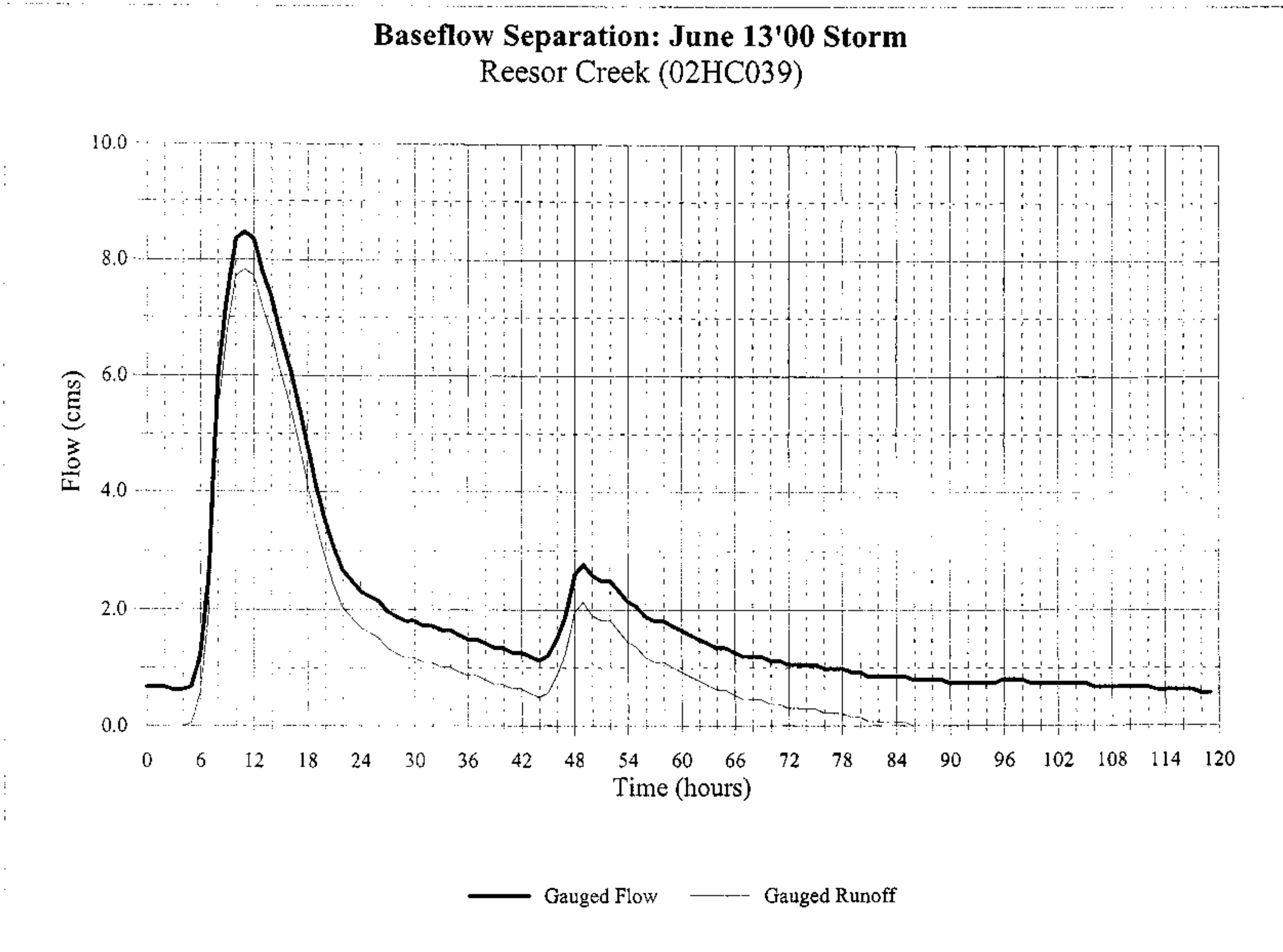


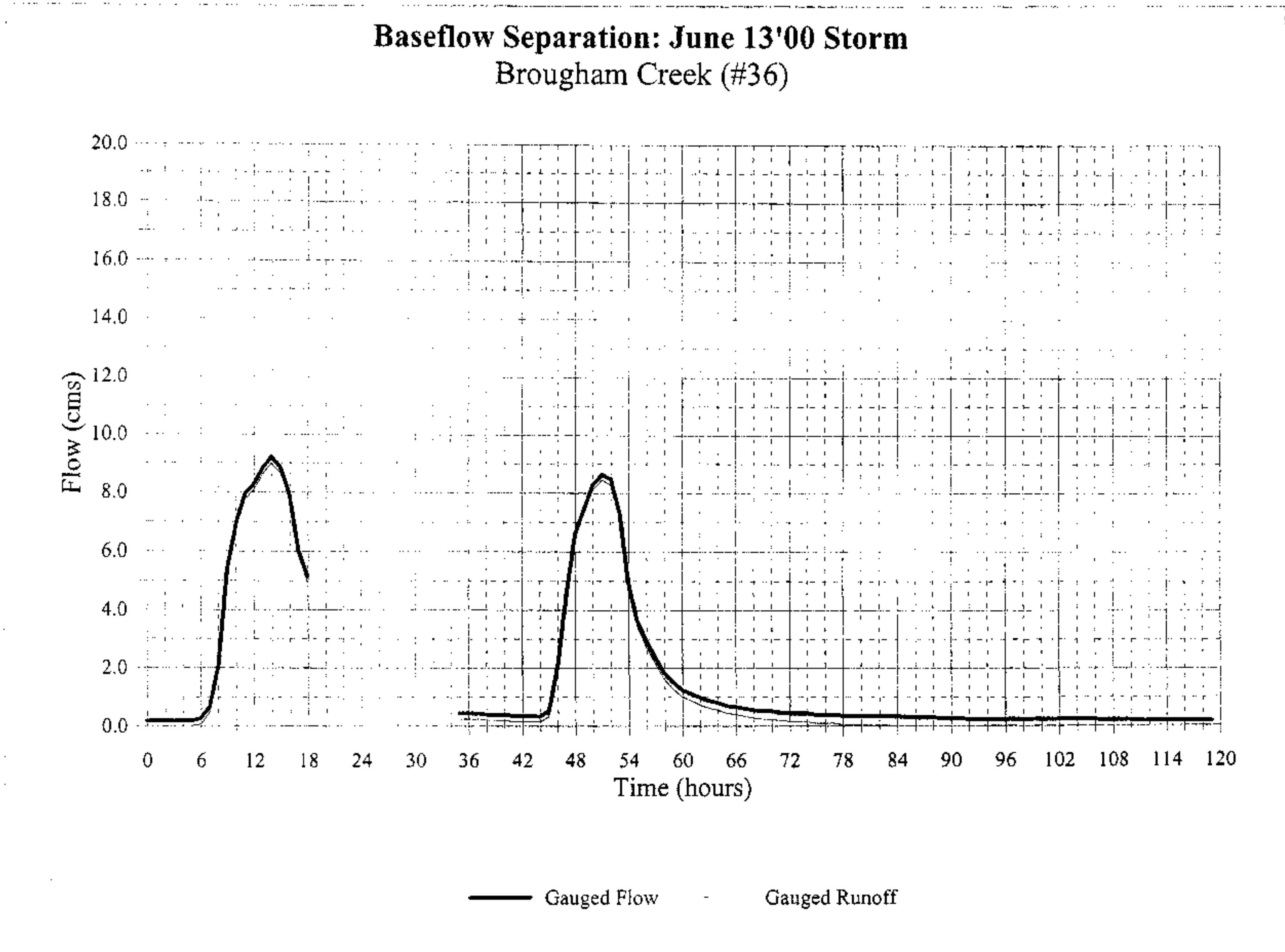
Baseflow Separation: Sept 29 '99 Storm
East Duffins Creek (02HC019)
Flow (cms)
5.0
4.0
3.0
2.0
1.0
0.0
0
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60
64
68
72
Time (hours)
Gauged Flow
Gauged Runoff

Baseflow Separation: Sept 29 '99 Storm

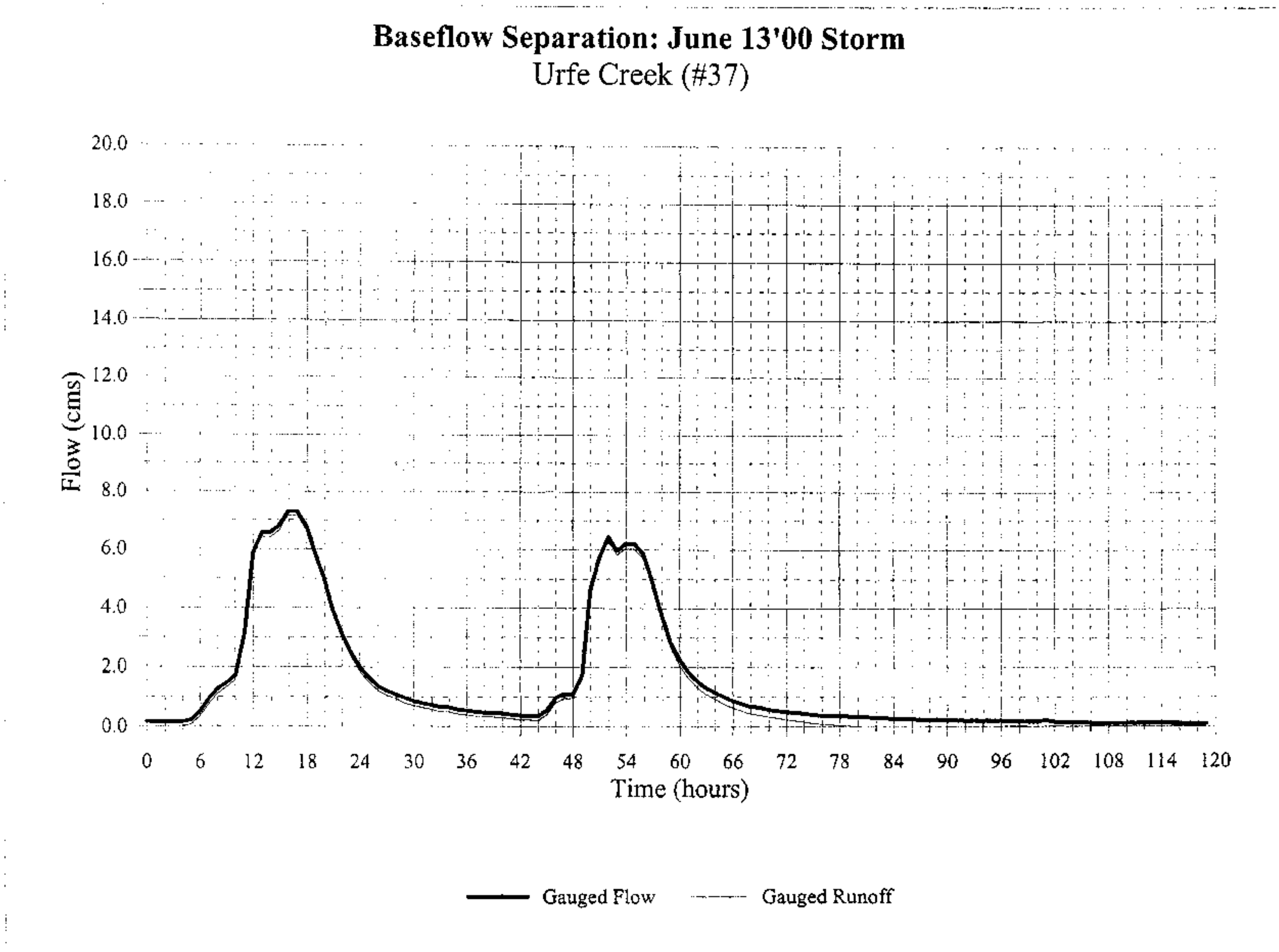
Duffins Creek at Ajax (02HC049)




Baseflow Separation: June 13'00 Storm
Reesor Creek (02HC039)
Flow (cms)
0.0
2.0
4.0
6.0
8.0
10.0
0
6
12
18
24
30
36
42
48
54
60
66
72
78
84
90
96
102
108
114
120
Time (hours)
Gauged Flow
Gauged Runoff

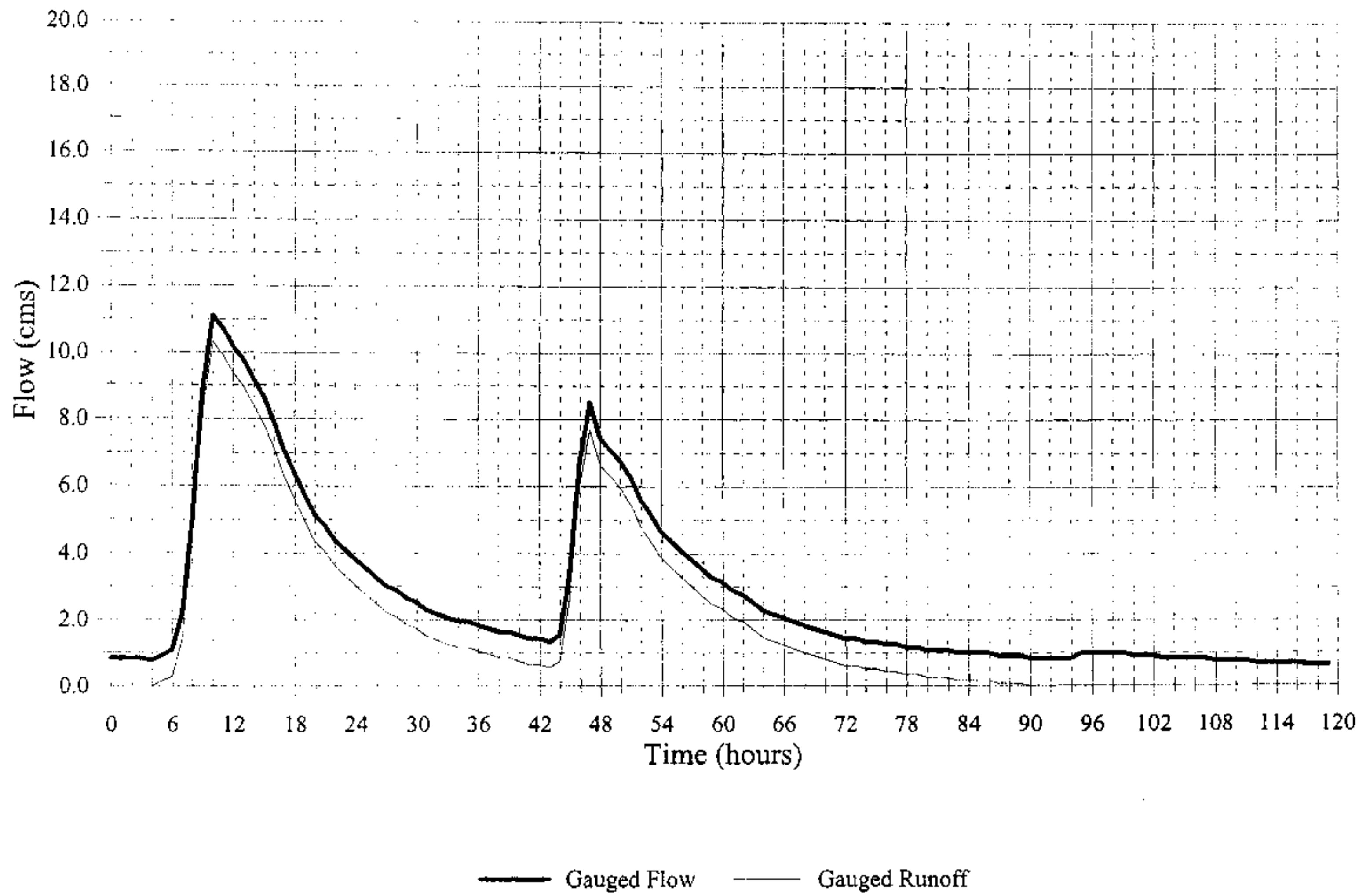


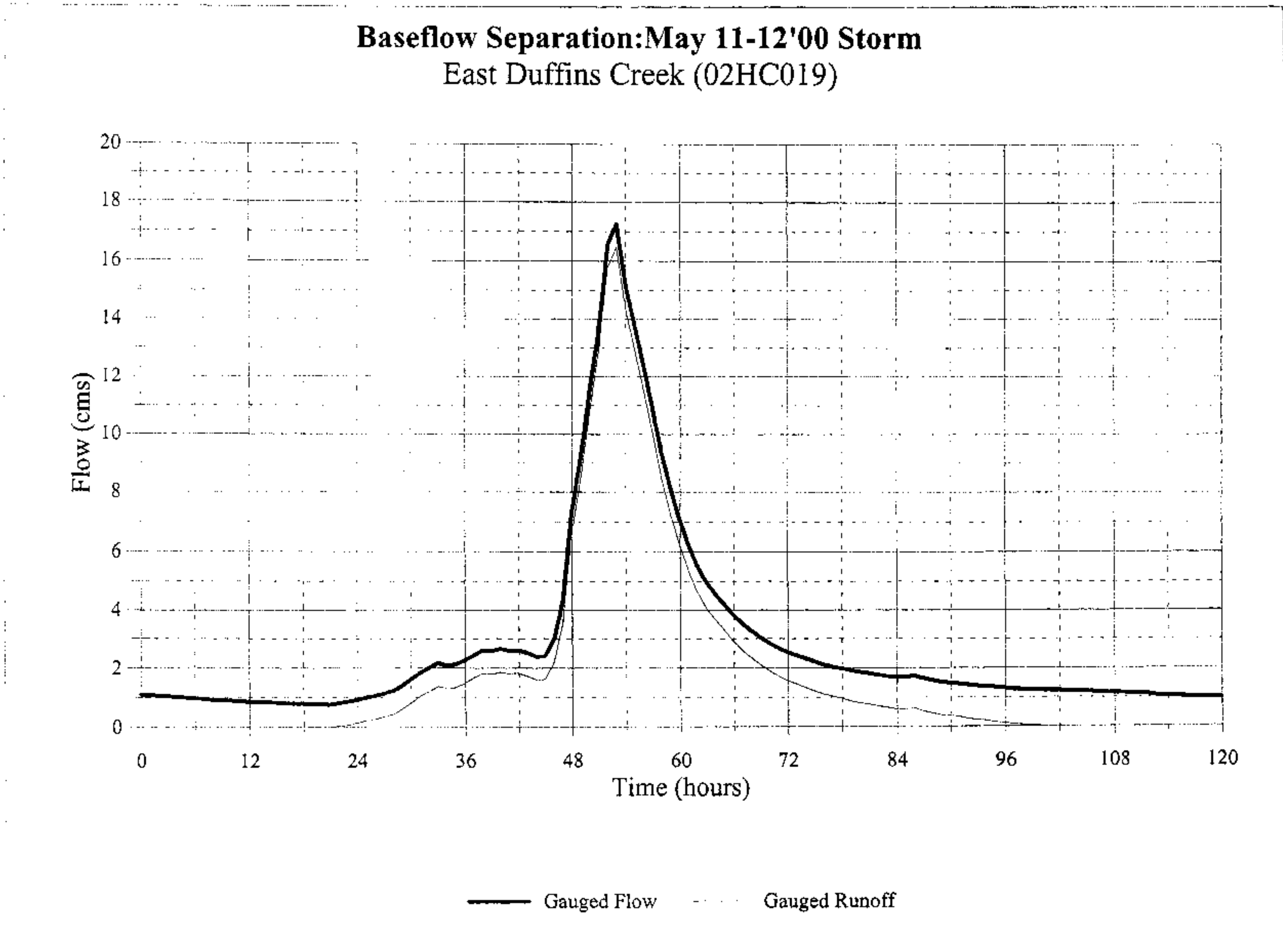
Baseflow Separation: June 13'00 Storm
Brougham Creek (#36)
Flow (cms)
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0
6
12
18
24
30
36
42
48
54
60
66
72
78
84
90
96
102
108
114
120
Time (hours)
Gauged Flow
Gauged Runoff


Baseflow Separation: June 13'00 Storm
Urfe Creek (#37)
Flow (cms)
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0
6
12
18
24
30
36
42
48
54
60
66
72
78
84
90
96
102
108
114
120
Time (hours)
Gauged Flow
Gauged Runoff

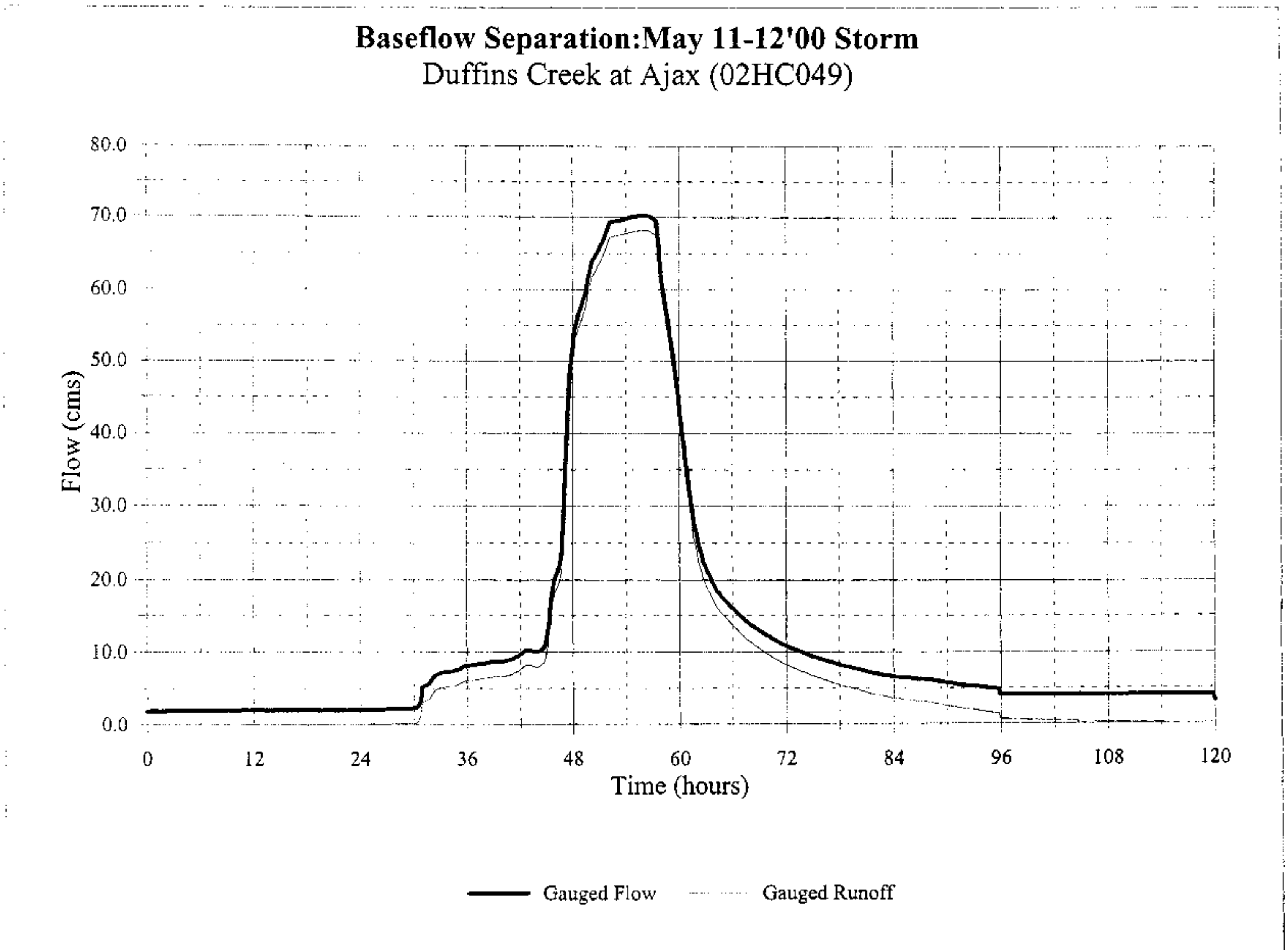
Baseflow Separation: June 13'00 Storm

W.Duffins Creek @Green River (02HC038)



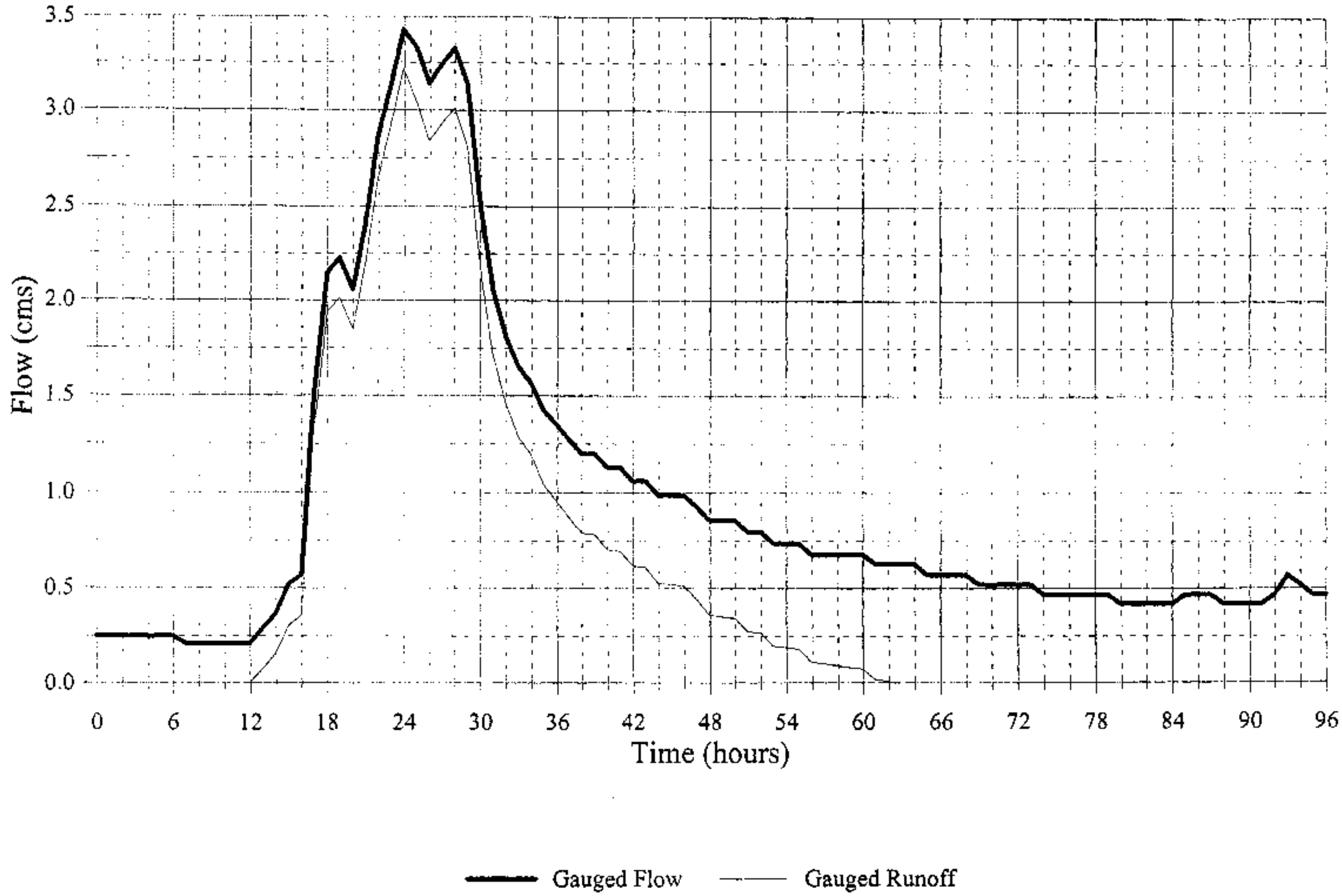


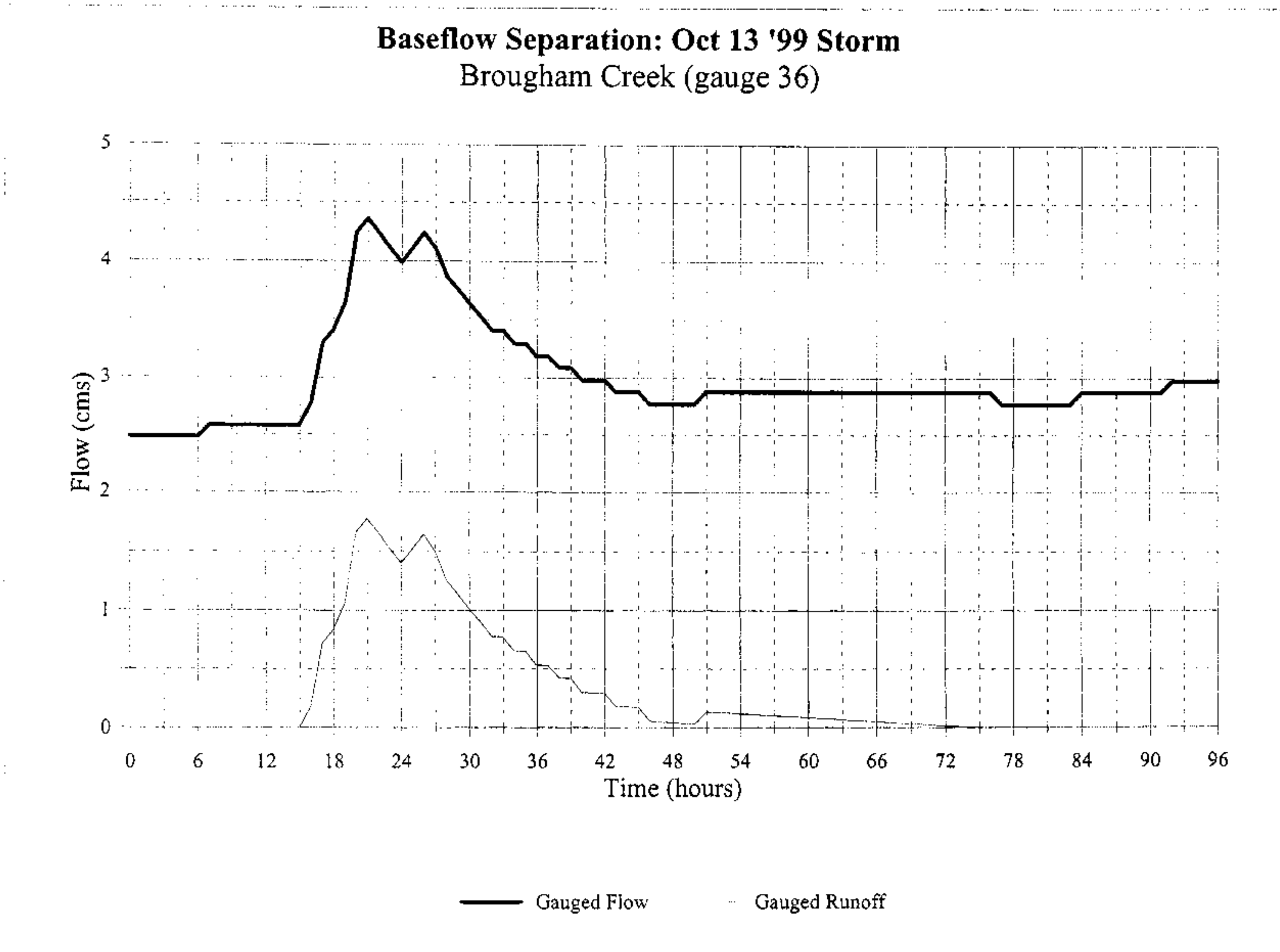
Baseflow Separation:May 11-12'00 Storm
East Duffins Creek (02HC019)
Flow (cms)
20
18
16
14
12
10
8
6
4
2
0
0
12
24
36
48
60
72
84
96
108
120
Time (hours)
Gauged Flow
Gauged Runoff



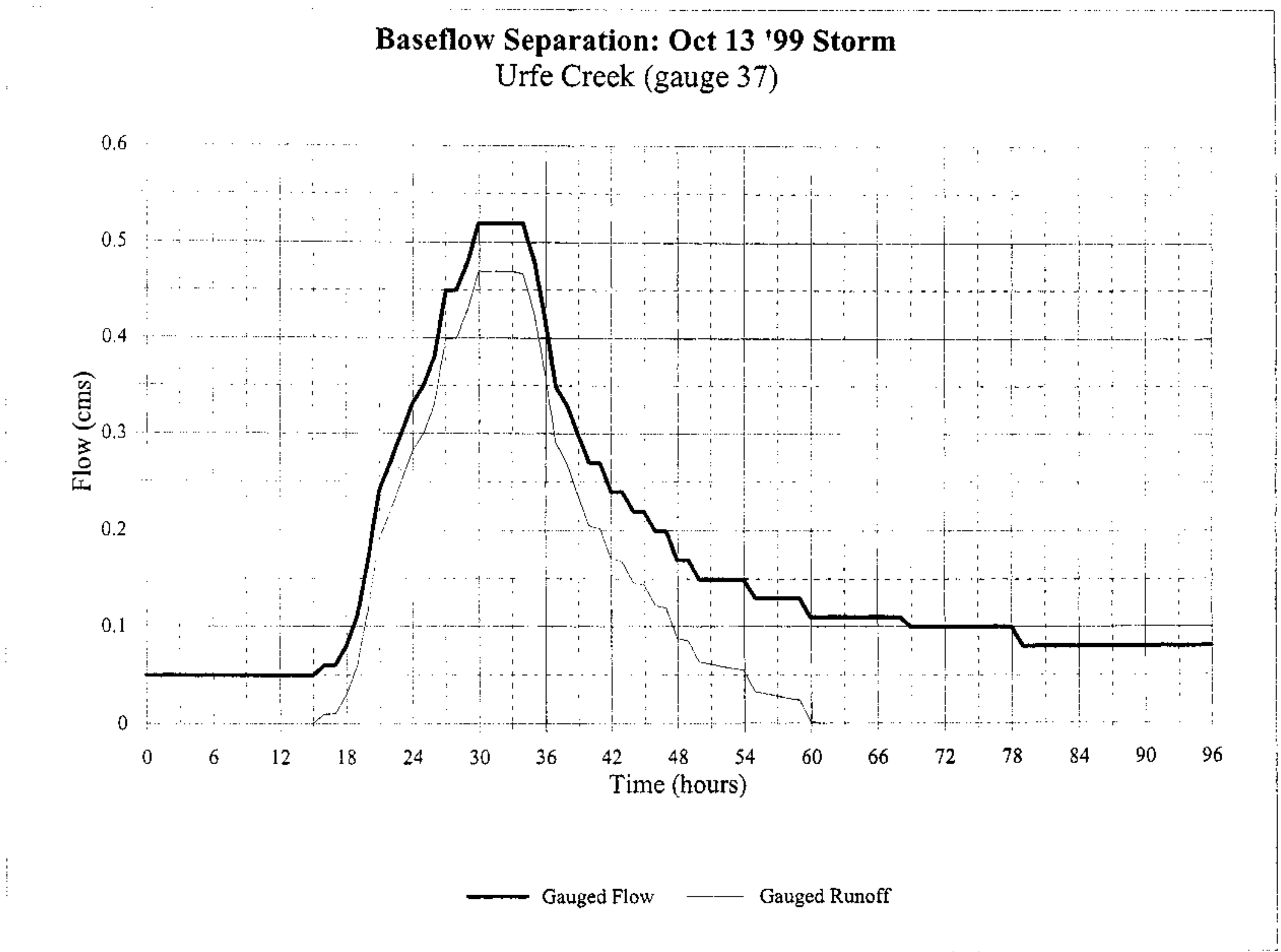
Baseflow Separation:May 11-12'00 Storm
Duffins Creek at Ajax (02HC049)
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Flow (cms)
0
12
24
36
48
60
72
84
96
108
120
Time (hours)
Gauged Flow
Gauged Runoff

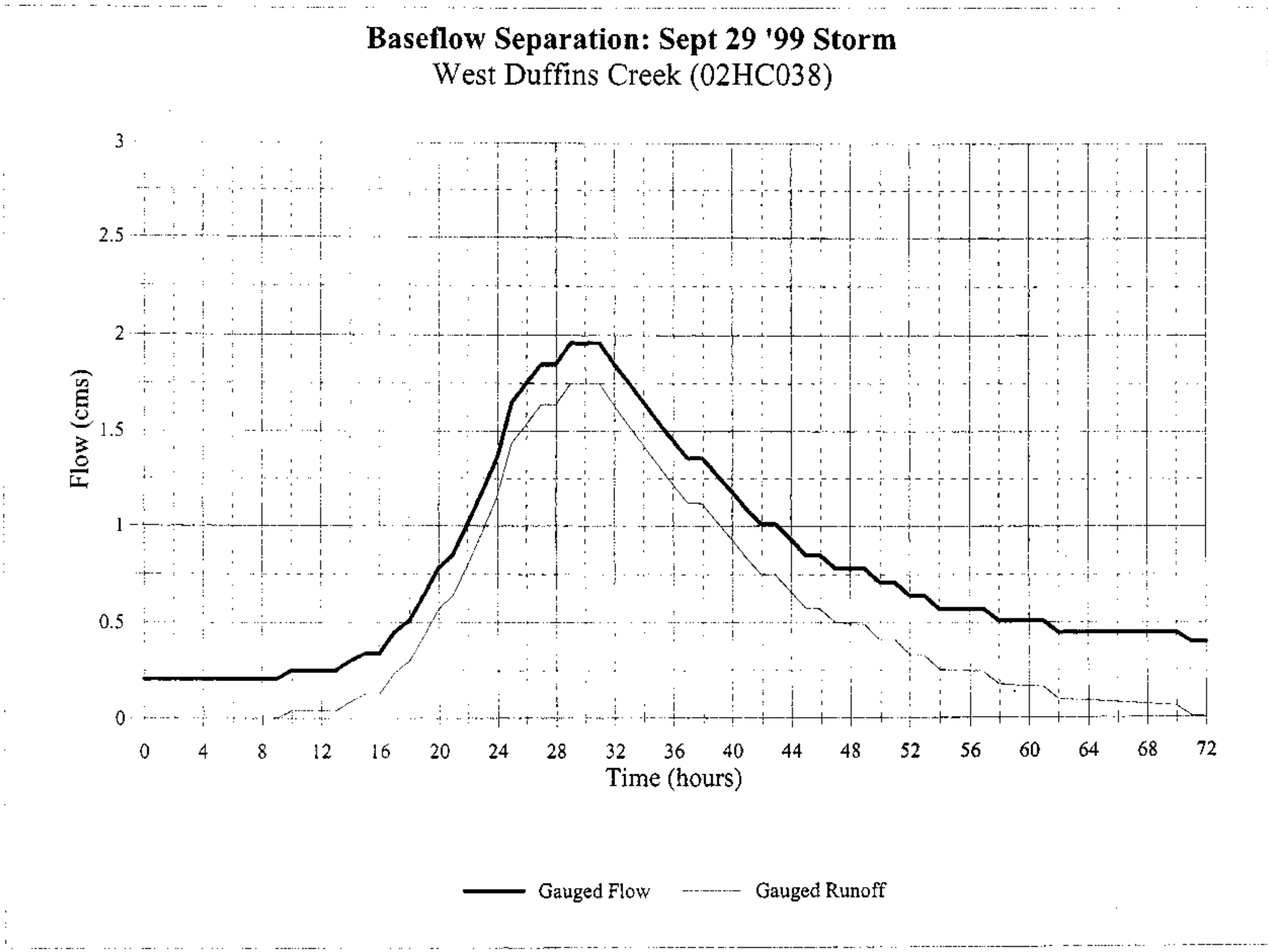
Baseflow Separation: Oct 13 '99 Storm
Reesor Creek (02HC039)



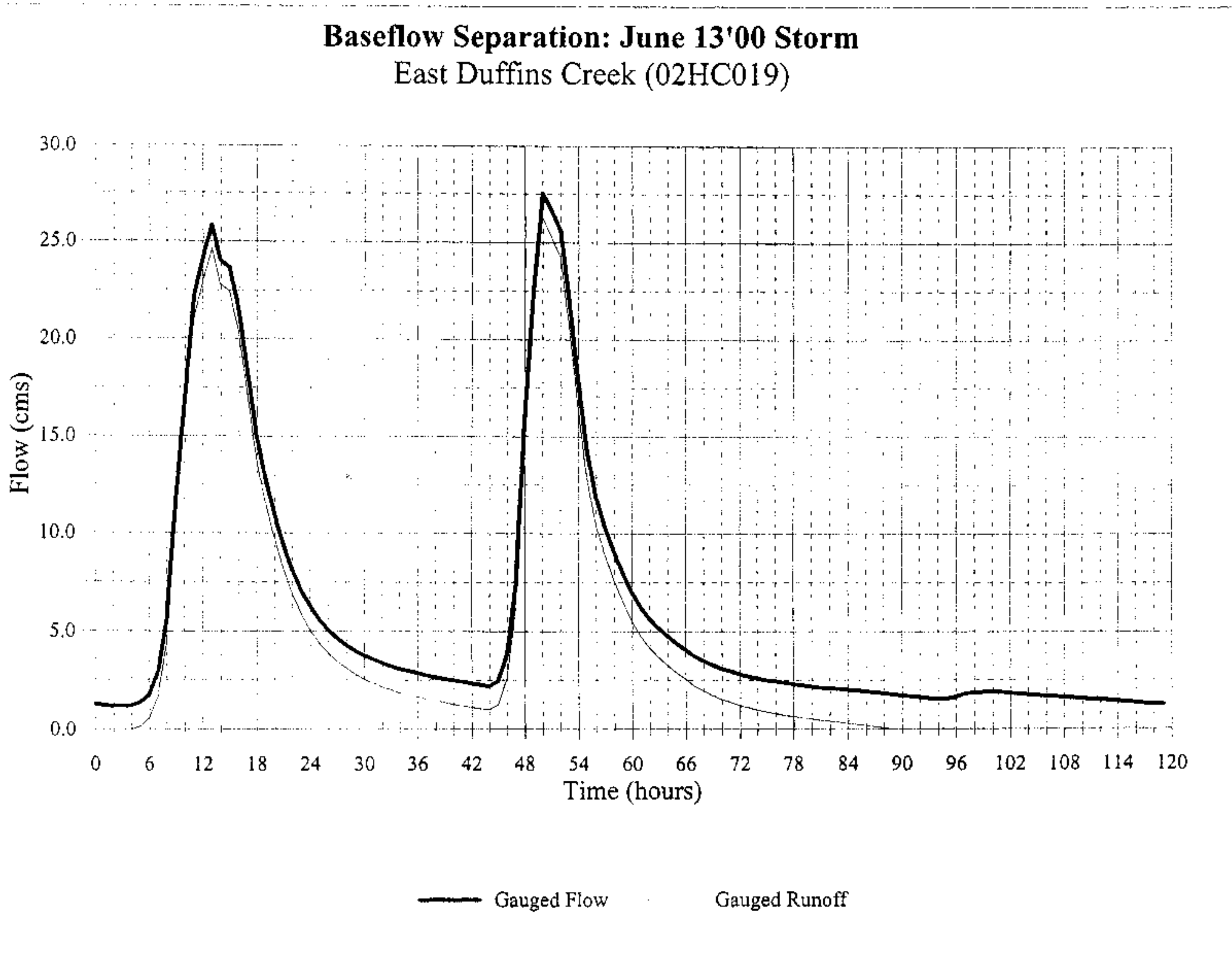


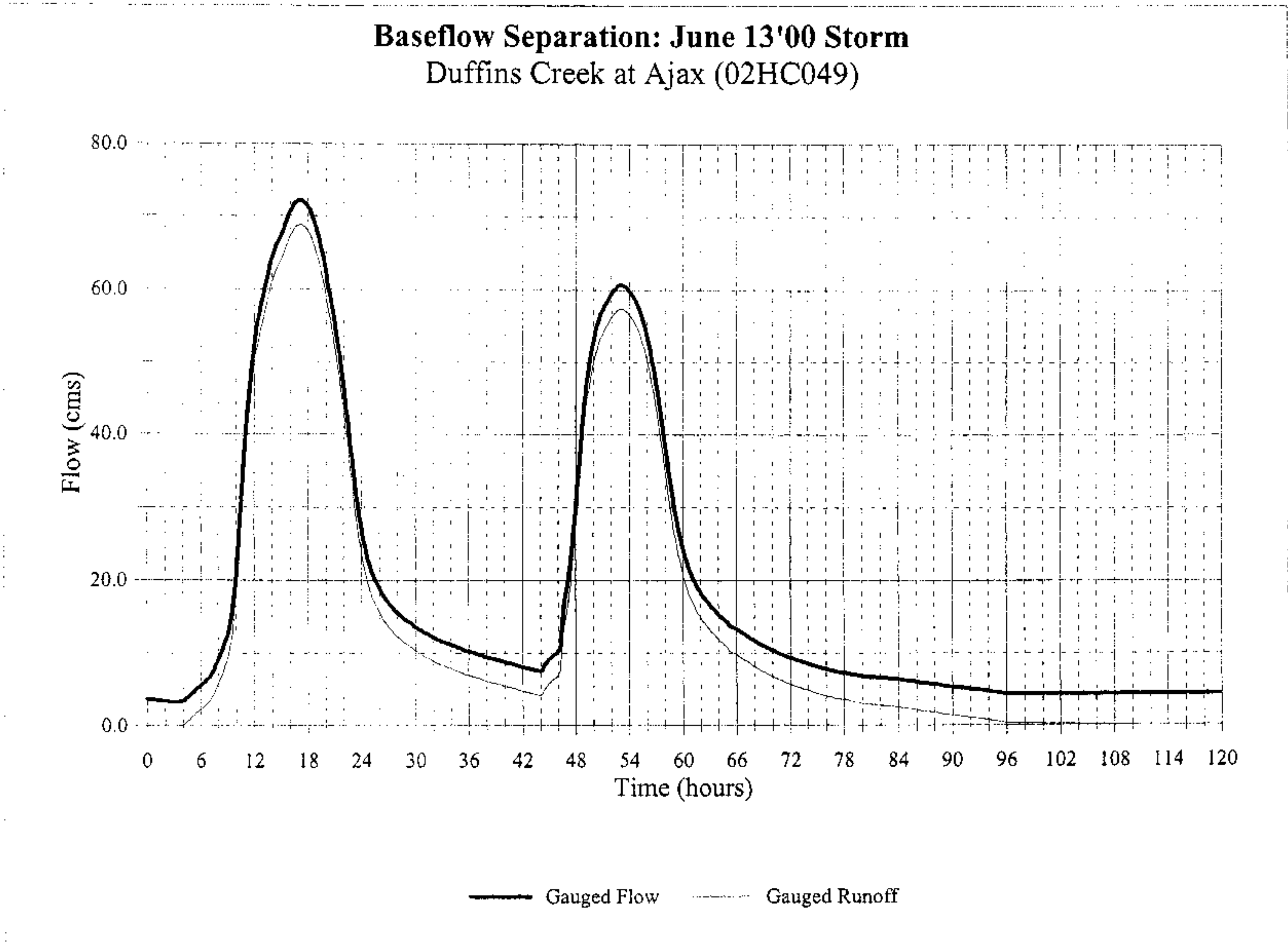
Baseflow Separation: Oct 13 '99 Storm
Brougham Creek (gauge 36)
Flow (cms)
5
4
3
2
1
0
0
6
12
18
24
30
36
42
48
54
60
66
72
78
84
90
96
Time (hours)
Gauged Flow
Gauged Runoff


Baseflow Separation: Oct 13 '99 Storm
Urfe Creek (gauge 37)
Flow (cms)
0.6
0.5
0.4
0.3
0.2
0.1
0
0
6
12
18
24
30
36
42
48
54
60
66
72
78
84
90
96
Time (hours)
Gauged Flow
Gauged Runoff

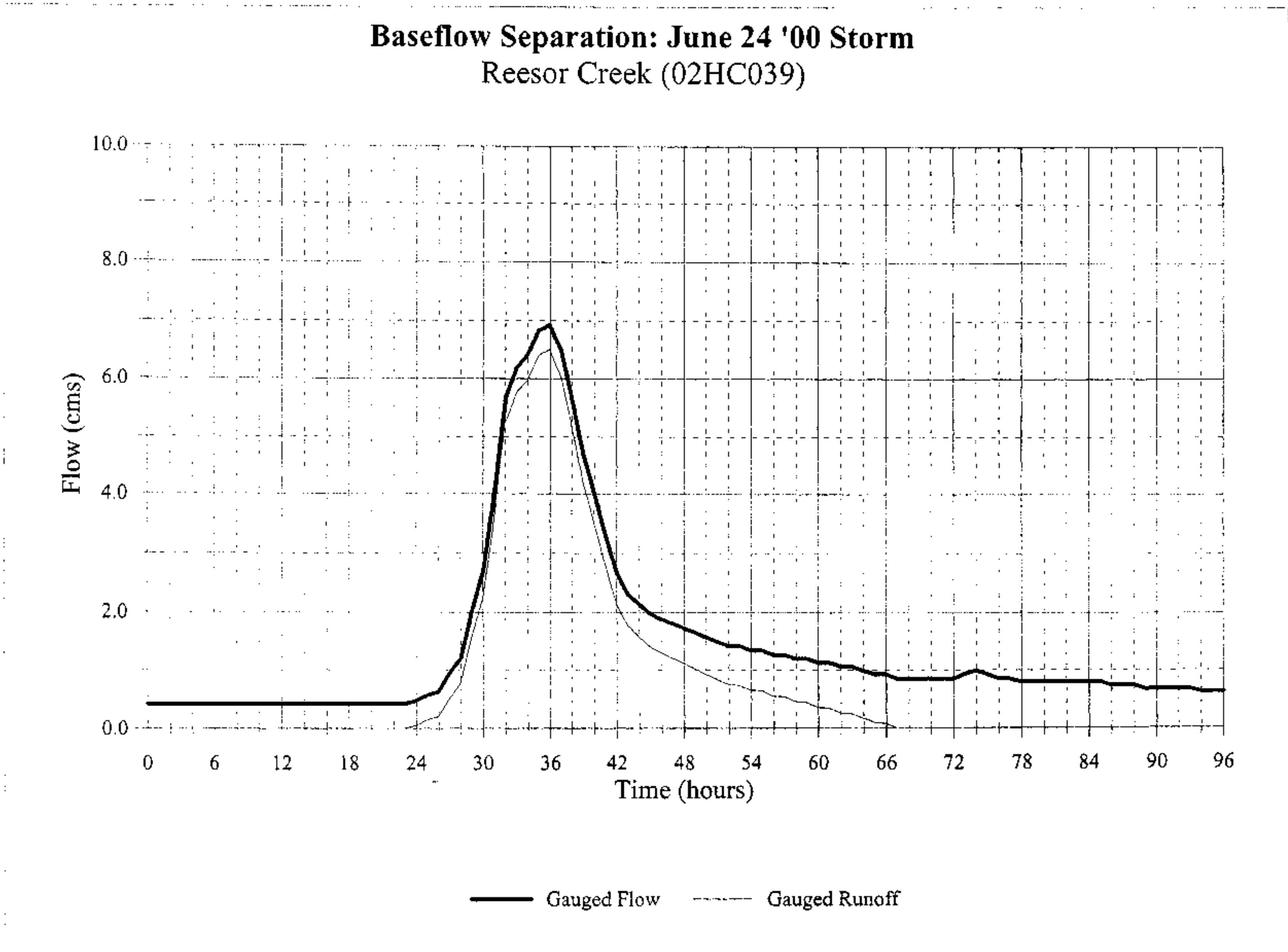


Baseflow Separation: Sept 29 '99 Storm
West Duffins Creek (02HC038)
Flow (cms)
3
2.5
2
1.5
1
0.5
0
0 4 8 12 16 20 24 28 32 36 40 44 48 52 56 60 64 68 72
Time (hours)
Gauged Flow
Gauged Runoff

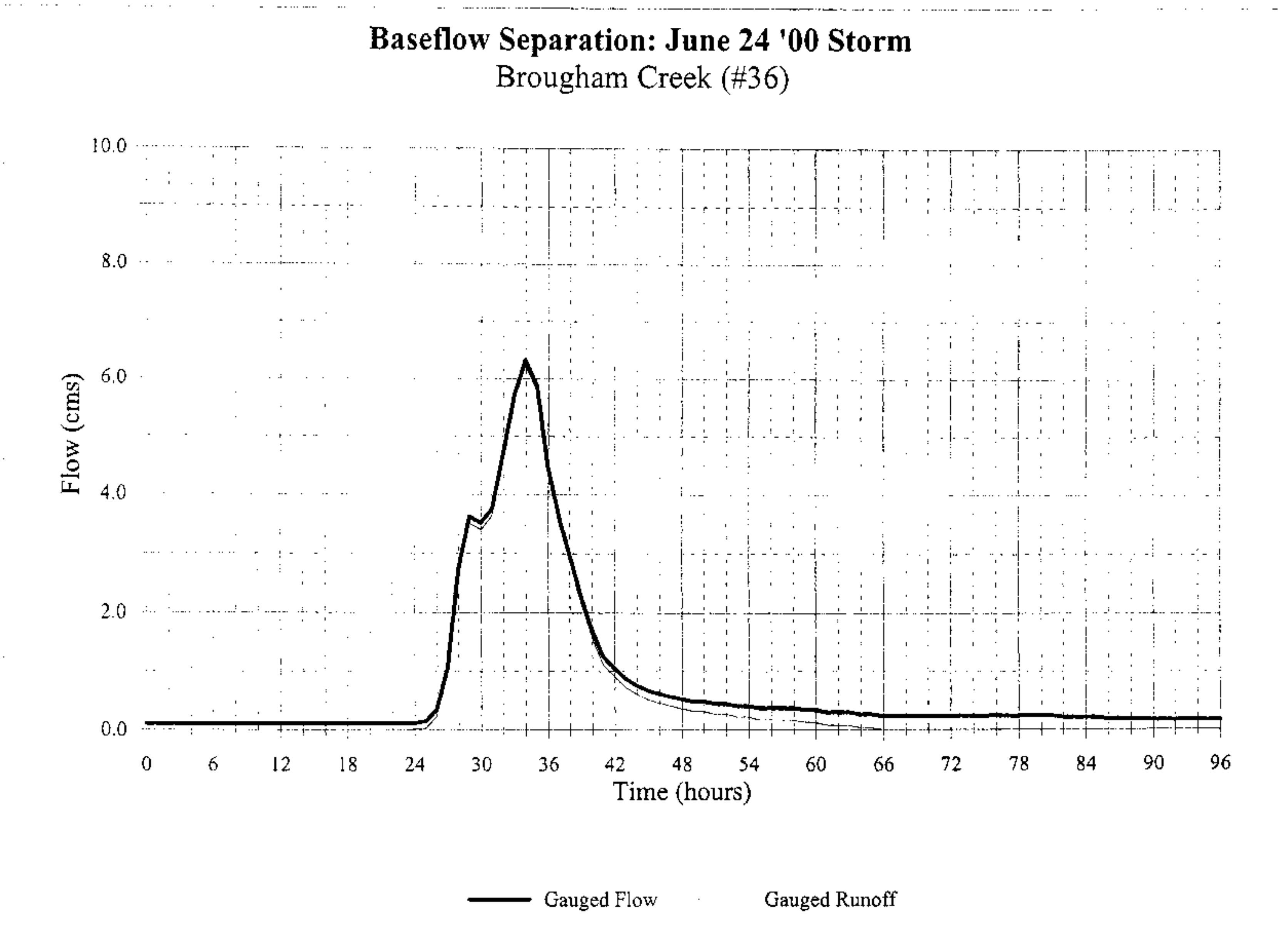

Baseflow Separation: June 13'00 Storm
East Duffins Creek (02HC019)
Flow (cms)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0
6
12
18
24
30
36
42
48
54
60
66
72
78
84
90
96
102
108
114
120
Time (hours)
Gauged Flow
Gauged Runoff



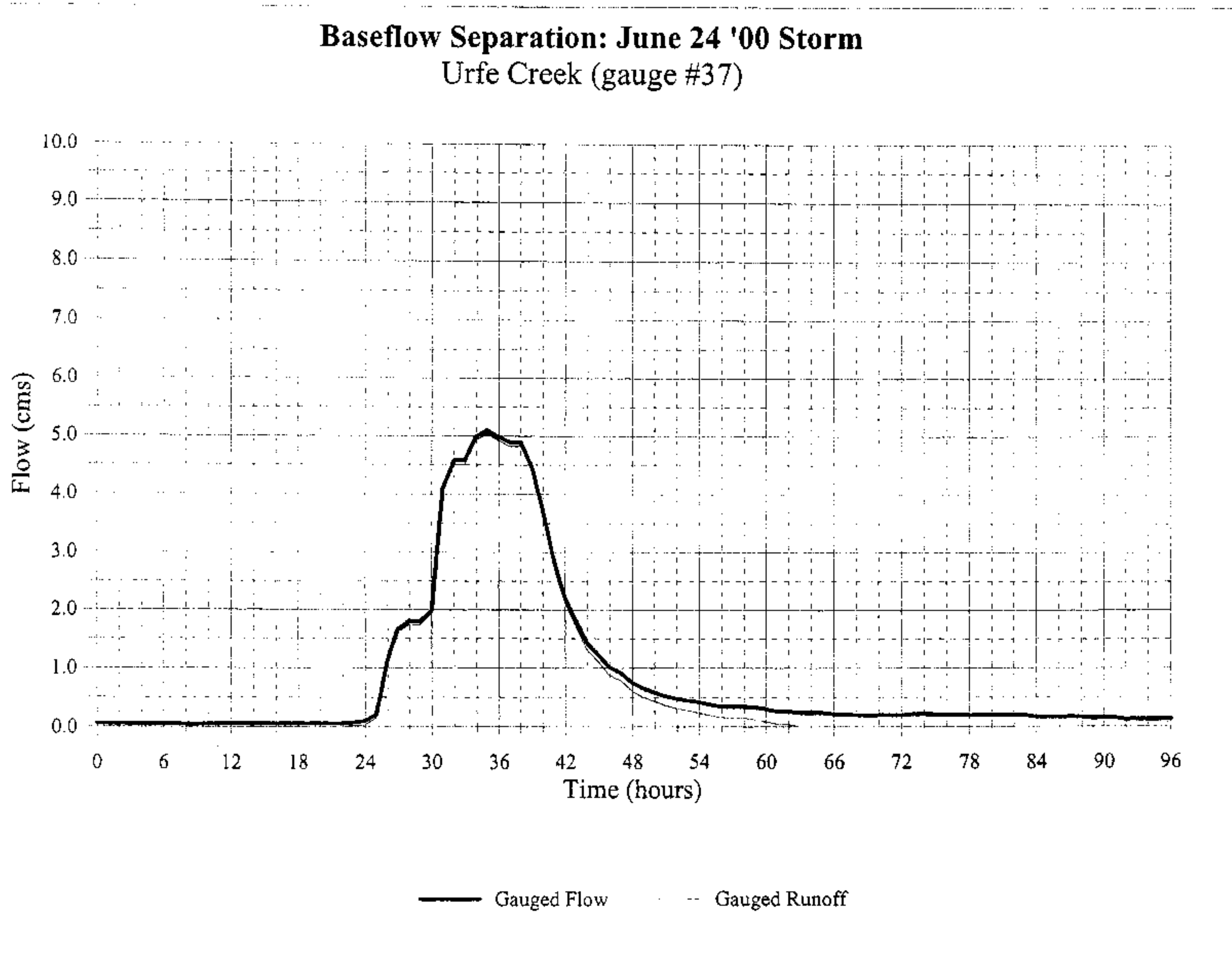
Baseflow Separation: June 13'00 Storm
Duffins Creek at Ajax (02HC049)
80.0
60.0
40.0
20.0
0.0
Flow (cms)
0 6 12 18 24 30 36 42 48 54 60 66 72 78 84 90 96 102 108 114 120
Time (hours)
Gauged Flow
Gauged Runoff

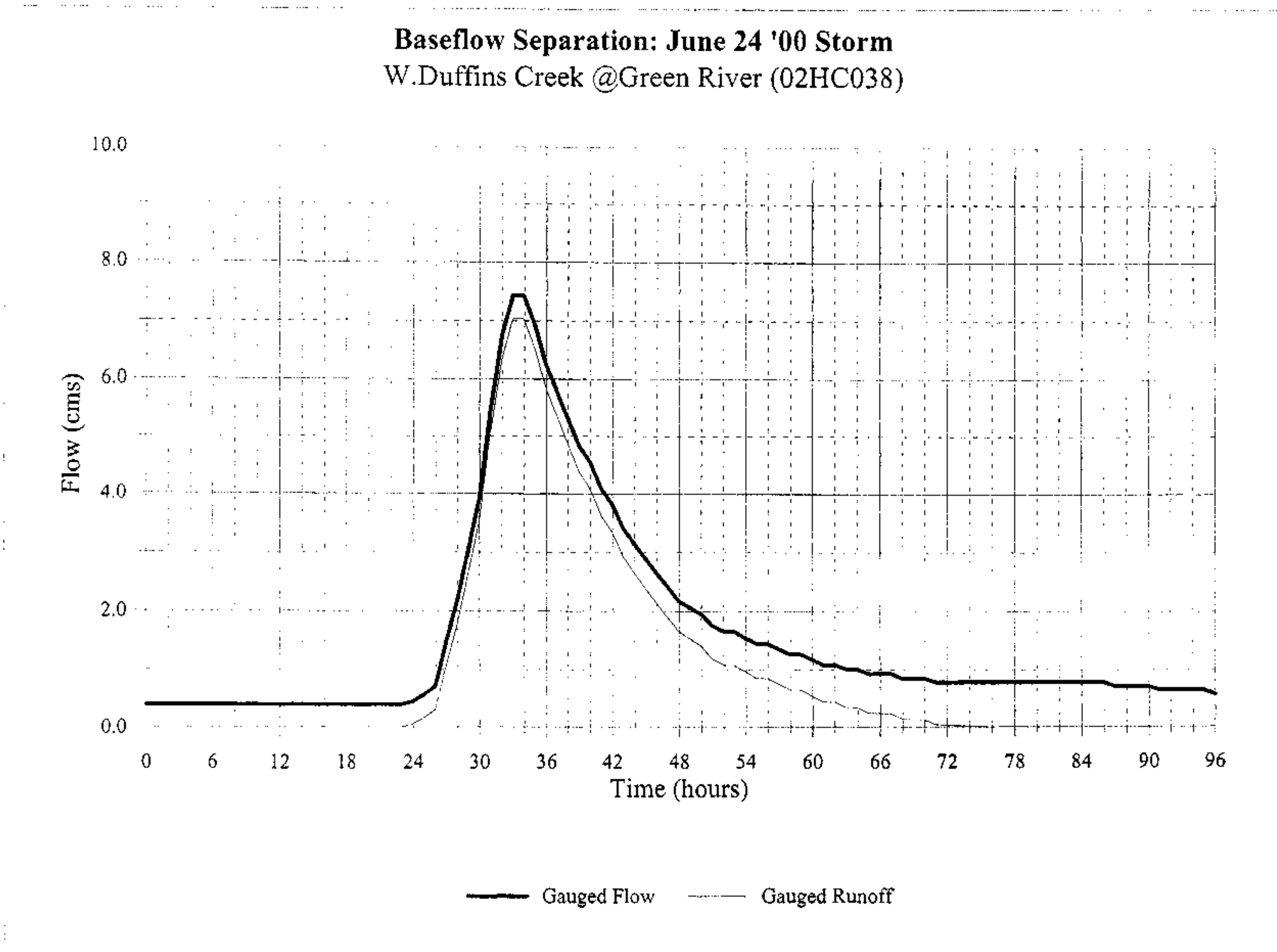


Baseflow Separation: June 24 '00 Storm
Reesor Creek (02HC039)
Flow (cms)
10.0
8.0
6.0
4.0
2.0
0.0
0
6
12
18
24
30
36
42
48
54
60
66
72
78
84
90
96
Time (hours)
Gauged Flow
Gauged Runoff

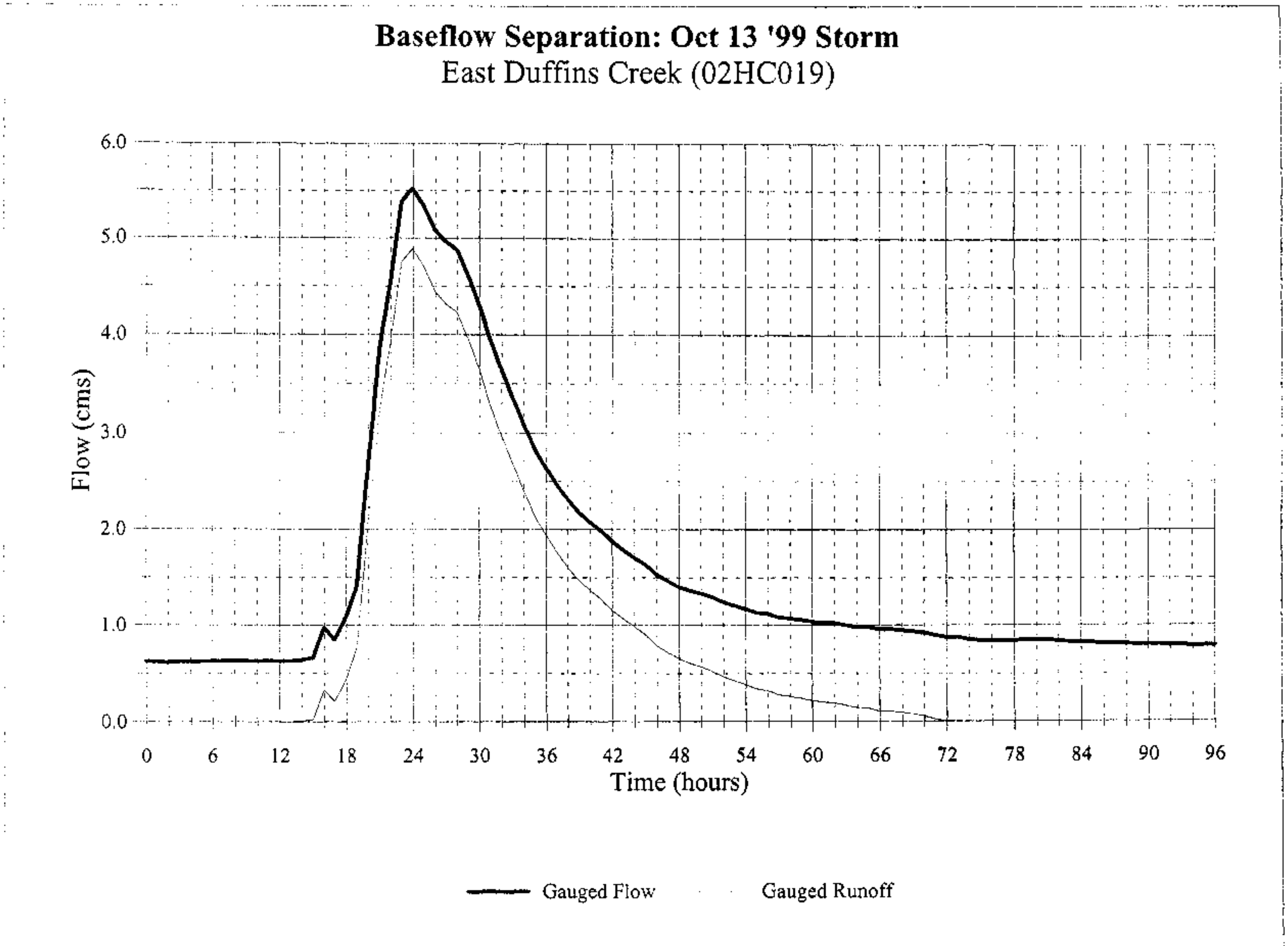


Baseflow Separation: June 24 '00 Storm
Brougham Creek (#36)
10.0
8.0
6.0
4.0
2.0
0.0
Flow (cms)
0
6
12
18
24
30
36
42
48
54
60
66
72
78
84
90
96
Time (hours)
Gauged Flow
Gauged Runoff


Baseflow Separation: June 24 '00 Storm
Urfe Creek (gauge #37)
Flow (cms)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
6
12
18
24
30
36
42
48
54
60
66
72
78
84
90
96
Time (hours)
Gauged Flow
Gauged Runoff

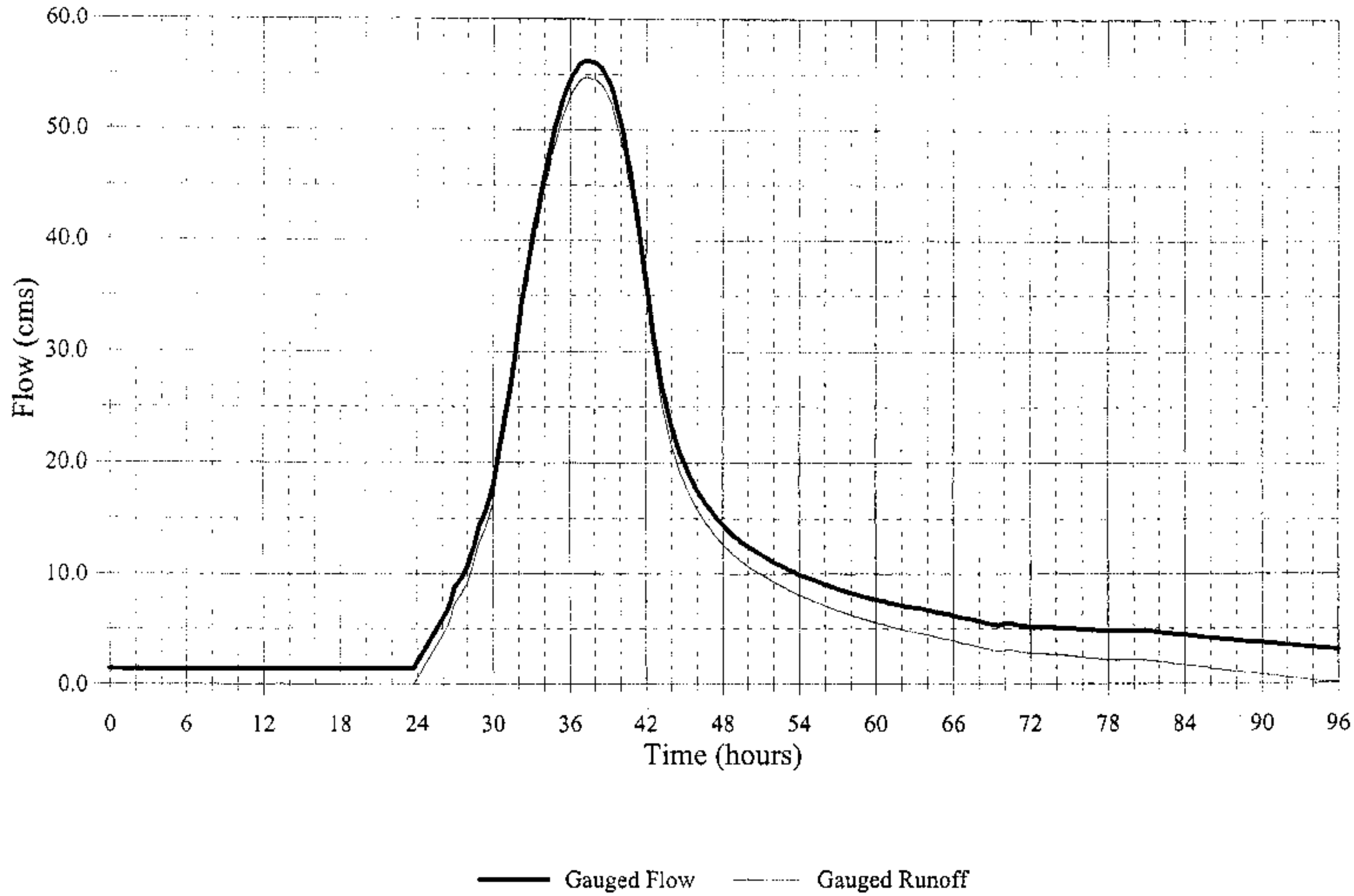


Baseflow Separation: June 24 '00 Storm
W.Duffins Creek @Green River (02HC038)
10.0
8.0
6.0
4.0
2.0
0.0
Flow (cms)
0
6
12
18
24
30
36
42
48
54
60
66
72
78
84
90
96
Time (hours)
Gauged Flow
Gauged Runoff



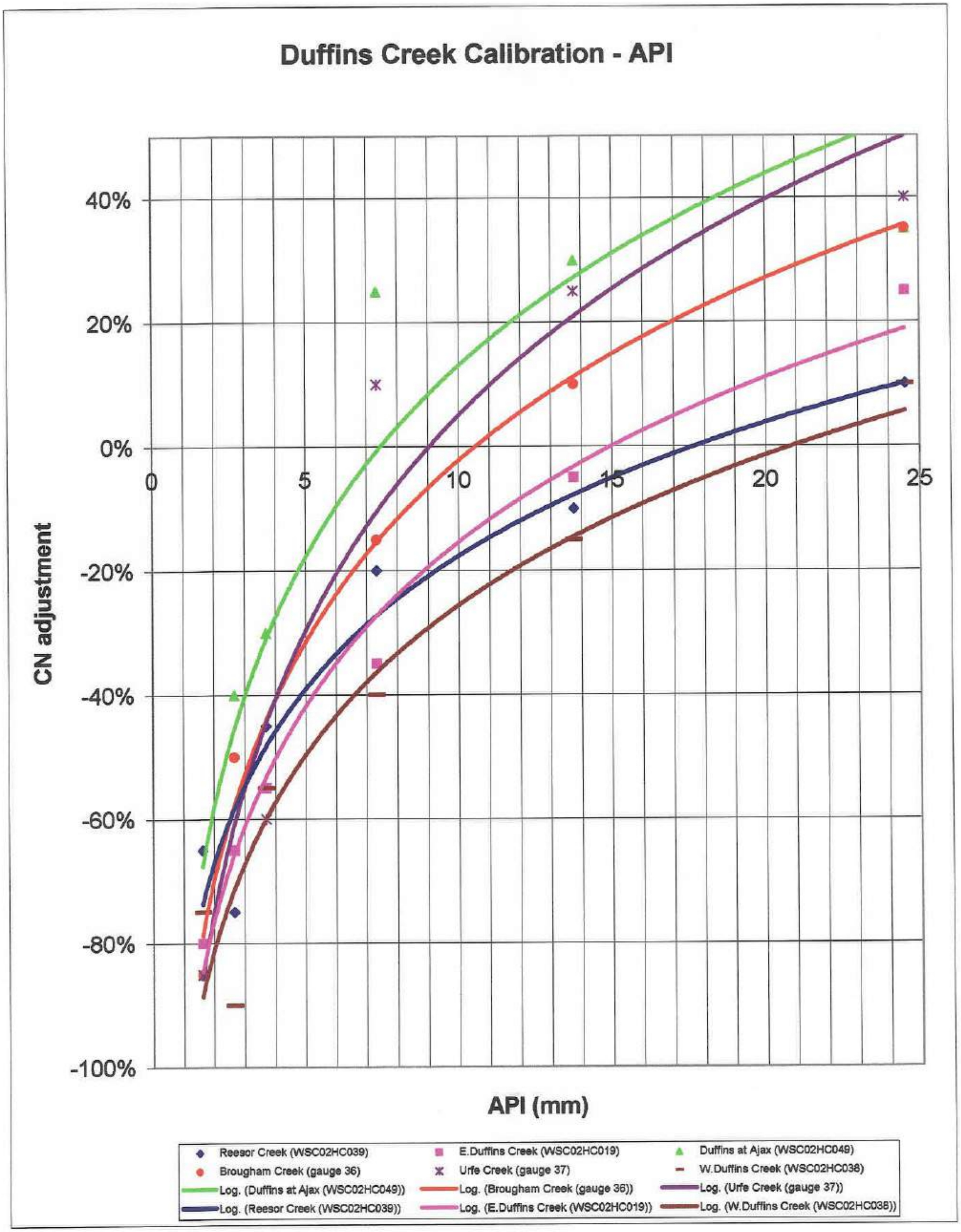
Baseflow Separation: Oct 13 '99 Storm
East Duffins Creek (02HC019)
Flow (cms)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
6
12
18
24
30
36
42
48
54
60
66
72
78
84
90
96
Time (hours)
Gauged Flow
Gauged Runoff

Baseflow Separation: June 24 '00 Storm
Duffins Creek at Ajax (02HC049)

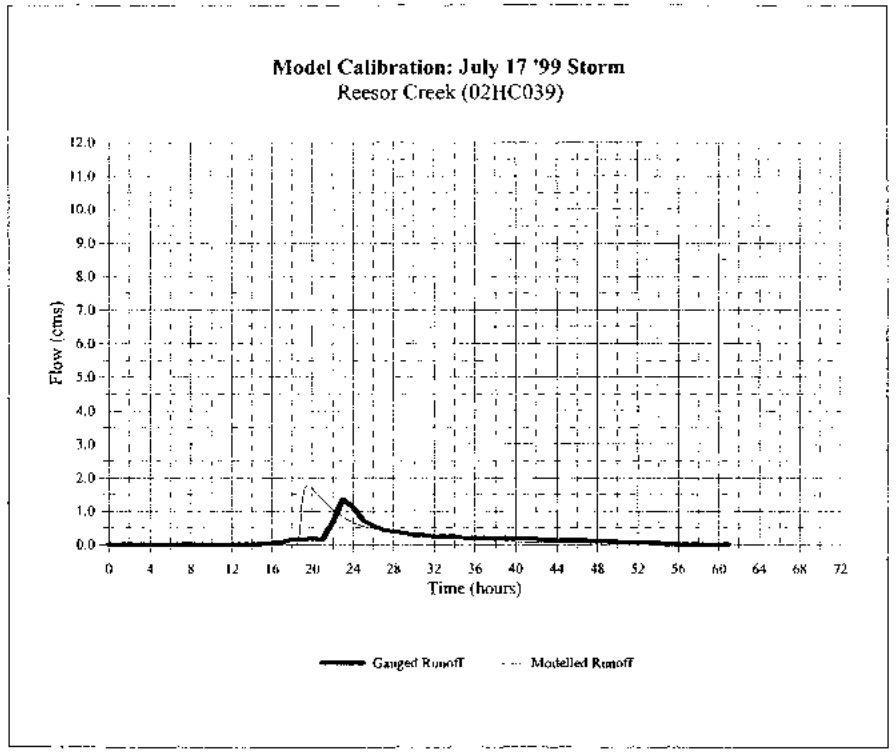


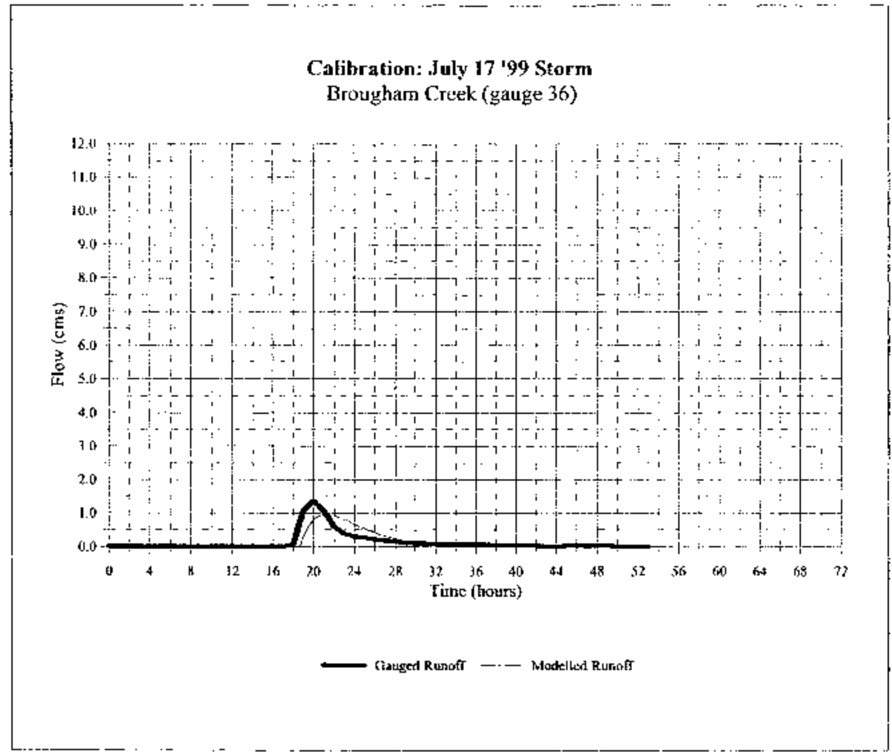
APPENDIX C:

Hydrologic Model Calibration Results



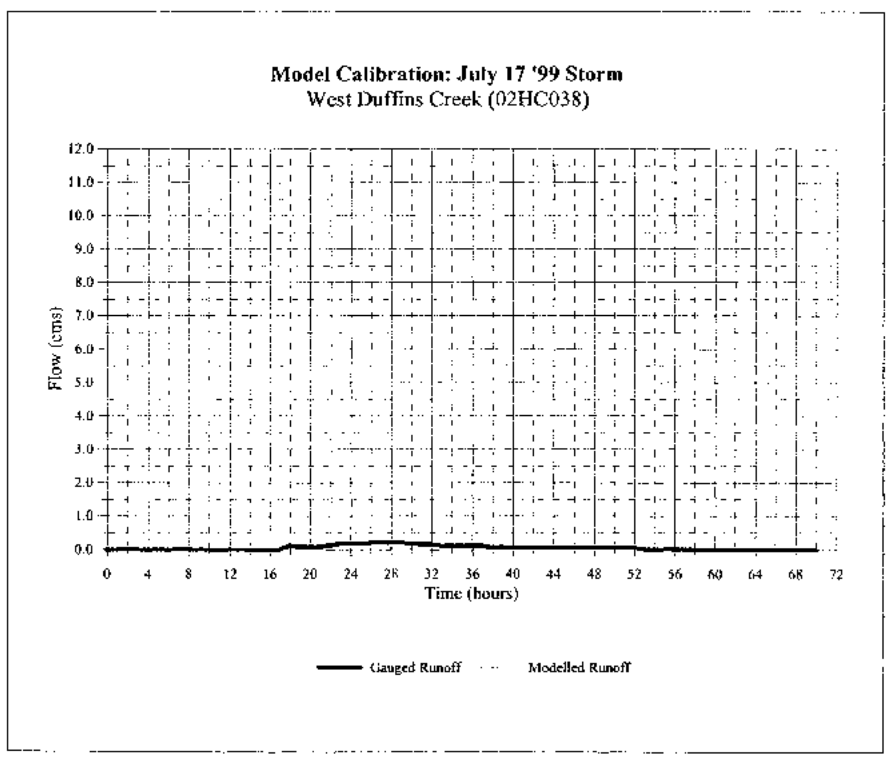
Duffins Creek Calibration - API
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
CN adjustment
0
5
10
15
20
25
API (mm)
Reesor Creek (WSC02HC039)
E.Duffins Creek (WSC02HC019)
Duffins at Ajax (WSC02HC049)
Brougham Creek (gauge 36)
Urfe Creek (gauge 37)
W.Duffins Creek (WSC02HC038)
Log. (Duffins at Ajax (WSC02HC049))
Log. (Brougham Creek (gauge 36))
Log. (Urfe Creek (gauge 37))
Log. (Reesor Creek (WSC02HC039))
Log. (E.Duffins Creek (WSC02HC019))
Log. (W.Duffins Creek (WSC02HC038))

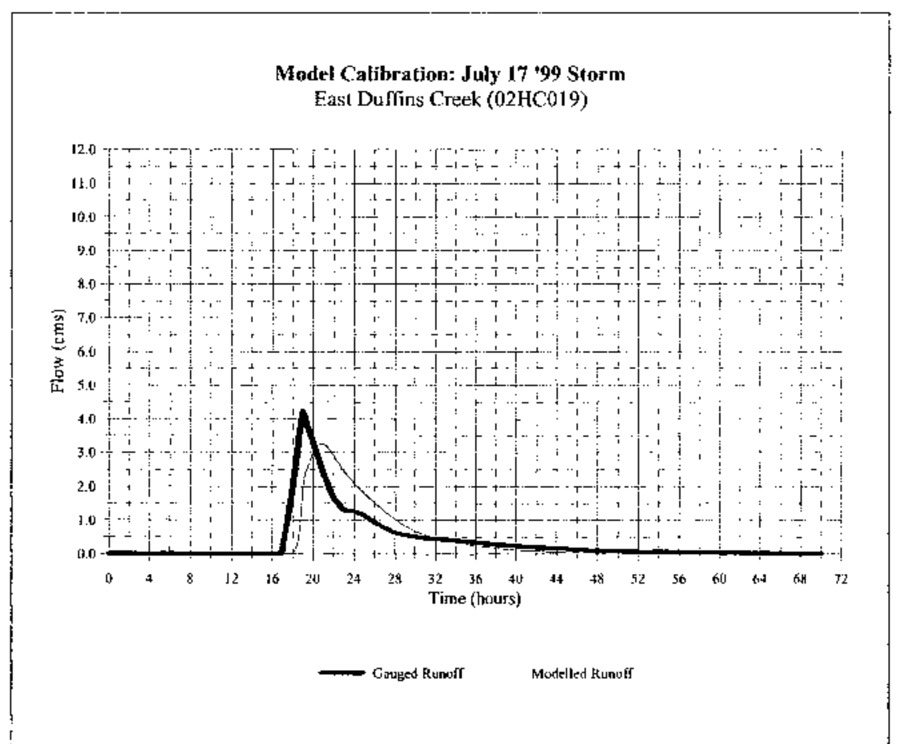


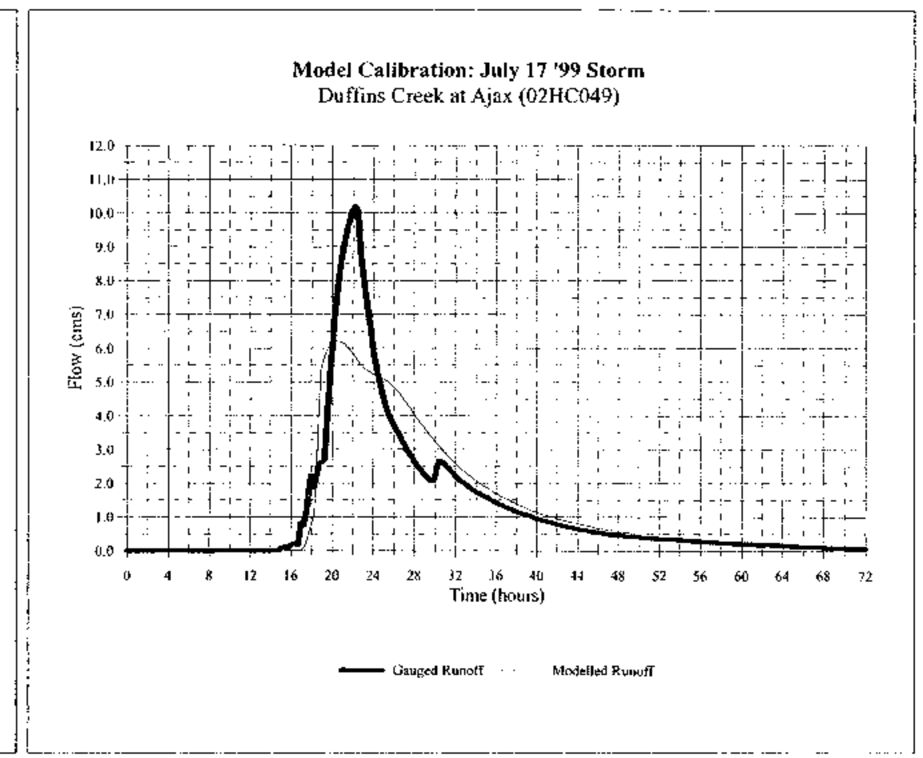


Calibration: July 17'99 Storm
Urfe Creek (gauge 37)

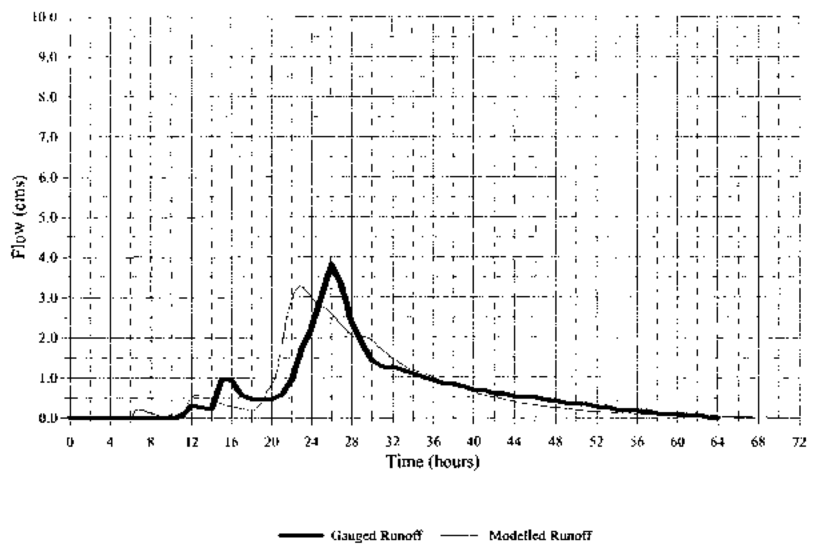
**Note: Gauge data is suspect.
Calibration not possible**



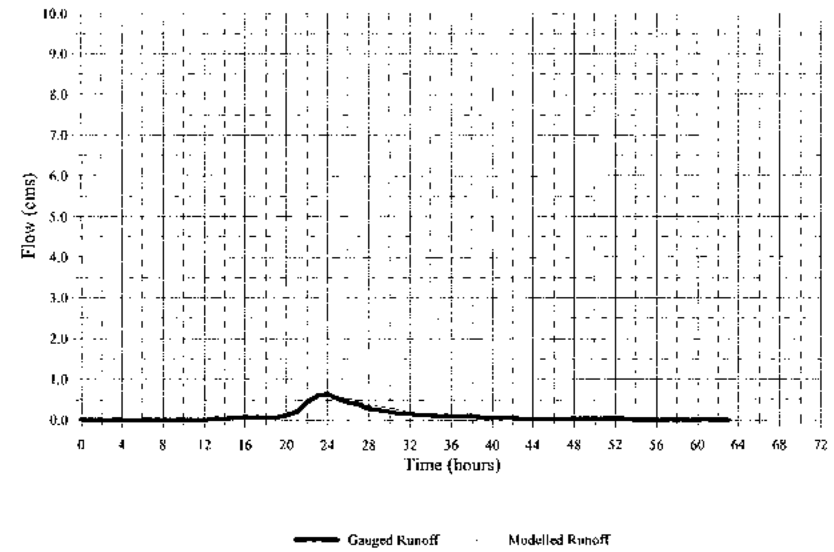




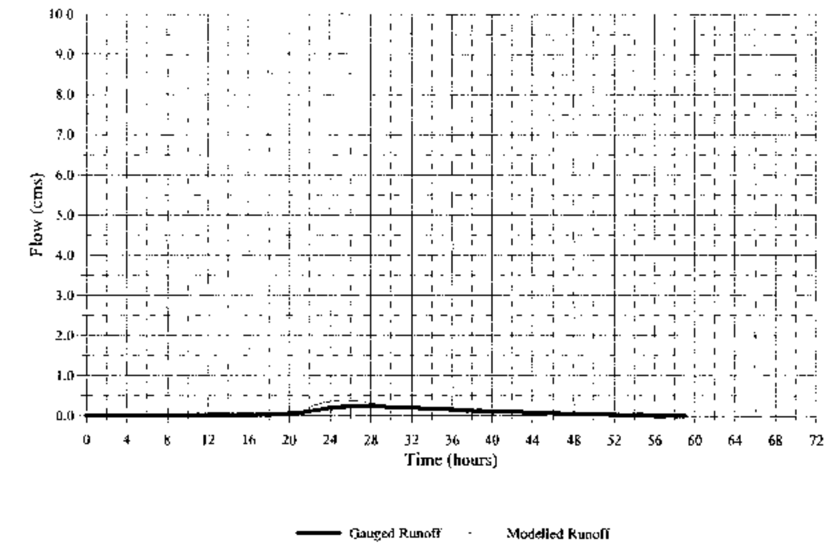
Model Calibration: Sept 29 '99 Storm
Reesor Creek (02HC039)



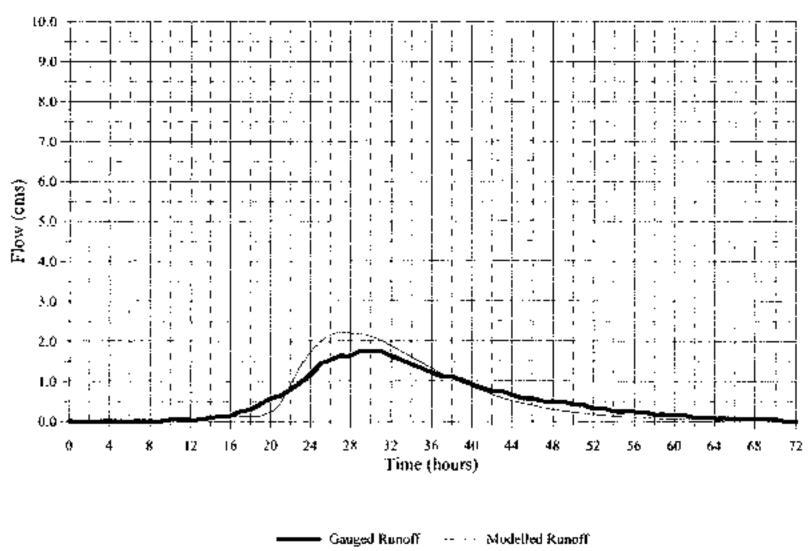
Model Calibration: Sept 29 '99 Storm
Brougham Creek (gauge #36)



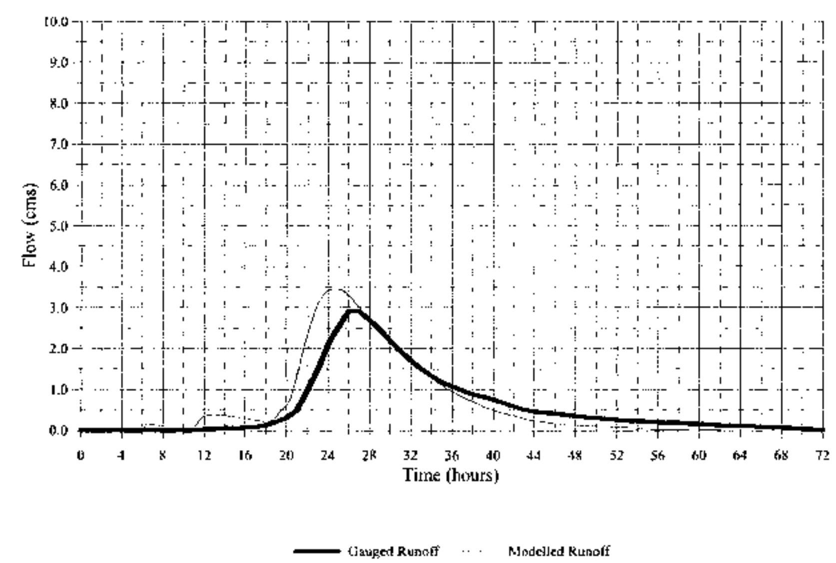
Model Calibration: Sept 29 '99 Storm
Urfe Creek (gauge #37)



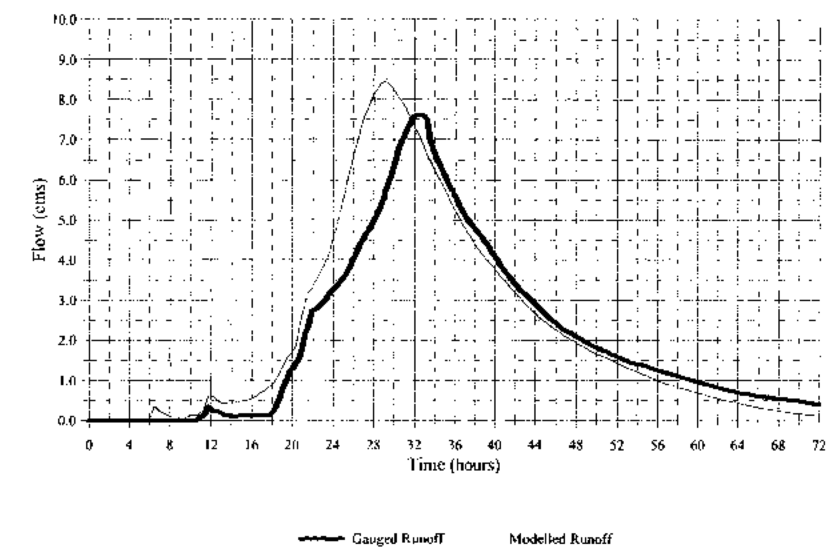
Model Calibration: Sept 29 '99 Storm
W.Duffins Creek @Green River (02HC038)



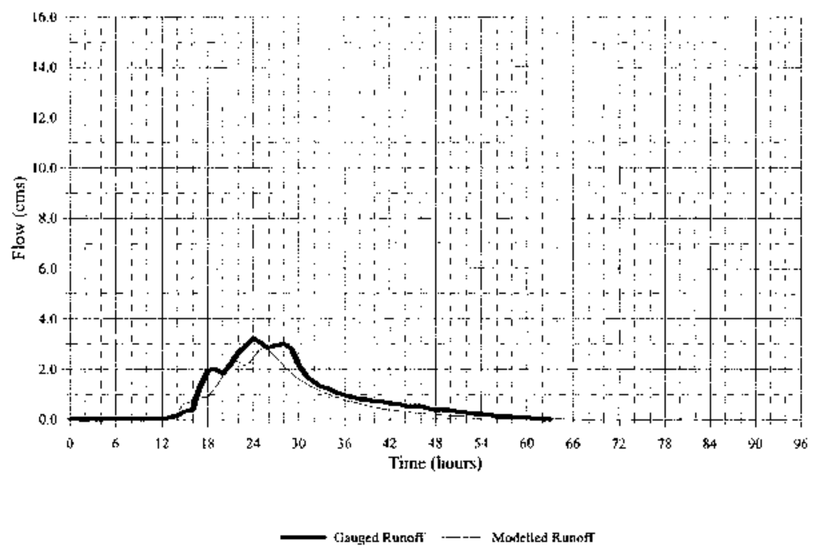
Model Calibration: Sept 29 '99 Storm
East Duffins Creek (02HC019)



Model Calibration: Sept 29 '99 Storm
Duffins Creek at Ajax (02HC049)



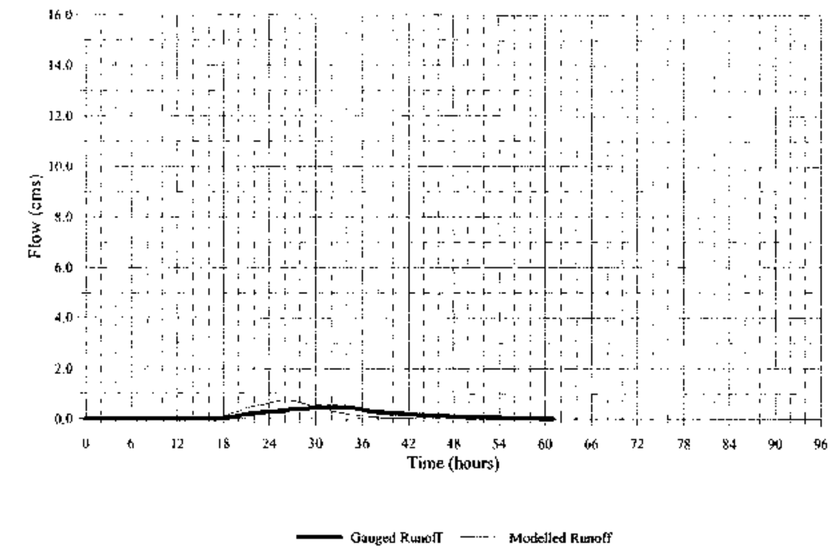
Model Calibration: Oct 13 '99 Storm
Reesor Creek (02HC039)



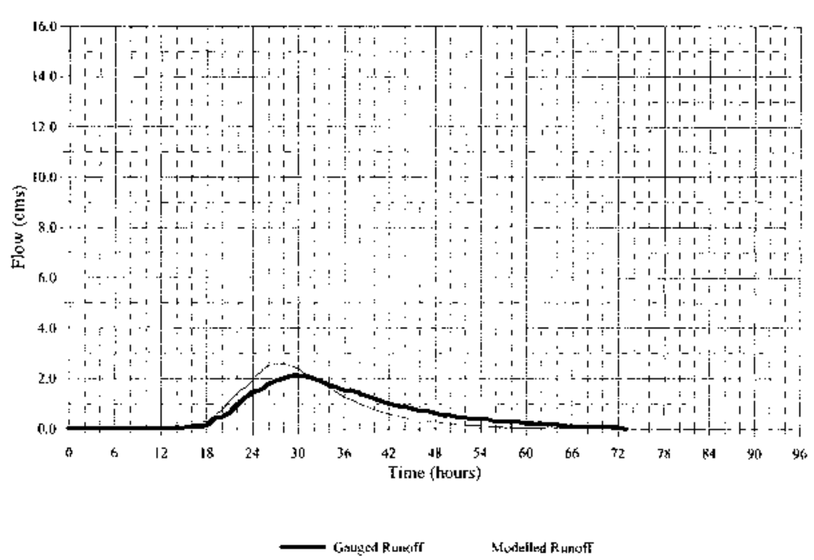
Calibration: October 13'99 Storm
Brougham Creek (gauge 36)

Note: Gauge data is suspect.
Calibration not possible

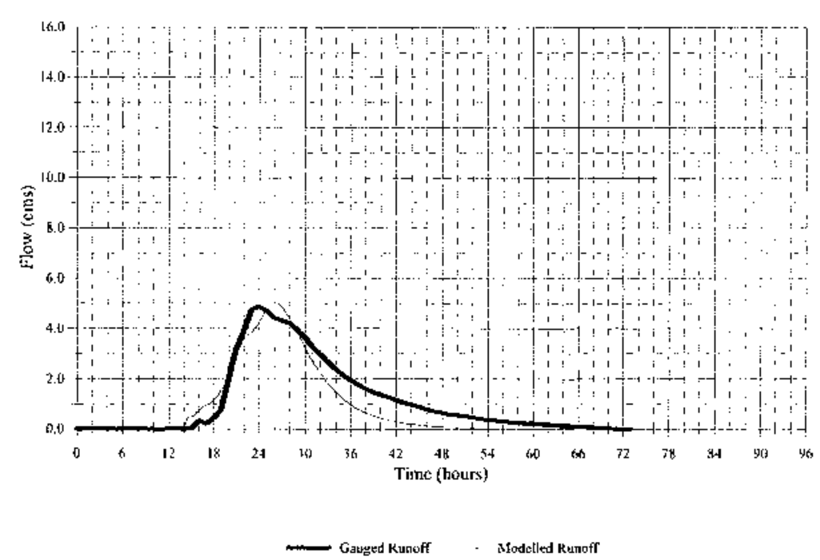
Model Calibration: Oct 13 '99 Storm
Urfe Creek (gauge 37)



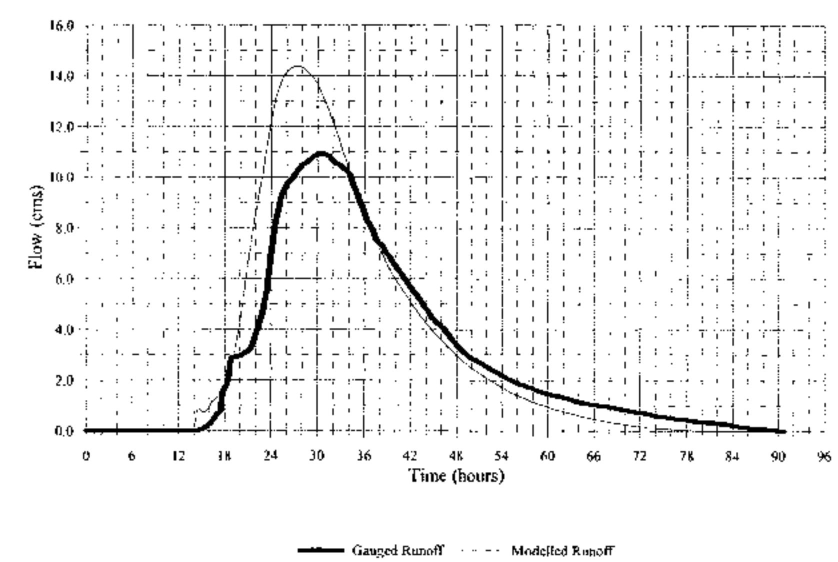
Model Calibration: Oct 13 '99 Storm
West Duffins Creek (02HC038)

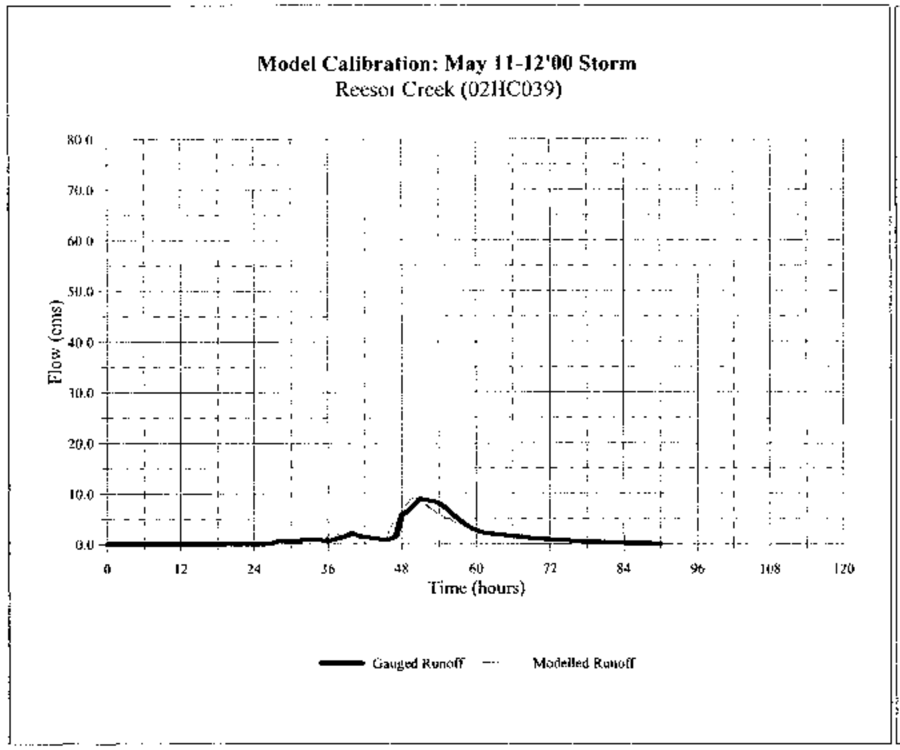


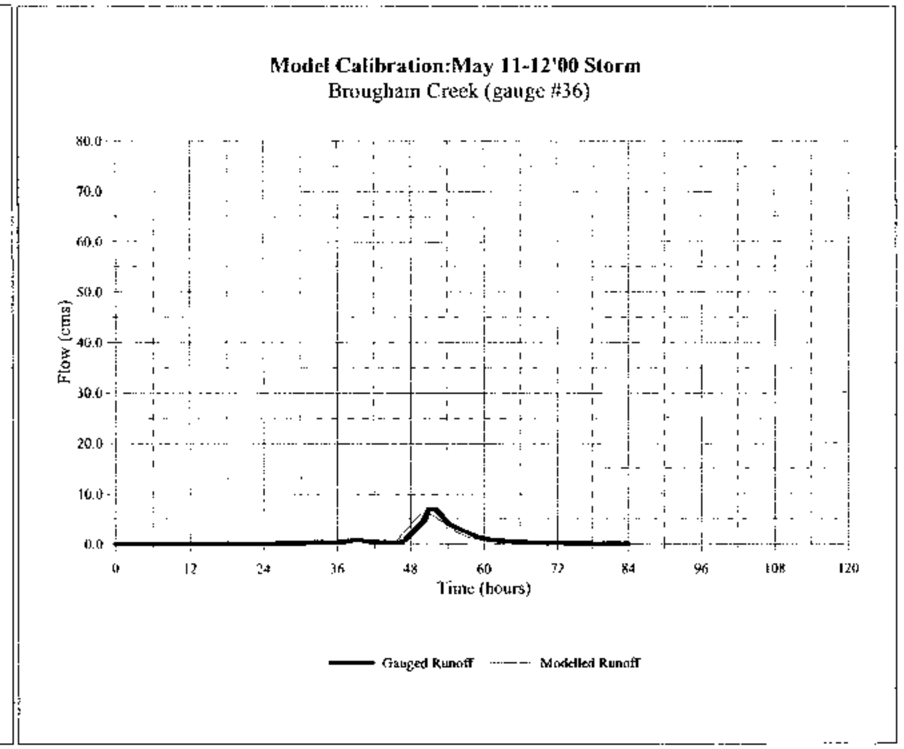
Model Calibration: Oct 13 '99 Storm
East Duffins Creek (02HC019)

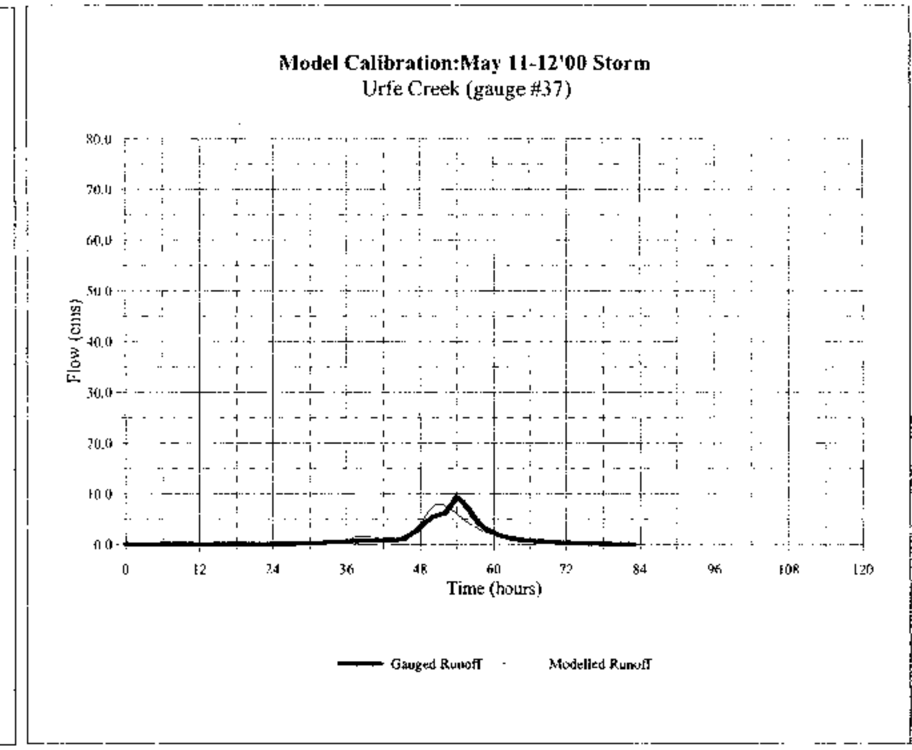


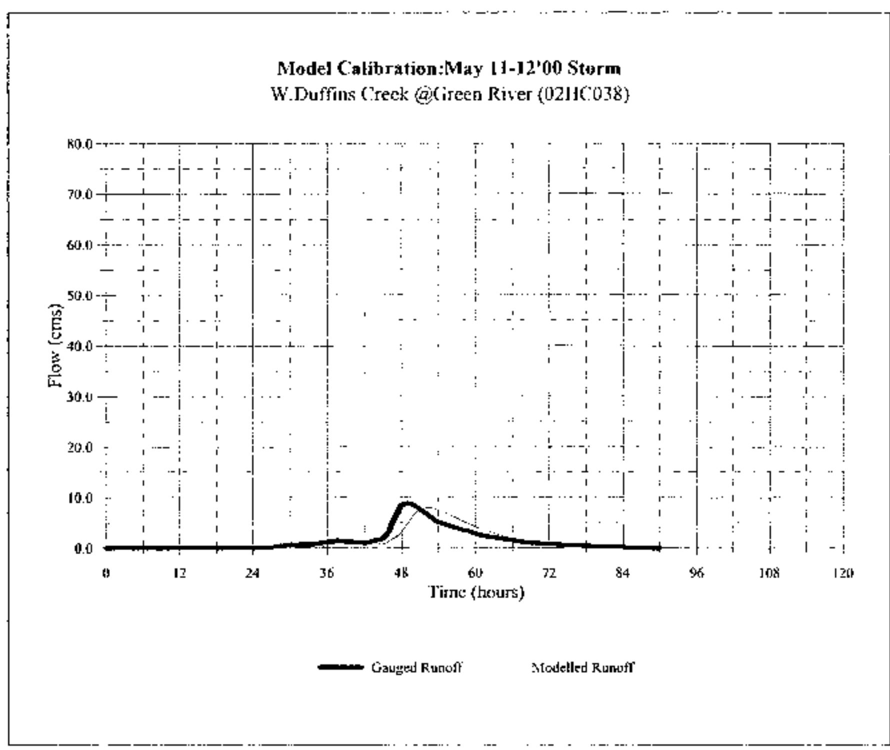
Model Calibration: Oct 13 '99 Storm
Duffins Creek at Ajax (02HC049)

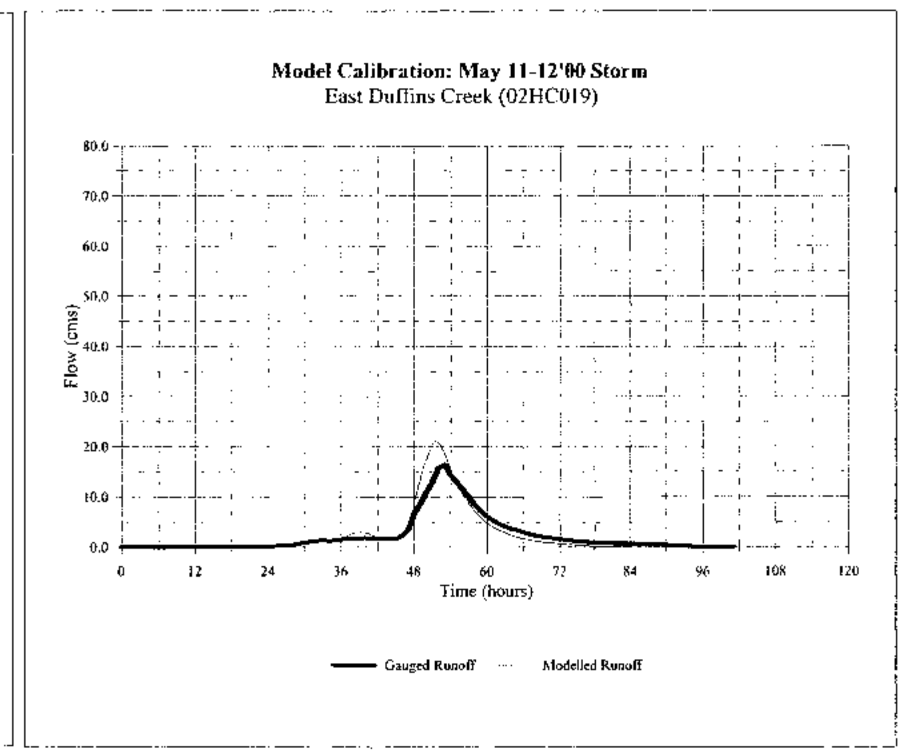


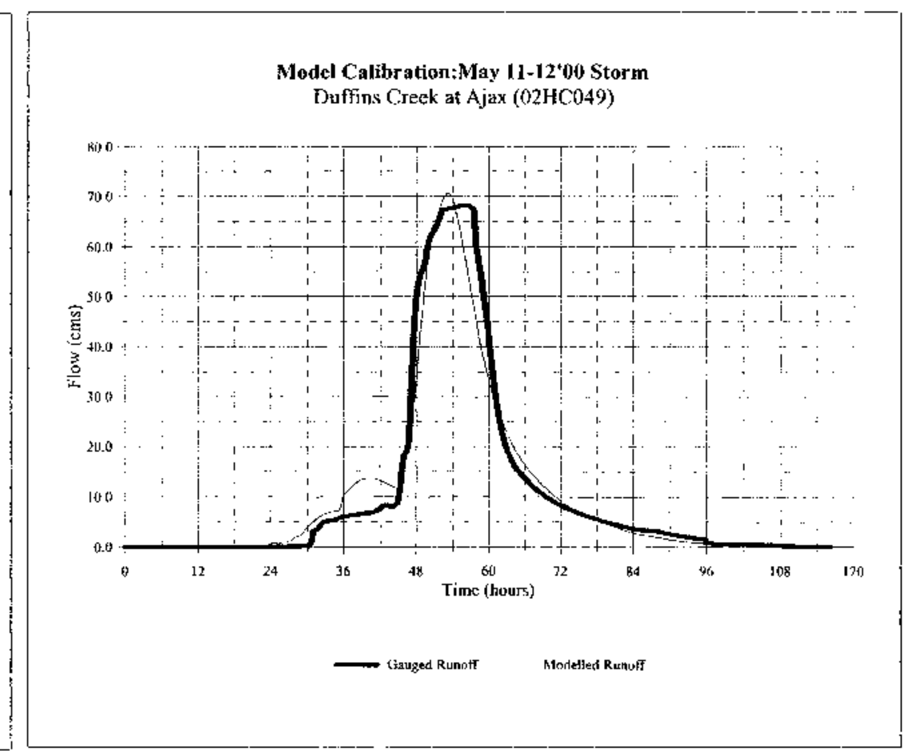

Model Calibration: May 11-12'00 Storm
Reesor Creek (02HC039)
Flow (cms)
Time (hours)
Gauged Runoff
Modelled Runoff

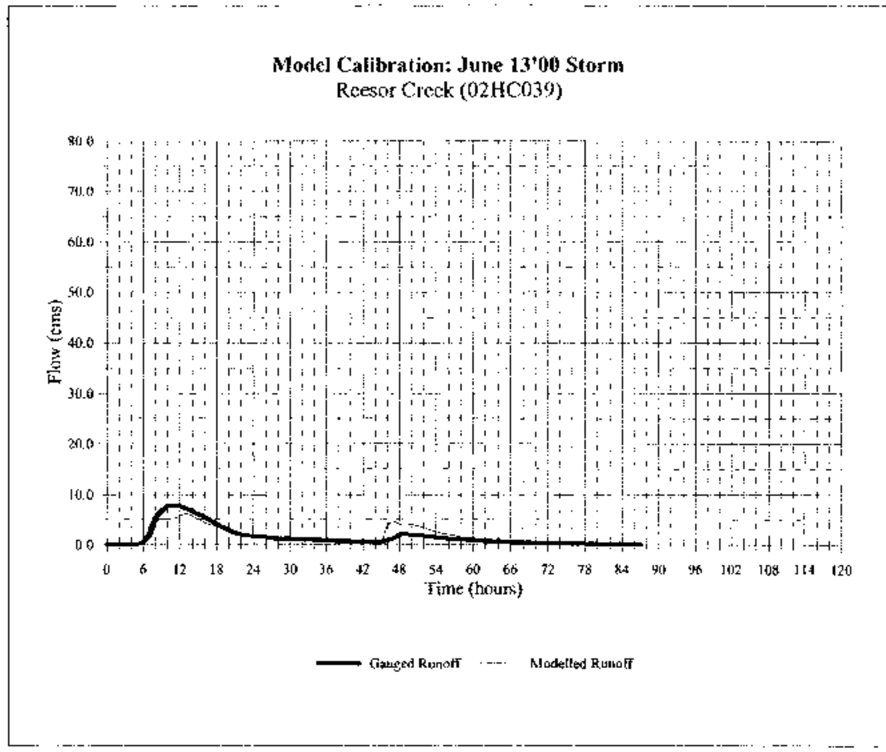

Model Calibration:May 11-12'00 Storm
Brougham Creek (gauge #36)
Flow (cms)
Time (hours)
Gauged Runoff
Modelled Runoff

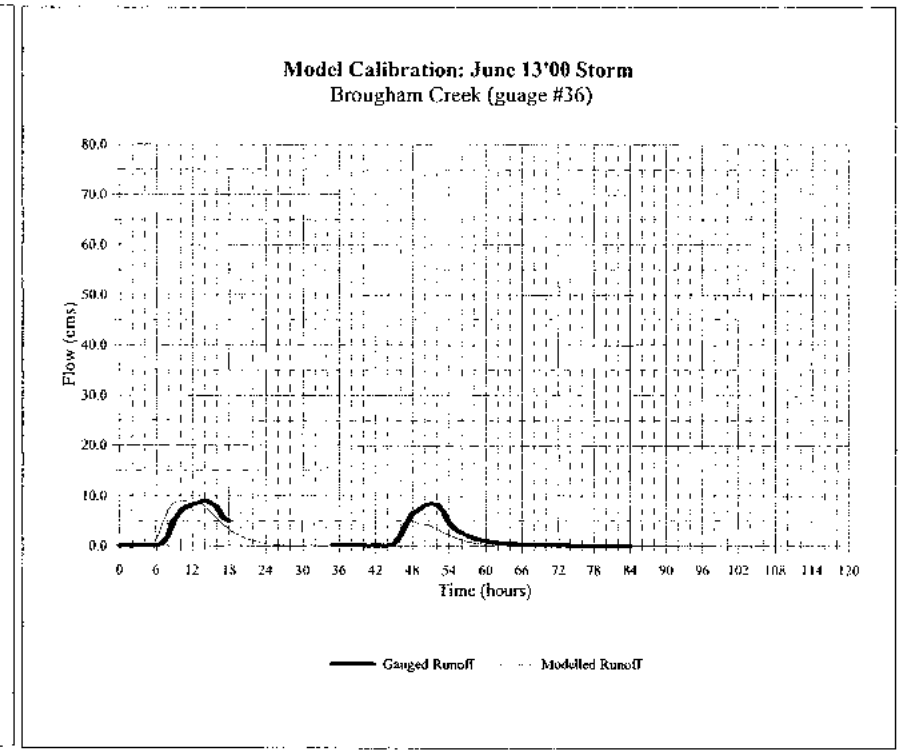

Model Calibration:May 11-12'00 Storm
Urfe Creek (gauge #37)
Flow (cms)
Time (hours)
Gauged Runoff
Modelled Runoff

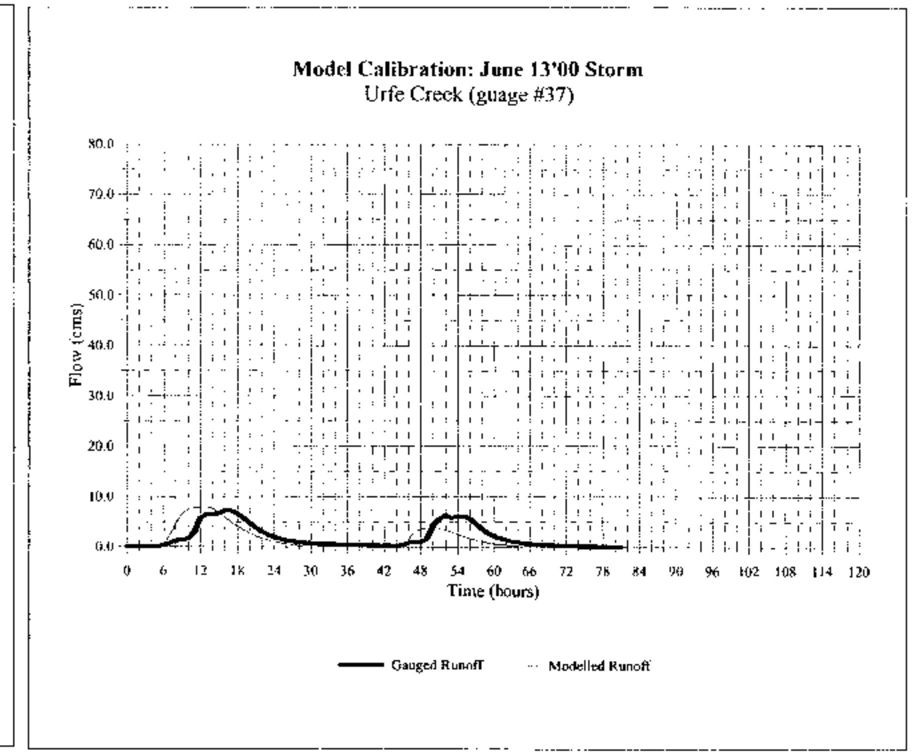

Model Calibration:May 11-12'00 Storm
W.Duffins Creek @Green River (02HC038)
Flow (cms)
Time (hours)
Gauged Runoff
Modelled Runoff

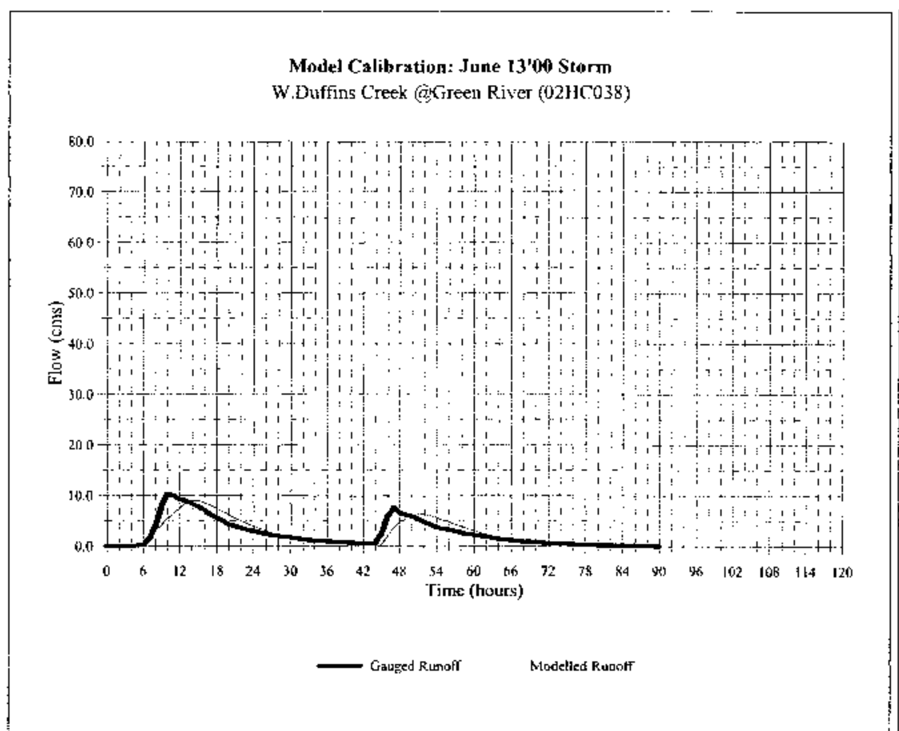

Model Calibration: May 11-12'00 Storm
East Duffins Creek (02HC019)
Flow (cms)
Time (hours)
Gauged Runoff
Modelled Runoff

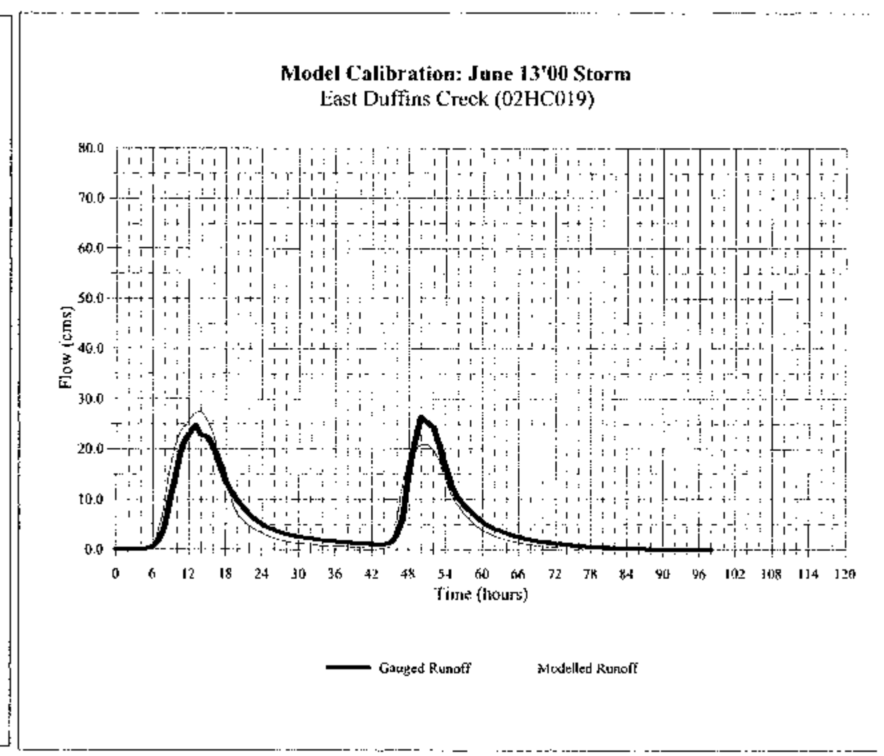

Model Calibration:May 11-12'00 Storm
Duffins Creek at Ajax (02HC049)
Flow (cms)
Time (hours)
Gauged Runoff
Modelled Runoff

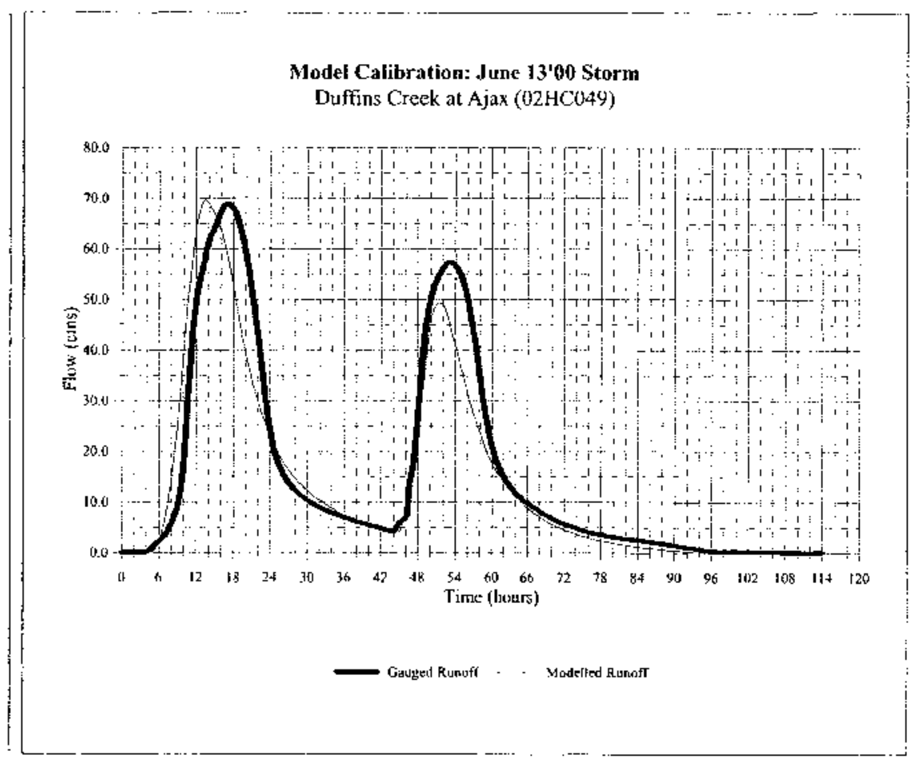

Model Calibration: June 13'00 Storm
Reesor Creek (02HC039)
Flow (cms)
Time (hours)
Gauged Runoff
Modelled Runoff

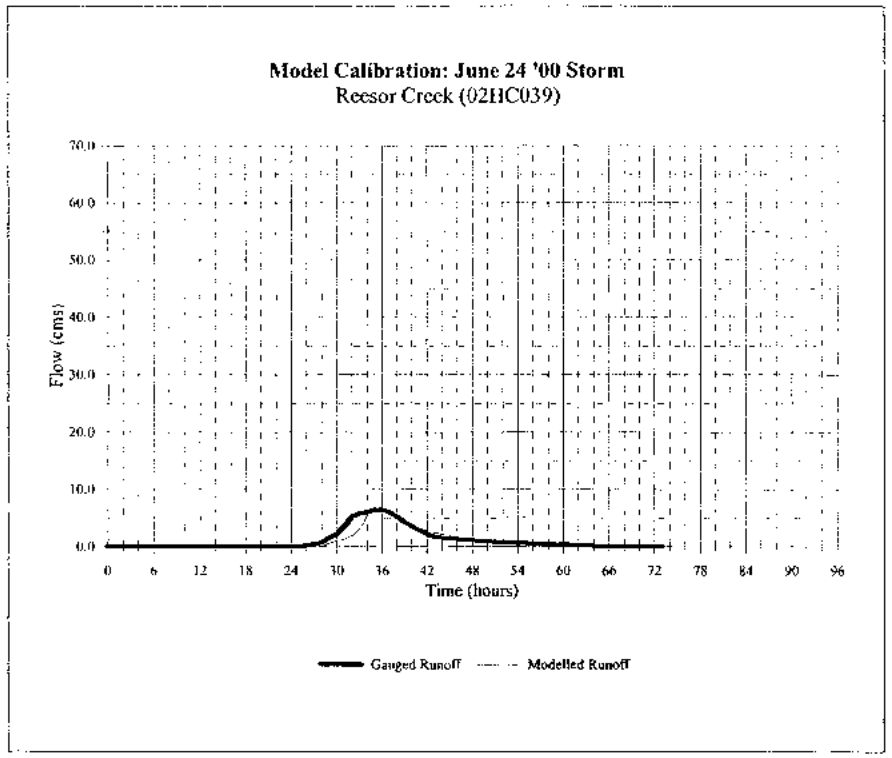

Model Calibration: June 13'00 Storm
Brougham Creek (guage #36)
Flow (cms)
Time (hours)
Gauged Runoff
Modelled Runoff

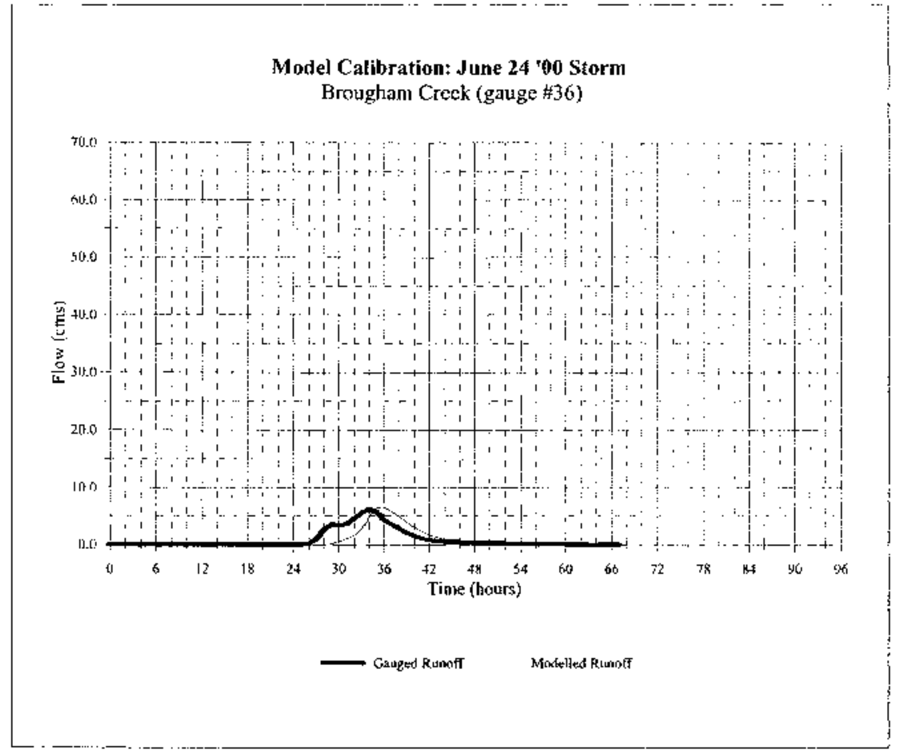

Model Calibration: June 13'00 Storm
Urfe Creek (guage #37)
Flow (cms)
Time (hours)
Gauged Runoff
Modelled Runoff

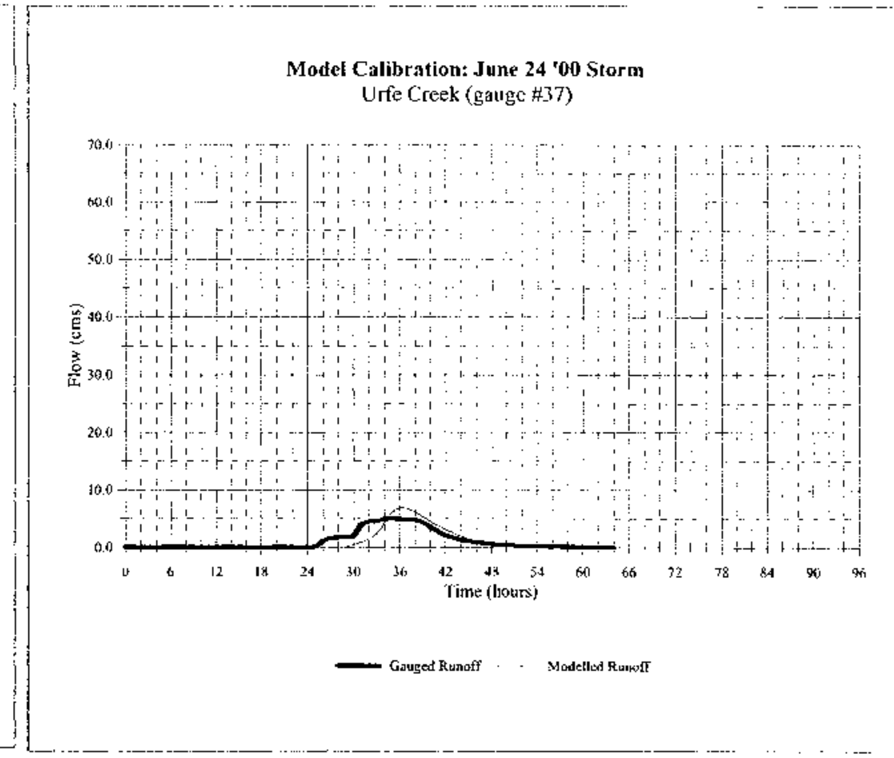

Model Calibration: June 13'00 Storm
W.Duffins Creek @Green River (02HC038)
Flow (cms)
Time (hours)
Gauged Runoff
Modelled Runoff

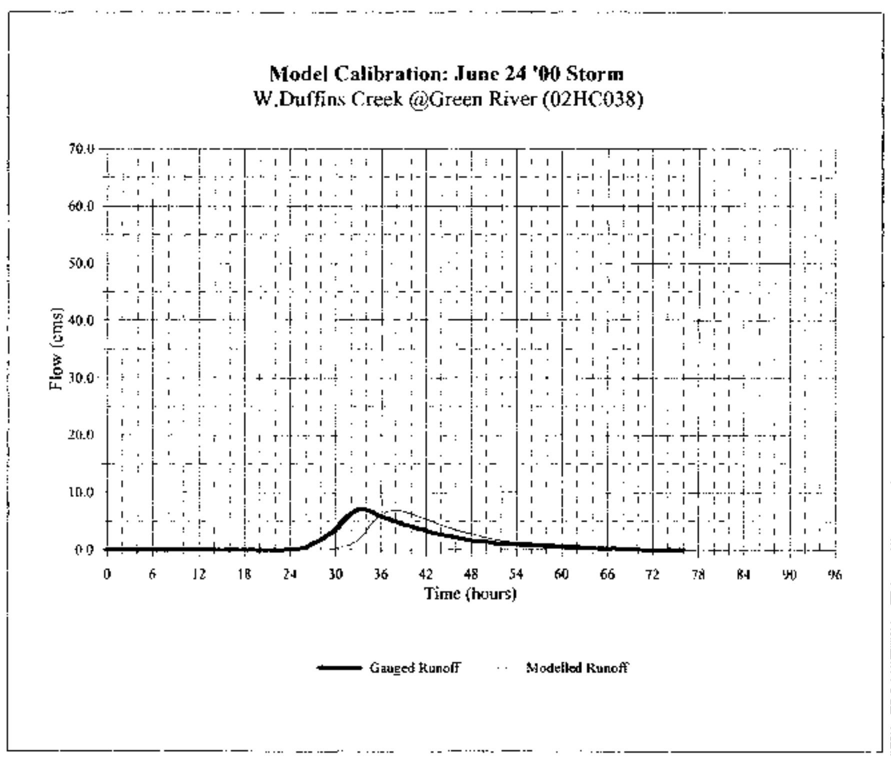

Model Calibration: June 13'00 Storm
East Duffins Creek (02HC019)
Flow (cms)
Time (hours)
Gauged Runoff
Modelled Runoff

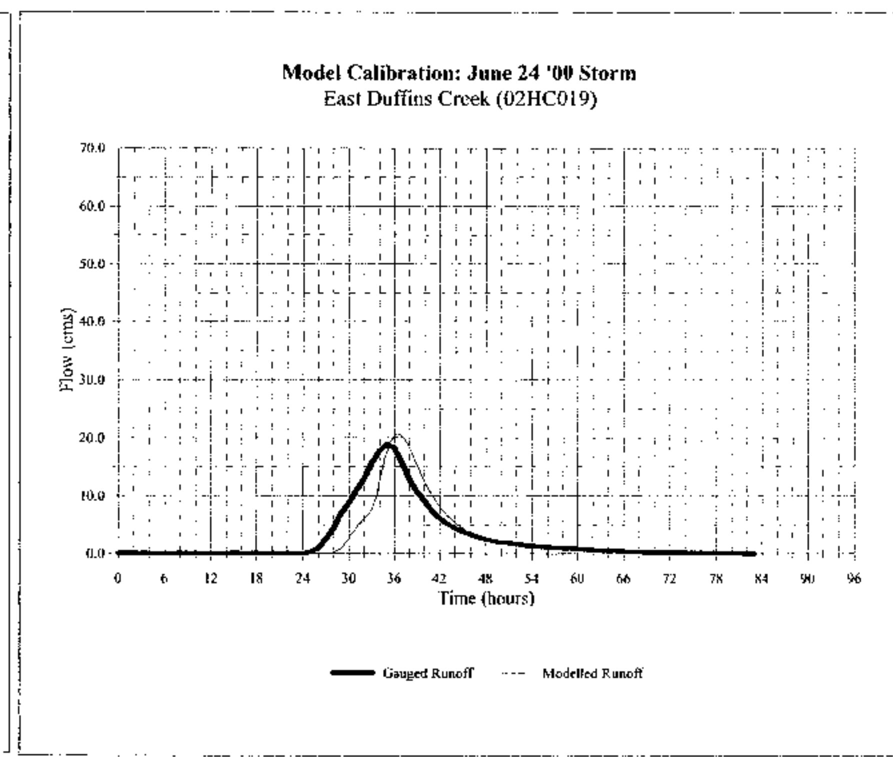

Model Calibration: June 13'00 Storm
Duffins Creek at Ajax (02HC049)
Flow (cms)
Time (hours)
Gauged Runoff
Modelled Runoff

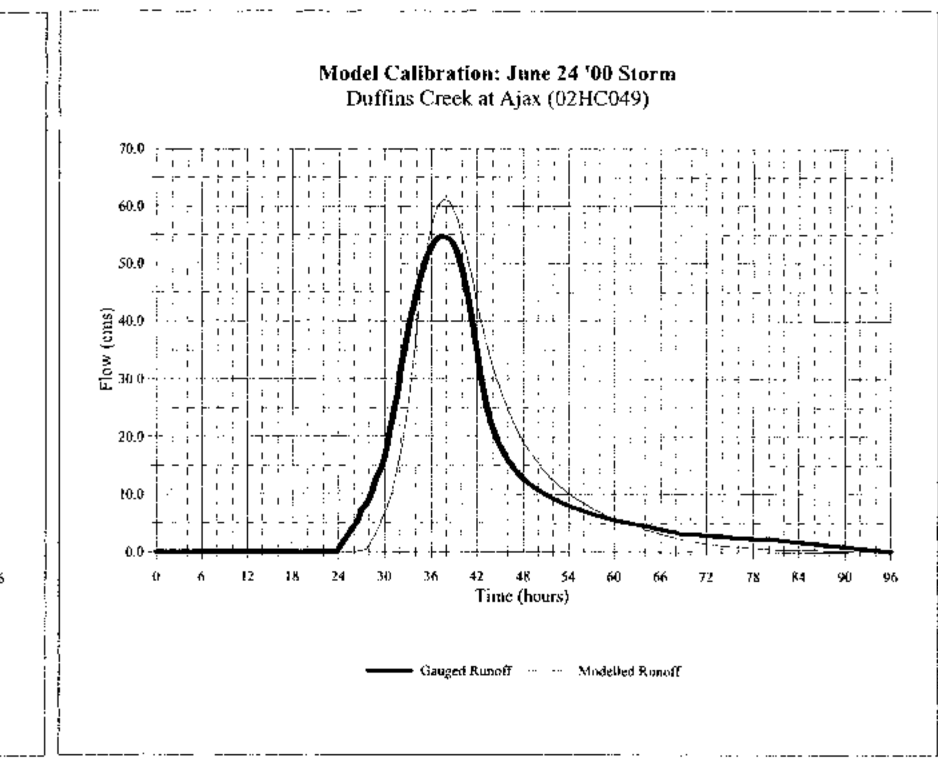

Model Calibration: June 24 '00 Storm
Reesor Creek (02HC039)
Flow (cms)
Time (hours)
Gauged Runoff
Modelled Runoff


Model Calibration: June 24 '00 Storm
Brougham Creek (gauge #36)
Flow (cms)
Time (hours)
Gauged Runoff
Modelled Runoff


Model Calibration: June 24 '00 Storm
Urfe Creek (gauge #37)
Flow (cms)
Time (hours)
Gauged Runoff
Modelled Runoff


Model Calibration: June 24 '00 Storm
W.Duffins Creek @Green River (02HC038)
Flow (cms)
Time (hours)
Gauged Runoff
Modelled Runoff


Model Calibration: June 24 '00 Storm
East Duffins Creek (02HC019)
Flow (cms)
Time (hours)
Gauged Runoff
Modelled Runoff


Model Calibration: June 24 '00 Storm
Duffins Creek at Ajax (02HC049)
Flow (cms)
Time (hours)
Gauged Runoff
Modelled Runoff

APPENDIX D:
Design Storm Hyetographs

```
2
2-YEAR DESIGN STORM: TORONTO BLOOR ST.
15.0
48
00.4
00.4
00.4
00.4
00.4
00.4
00.4
00.4
02.6
02.6
02.6
02.6
07.4
07.4
07.4
07.4
20.0
20.0
20.0
20.0
05.6
05.6
05.6
05.6
03.0
03.0
03.0
03.0
01.7
01.7
01.7
01.7
00.9
00.9
00.9
00.9
00.4
00.4
00.4
00.4
00.4
00.4
00.4
00.4
00.4
00.4
00.4
00.4
-1
```

```
2
5-YEAR DESIGN STORM: TORONTO BLOOR ST.
15.0
48
00.6
00.6
00.6
00.6
00.6
00.6
00.6
00.6
03.3
03.3
03.3
03.3
09.4
09.4
09.4
09.4
25.4
25.4
25.4
25.4
07.2
07.2
07.2
07.2
03.9
03.9
03.9
03.9
02.2
02.2
02.2
02.2
01.1
01.1
01.1
01.1
00.6
00.6
00.6
00.6
00.6
00.6
00.6
00.6
00.6
00.6
00.6
00.6
-1
```

```
2
10-YEAR DESIGN STORM: TORONTO BLOOR ST.
15.0
48
00.6
00.6
00.6
00.6
00.6
00.6
00.6
00.6
03.8
03.8
03.8
03.8
10.7
10.7
10.7
10.7
29.0
29.0
29.0
29.0
08.2
08.2
08.2
08.2
04.4
04.4
04.4
04.4
02.5
02.5
02.5
02.5
01.3
01.3
01.3
01.3
00.6
00.6
00.6
00.6
00.6
00.6
00.6
00.6
00.6
00.6
00.6
00.6
-1
```

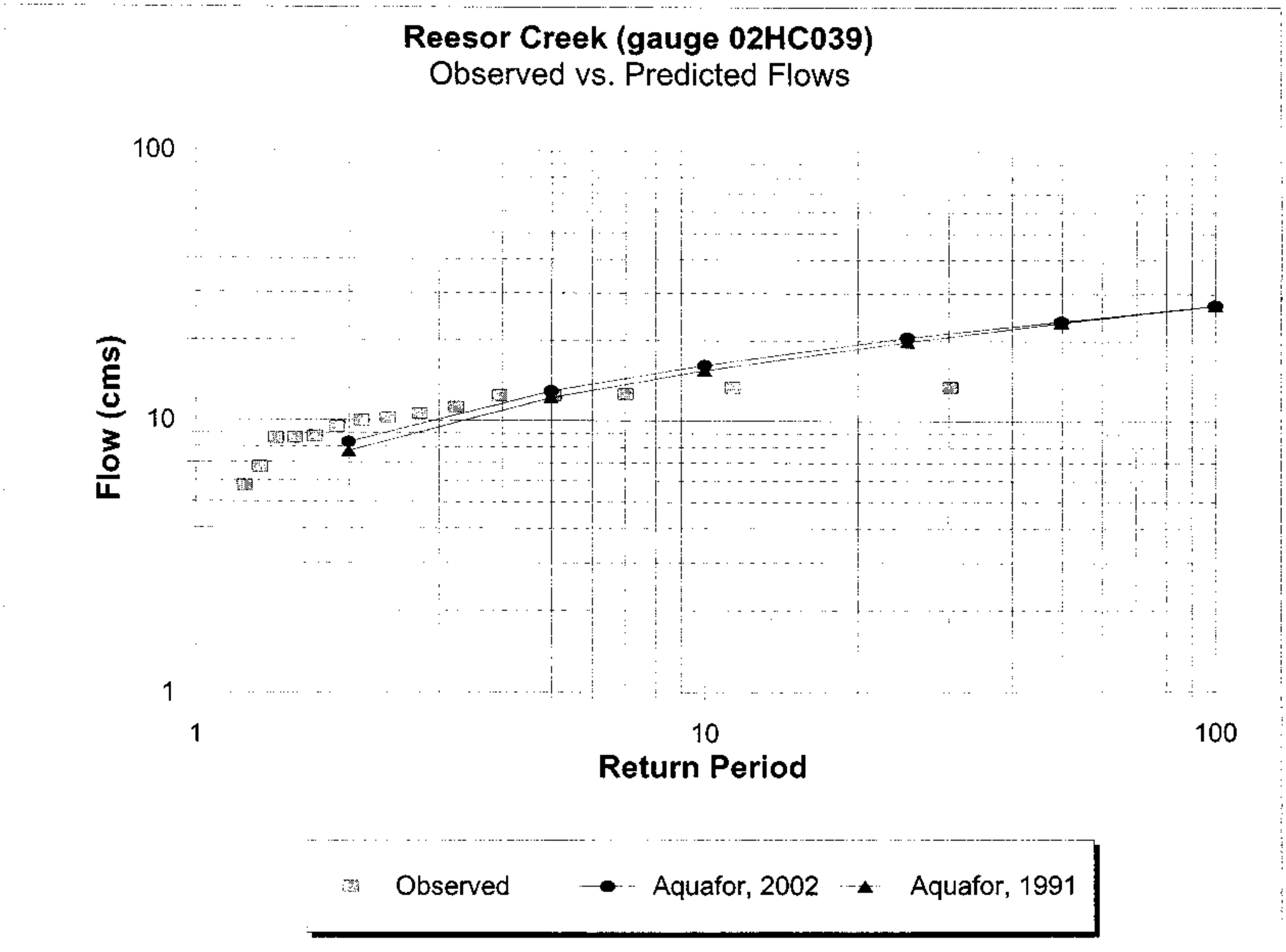
```
2
25-YEAR DESIGN STORM: TORONTO BLOOR ST.
15.0
48
00.7
00.7
00.7
00.7
00.7
00.7
00.7
00.7
04.4
04.4
04.4
04.4
12.4
12.4
12.4
12.4
33.5
33.5
33.5
33.5
09.5
09.5
09.5
09.5
05.1
05.1
05.1
05.1
02.9
02.9
02.9
02.9
01.5
01.5
01.5
01.5
00.7
00.7
00.7
00.7
00.7
00.7
00.7
00.7
00.7
00.7
00.7
00.7
-1
```

2
50-YEAR DESIGN STORM: TORONTO BLOOR ST.
15.0
48
00.8
00.8
00.8
00.8
00.8
00.8
00.8
00.8
04.8
04.8
04.8
04.8
13.6
13.6
13.6
13.6
36.9
36.9
36.9
36.9
10.4
10.4
10.4
10.4
05.6
05.6
05.6
05.6
03.2
03.2
03.2
03.2
01.6
01.6
01.6
01.6
00.8
00.8
00.8
00.8
00.8
00.8
00.8
00.8
00.8
00.8
00.8
00.8
-1

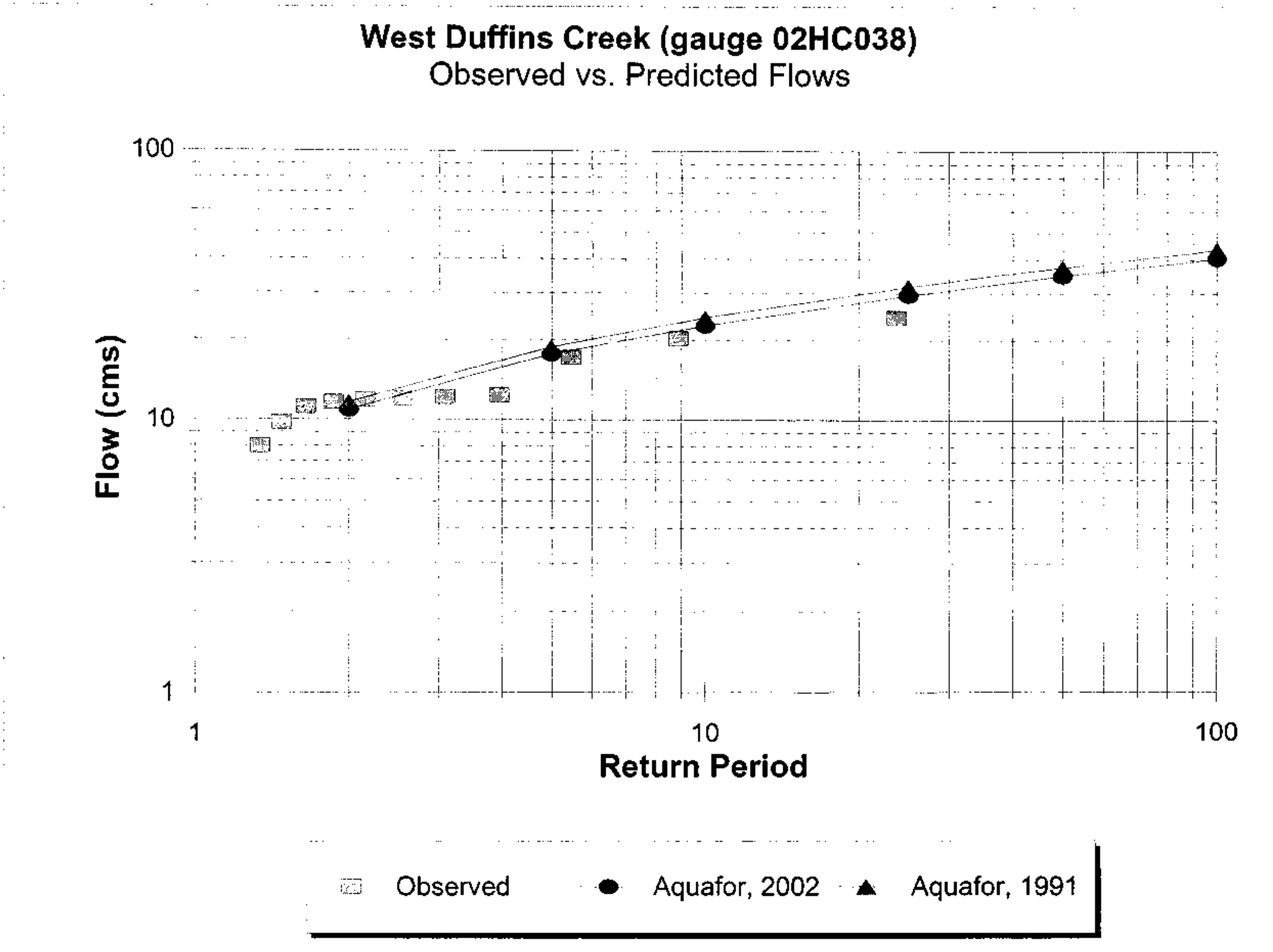
```
2
100-YEAR DESIGN STORM: TORONTO BLOOR ST.
15.0
48
00.9
00.9
00.9
00.9
00.9
00.9
00.9
00.9
05.2
05.2
05.2
05.2
14.9
14.9
14.9
14.9
40.2
40.2
40.2
40.2
11.4
11.4
11.4
11.4
06.1
06.1
06.1
06.1
03.5
03.5
03.5
03.5
01.7
01.7
01.7
01.7
00.9
00.9
00.9
00.9
00.9
00.9
00.9
00.9
00.9
00.9
00.9
00.9
-1
```

```
2
HURRICANE HAZEL DESIGN STORM:
15.0
48
06.0
06.0
06.0
06.0
04.0
04.0
04.0
04.0
06.0
06.0
06.0
06.0
13.0
13.0
13.0
13.0
17.0
17.0
17.0
17.0
13.0
13.0
13.0
13.0
23.0
23.0
23.0
23.0
13.0
13.0
13.0
13.0
13.0
13.0
13.0
13.0
53.0
53.0
53.0
53.0
38.0
38.0
38.0
38.0
13.0
13.0
13.0
13.0
-1
```

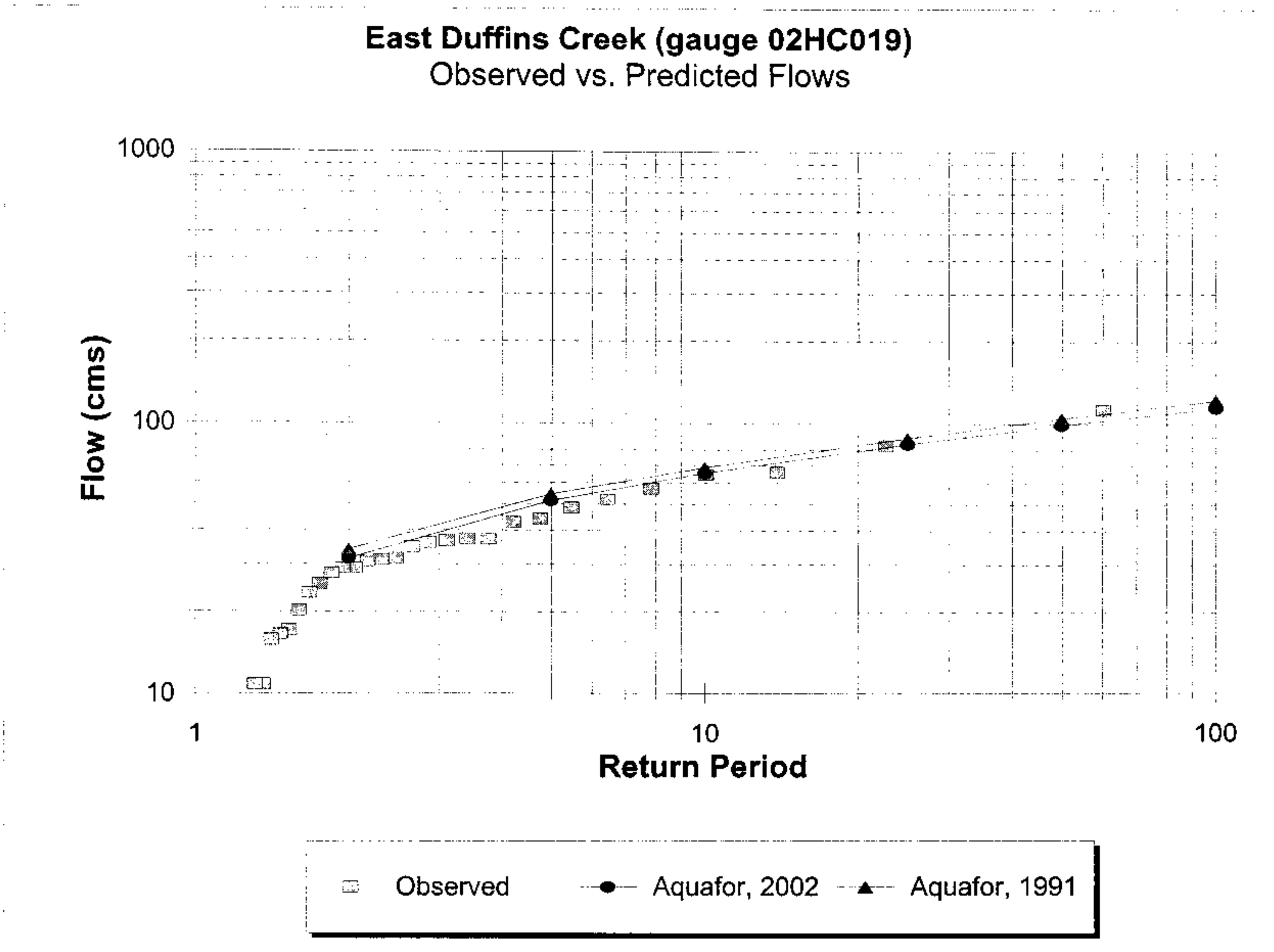
APPENDIX E:
Flood Frequency Curves

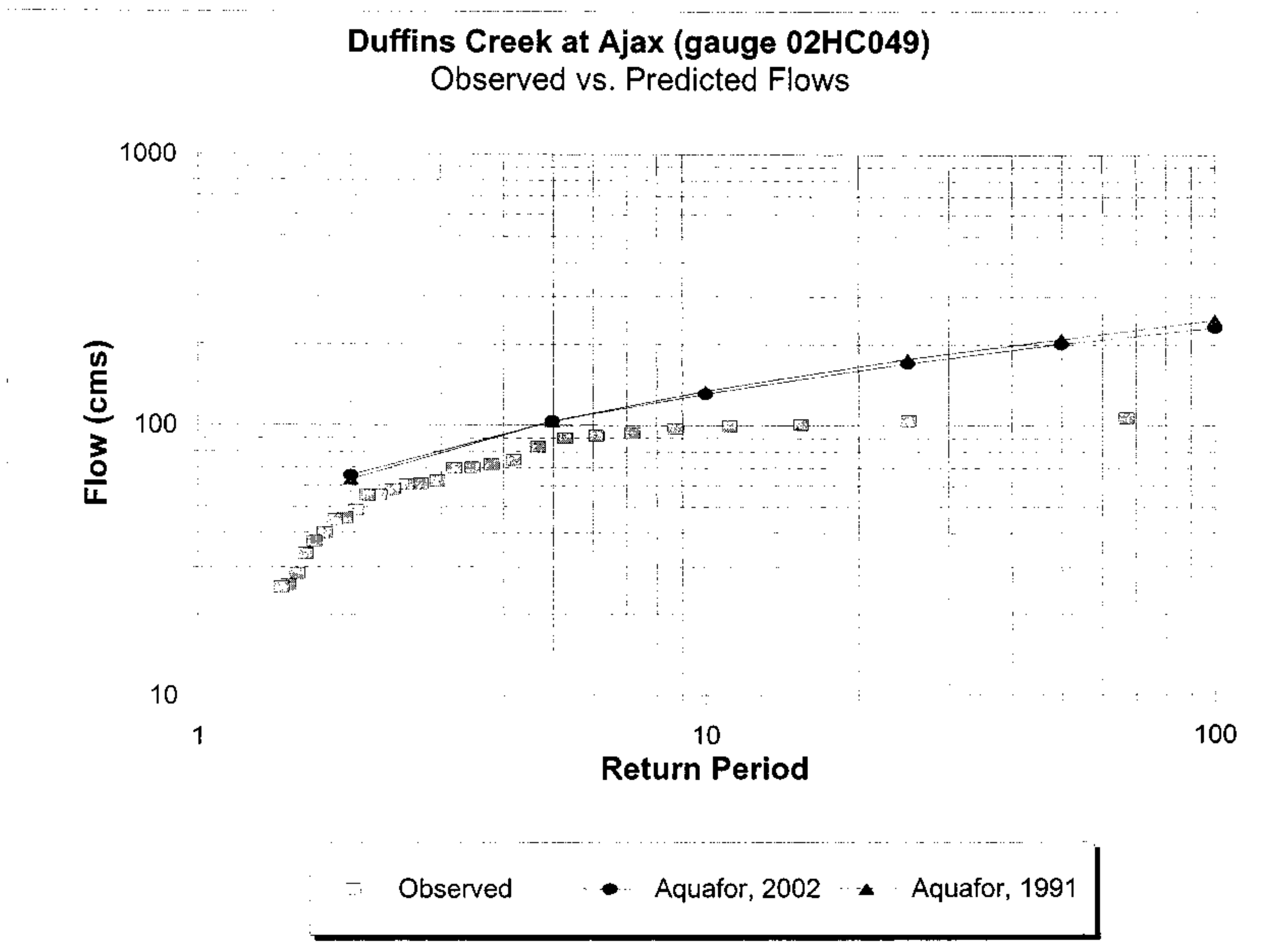


Reesor Creek (gauge 02HC039)
Observed vs. Predicted Flows
100
10
1
Flow (cms)
1
10
100
Return Period
Observed
Aquafor, 2002
Aquafor, 1991



West Duffins Creek (gauge 02HC038)
Observed vs. Predicted Flows
Flow (cms)
100
10
1
1
10
100
Return Period
Observed
Aquafor, 2002
Aquafor, 1991


East Duffins Creek (gauge 02HC019)
Observed vs. Predicted Flows
Flow (cms)
1000
100
10
1
10
100
Return Period
Observed
Aquafor, 2002
Aquafor, 1991



Duffins Creek at Ajax (gauge 02HC049)
Observed vs. Predicted Flows
1000
100
10
Flow (cms)
1
10
100
Return Period
Observed
Aquafor, 2002
Aquafor, 1991

APPENDIX F:
Comparison of 1991 vs. 2002 Models
(TRCA and Aquafor Correspondence)

**Aquafor
Beech
Limited**

12 April 2002

The Toronto and Region Conservation
5 Shoreham Drive
Downsview, Ontario
M3N 1S4

Attention: **Ms. Marilee Gadzovski, P.Eng.**
Watershed Management Coordinator, Resource Science Section

Reference: **Duffins Creek Hydrology Update**

Dear Ms. Gadzovski:

Thank you for your 15 March 2002 e-mail regarding the above-noted study. Further to your review of the model results and comparison to the previous 1991 study, enclosed is additional information and data to provide the clarifications you requested.

In general, the most significant differences between the 1991 and 2002 models include the following:

- subcatchment discretization has been refined, with some significant changes in the headwaters;
- the CN* values are now higher by approximately +10 to +15, on average;
- the Nashyd "n" parameter has been lowered from a range of 2 to 4, to a range of 1.5 to 2;
- the updated model is based on current landuses and therefore includes additional development that has taken place since the 1991 study;
- the updated model uses a higher impervious value in the Standhyd command for some developments that were likely under-estimated in 1991; and
- the updated model also includes existing stormwater management ponds.

Despite the differences listed above, comparison of flood frequency results at the streamflow gauge locations (report Appendix E) indicates very little difference in the return period flow

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estimates from the 1991 model. This is due mainly to the fact that the lower "n" values tend to "counteract" the effects of the higher CN* values. Therefore, the updated model predicts higher runoff volumes, but with a "dampened" runoff response.

It should be noted that the GIS database offered more precise information and a standardized method to derive the 2002 model parameters, than was available in 1991. Therefore, the updated model can be looked at as a refinement or improvement over the 1991 model based on:

- better background information;
- more gauge locations and further calibration;
- better representation of the urban components (percent impervious, stormwater management ponds, etc.).

Further comments are provided below with respect to the significant differences in peak flow estimates which you noted at several Flow Nodes:

<u>**West Duffins Creek - Node 5 (and hence Node 6.1 and 8.1)**</u>
Subsequent to your comments, our telephone conversations have confirmed that the drainage area to this location has indeed increased significantly from the 1991 model (approximately 50%) with the inclusion of subcatchment 15. Therefore, the flow increases noted at these nodes appear reasonable.

<u>**Michell Creek - Nodes 13.0 and 14.1**</u>
A large portion of this drainage area has been revised, and is now smaller than the 1991 model. However, other model parameter revisions have produced an increase in the flow estimates, including higher CN* values (78 vs. 66), lower Tp values, and a new urban component (68 ha at 40% impervious vs. 0 ha). For comparison, peak flow estimates were also generated at these locations using the equations derived as part of the Regional Headwater Hydrology Study (RHHS). The following summary indicates that the results from the 2002 model agree well with the RHHS estimates:

Node 13.0:

Source	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	Regional
1991 model	5.7	9.0	11.2	14.4	16.9	19.6	91.9
2002 model	7.9	12.3	15.3	19.5	22.7	26.1	97.4
RHHS	8.4	13.1	16.8	21.9	28.2	31.8	103.1

Node 14.1:

Source	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	Regional
1991 model	6.7	10.6	13.3	17.2	20.3	23.6	117.7
2002 model	10.5	16.6	20.8	26.8	31.4	35.8	129.5
RHHS	10.2	15.9	20.5	26.5	33.9	38.5	131.1

Millers Creek - Node 27.0

Model parameter revisions have produced an increase in the flow estimates at this location, including higher CN* values (55 vs. 77), and an increase in the overall urban area (522 ha vs. 783 ha). However, the biggest factor behind the increase is a revision to the impervious component of the urban area. The impervious fraction in the 1991 model was set at only 7%. This has been revised in the 2002 model to a more realistic value of 45%.

Reesor Creek - Node 3.0

Model parameter revisions have produced an increase in the flow estimates at this location, including higher CN* values (60 vs. 70), and a new urban component (88 ha at 50% impervious vs. 0 ha). In fact, the flows from this catchment in the 1991 model are roughly the same as the flows from just the rural portion of this catchment in the 2002 model. Therefore, the increase can be attributed mainly to the new urban development within this small headwater catchment.

Brougham Creek - Node 20.0

Model parameter revisions have produced a decrease in the flow estimates at this location, including higher Tp's and, most importantly, lower Nashyd "n" values (4 vs.2). It should also be noted that Brougham Creek streamflow gauge data was available for calibration of the 2002 model, but not the 1991 model. For comparison, peak flow estimates were also generated at this location using the RHHS equations. The following summary indicates that the results from the 2002 model agree reasonably well with the RHHS estimates:

Node 20.0:

Source	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	Regional
1991 model	9.6	15.0	18.8	24.2	28.5	32.9	124.9
2002 model	6.8	10.7	13.3	17.0	19.8	22.8	88.3
RHHS	4.9	7.9	10.4	13.6	16.9	19.9	76.6

Urfe Creek - Node 23.1

Model parameter revisions have produced a decrease in the flow estimates at this location, including higher Tp's and, most importantly, lower Nashyd "n" values (4 vs.2). It should also be noted that Urfe Creek streamflow gauge data was available for calibration of the 2002 model, but not the 1991 model. For comparison, peak flow estimates were also generated at this location using the RHHS equations. The following summary indicates that the results from the 2002 model agree well with the RHHS estimates:

Node 23.1:

Source	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	Regional
1991 model	5.9	9.9	12.5	16.1	19.1	22.2	106.2
2002 model	5.1	8.1	10.2	13.2	15.3	17.5	68.0
RHHS	4.2	7.0	9.1	11.8	14.5	17.3	70.5

Ganatsekiagon Creek - Node 25.2

Model parameter revisions have produced a decrease in the flow estimates at this location, including higher Tp's and, most importantly, lower Nashyd "n" values (4 vs.2). For comparison, peak flow estimates were also generated at this location using the RHHS equations. The following summary indicates that the results from the 2002 model agree well with the RHHS estimates:

Node 25.2:

Source	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	Regional
1991 model	5.6	8.9	11.4	15.0	17.9	21.0	107.5
2002 model	4.4	6.9	8.7	11.1	13.0	14.9	59.4
RHHS	3.8	6.2	8.1	10.6	12.9	15.4	62.8

We trust that the above information addresses your comments and questions regarding the Duffins Creek hydrologic model results. Should you have any further questions regarding the information contained herein, please contact myself at (905) 794-2367, Extension 276.

Sincerely,

AQUAFOR BEECH LIMITED

Greg R. Frew, P.Eng.
Water Resources and Environmental Engineer

GF:gf

AGRICULTURAL NON-POINT SOURCE (AGNPS) MODELLING OF THE DUFFINS AND CARRUTHERS CREEK WATERSHEDS

January, 2003

Prepared by:

Toronto and Region Conservation

Acknowledgments

Assistance with the AGNPS modelling work by Dr. Luis. Leon, University of Waterloo and Gary Bowen, TRCA Duffins and Carruthers Creek Watersheds Specialist, is gratefully acknowledged.

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1.0 INTRODUCTION

The Toronto and Region Conservation Authority (TRCA) and its municipal partners began developing the Duffins and Carruthers Creeks watershed management strategy in the summer of 2000. In support of the strategy, a number of technical studies were undertaken, including a surface water quality study. Each component study assessed watershed condition in response to three alternative land use scenarios, and the results of all studies were integrated to provide sound management direction. The surface water quality study evaluated water quality conditions during dry and wet weather (rainfall). The first part of this study, published separately (Beak, 2002), employed a spreadsheet model to predict annualized parameter concentrations and loads under both wet and dry weather conditions. The wet weather event-based evaluation, which is the subject of this paper, employed an agricultural non-point source water quality model (AGNPS) developed by the US Department of Agriculture.

The rationale for using the AGNPS model was based on several considerations. First, the AGNPS model is a robust model that has been successfully applied in several jurisdictions in the United States, and, to a lesser extent, Canada. Second, the model is compatible with the TRCA's GIS layers and Arcview software platform, thereby reducing the amount of time required to enter and modify input data. Finally, the modelling work builds upon an extensive field monitoring program and a detailed calibration and sensitivity analysis for the Duffins Creek watershed (Leon et al., 2002), which helps to improve confidence in model results.

This report presents the modelling results, an interpretation of the findings, and management strategy recommendations for the two watersheds. Suggestions are provided for future applications of AGNPS to watersheds in the TRCA jurisdiction..

2.0 STUDY AREA

Located in the most easterly portion of the TRCA jurisdiction, the Duffins and Carruthers Creek watersheds differ in size, management issues and scientific study. Carruthers Creek is small (38.4 km^2) relative to other watersheds in the TRCA jurisdiction, and it is also the least studied (TRCA 2002a). Duffins Creek with a drainage area of 283 km^2, is one of the healthiest watersheds along the north shore of Lake Ontario and is one of the most comprehensively studied watersheds for its size in Canada (TRCA 2002b).

For the purposes of this study, the Duffins Creek watershed was divided into subwatershed units, including Reesor-Stouffville Creek, West Duffins Creek, Ganatsekiagon Creek, Urfe Creek, East Duffins Creek and Millers Creek. **Figure 1** shows the Duffins Creek subwatersheds.

At the present time land use in the Duffins and Carruthers watersheds is mainly comprised of non intensive agriculture with growing urban areas in the lower portions of the watersheds (City of Pickering and the Town of Ajax). Agricultural practices in both watersheds have changed over the past 30 years due to modernization of farming practices and in response to expropriation of rural lands by the Federal and Provincial governments in the 1970s for the purpose of building a new International Airport and satellite community (Seaton). Thirty years after the lands were expropriated, the two levels of government finally announced plans for a regional airport and future urban development in North Pickering.

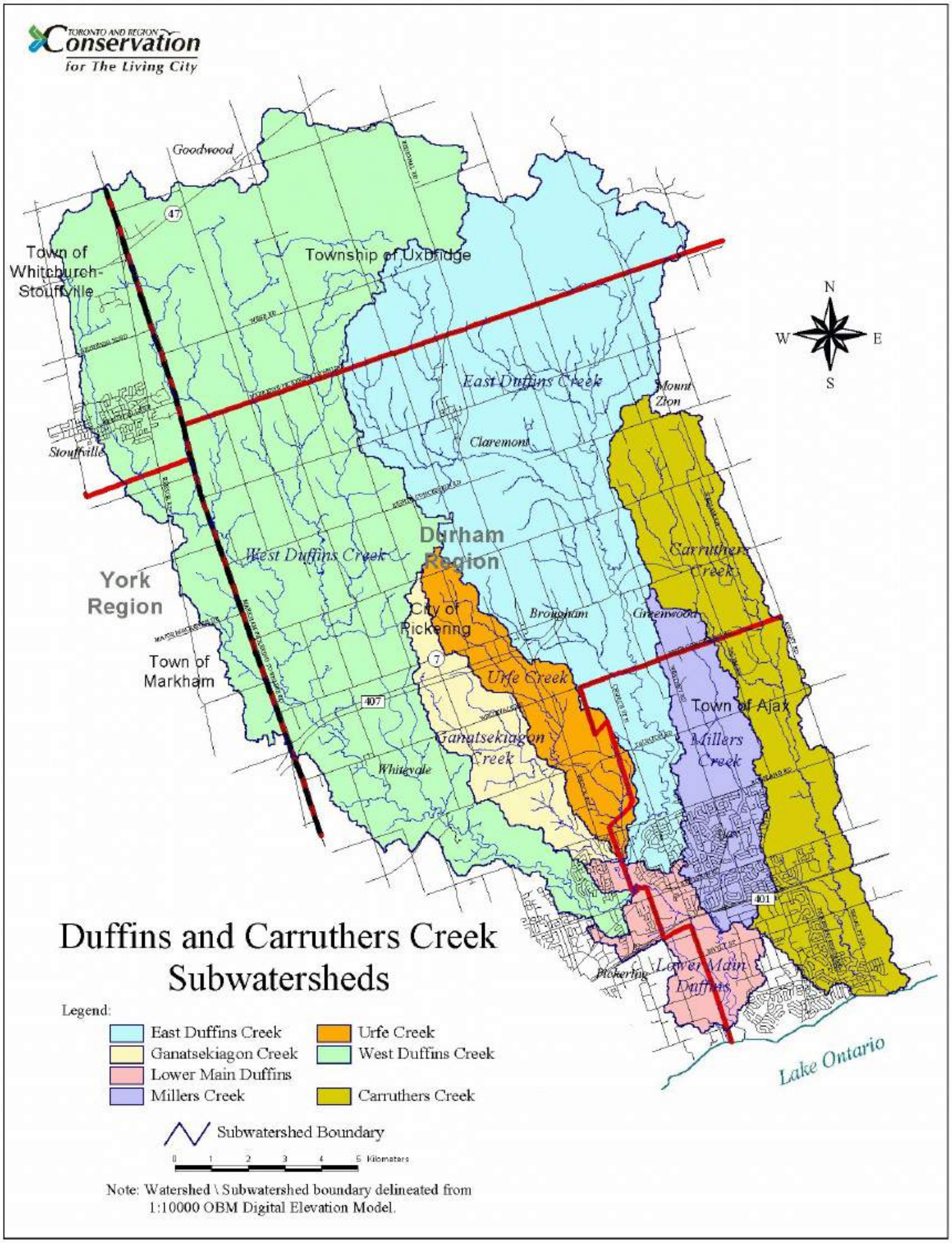

Figure 1: Duffins and Carruthers Creek watersheds and subwatersheds

Current agricultural practices include cash crops, market gardens, sod farms, orchards and dairy or beef operations. Increasing in number in both watersheds are riding stables and horse hobby farms. Federal and provincial land holdings continue to be farmed under short term lease arrangements.

3.0 PURPOSE AND OBJECTIVES

The AGNPS model was used for the following purposes:

1. To predict wet weather water quality conditions in each watershed and subwatershed in response to alternative land use and management scenarios through the evaluation of two parameters: total sediment yield and phosphate concentration.

2. To identify the predominant source areas (i.e. "priority management areas") in the Duffins and Carruthers watersheds that contribute the greatest proportion of the total sediment yield and phosphate concentration generated at the outlet of each study area during rain events by using the Trace Source Contribution analysis tool of the AGNPS model.

3. To evaluate the effectiveness of a non-point source management activity by simulating increased forest cover in the "priority management areas" as identified in the Trace Source Contribution analysis under the existing land use scenario.

4. To evaluate the use of the AGNPS model and provide recommendations for its future role in other TRCA watersheds.

4.0 METHODS

4.1 Alternative Land Use and Management Scenarios

The three scenarios, as commonly defined for analysis by all technical studies in the Duffins and Carruthers Creek watersheds, were as follows:

1. Existing Land Use (based on interpretation of 1999 Aerial photography)
2. Future Official Plan (assumed full build out of approved Regional and Local Official Plans, which projected land use up to 2020).
3. Future Official Plan with enhanced natural heritage cover.

Table 1 shows land cover associated with each scenario. A more detailed description of these three scenarios is provided in the Technical Analysis and Integration Process Summary Report for the Duffins and Carruthers Creek Waterhseds Plan (TRCA, 2003). Maps of land cover scenarios in the two watersheds are provided in **Appendix A**.

Table 1: The total area and percent land cover in the Duffins and Carruthers Creek watersheds and subwatersheds for three alternative land cover scenarios

	Size (ha.)	Existing Conditions (%)			Future Official Plan (%)			Future OP + Natural Heritage (%)		
		Agr.	Nat. Areas	Urban	Agr.	Nat. Areas	Urban	Agr.	Nat. Areas	Urban
West Duffins	13538	64	32	4	60	32	9	44	47	9
East Duffins	9202	51	45	4	49	46	5	31	64	5
Ganatsekiagon	1305	58	40	2	23	33	43	22	34	43
Urfe	1436	54	45	1	31	38	32	30	38	32
Millers	1698	38	25	38	16	23	61	16	23	61
Lower Main	1124	0	55	46	0	39	61	0	39	61
Whole Duffins	28303	55	38	7	48	36	15	34	50	15
Whole Carruthers	3812	48	34	18	33	33	33	27	40	33

A fourth scenario, unique to this study, is called the "Priority Management Areas Revegetation" scenario. This scenario was based on the "Existing" land use scenario, but simulated the effects that increased forest cover would have on pollutant loads, if selectively applied to areas identified as predominant sources of sediment load. Predominant source areas were defined as those grid cells which generate the highest proportion of the total sediment and phosphorus load. Percent forest cover within each cell was increased to a total of 30 to 60% (depending on the size of grid cells) to form the “Priority Management Area Revegetation” scenario. This cover would equate to a forested area of 300 x 500 m across the grid cell and might be achieved through such best management practices as riparian plantings, vegetated buffer strips, or reforestation.

4.2 AGNPS Model Description and Set-up

The AGNPS model (v 2.9) is a distributed water quality model, designed to predict water quality and hydrologic response conditions in agricultural watersheds for the purpose of developing and evaluating best management practices (BMPs). Developed by the U.S. Department of Agriculture, the AGNPS model is an event model, simulating conditions based on a single precipitation event, uniformly distributed across the catchment (Young et. al 1988.). It is considered by practitioners to be a robust, practical model for decision support purposes. (Mostaghimi *et al.*1997 and Leon *et al.* 2002.).

Hydrology outputs in the model are calculated using the Soil Conservation Service (SCS) curve number approach. According to this method, runoff is calculated simply by subtracting the infiltration volume from the amount of precipitation. The AGNPS model simulates soil loss and sediment yield in a two step process. The Universal Soil Loss Equation (USLE) is used to predict soil erosion for five particle sizes (silts, clays, sand, small and large aggregates). Eroded sediments are then transported in the receiving channel using a steady state continuity equation. The pollutant transport part of the model estimates chemical oxygen demand, soluble and sediment bound nitrogen, phosphorous concentrations and loads.

Watersheds modeled with AGNPS are divided into uniform grids. For each grid cell, inputs from GIS mapping of soils, land cover and topography (DEM) are automatically extracted using an interface (v 5.0) developed by Leon (1997). All user defined inputs to the model followed procedures established in the calibration study (Leon *et al.*, 2002), a copy of which is provided in **Appendix B**.

For the purposes of this study, AGNPS model runs for the Duffins watersheds and East and West Branches employed a 1.2 x 1.2 km grid size. For smaller subwatersheds in the Duffins Creek, grid sizes of 900 x 900 m (Ganatsekiagon, Reesor) and 600 x 600 m (Urfe, Millers) were used. The grid size for the Carruthers Creek watershed was 900 x 900 m.

The AGNPS model was developed using a US database of medium to large sized storm events. Following procedures from the Duffins Creek model calibration study (Luis *et al.*, 2002, Appendix A), two representative storm types were selected. The first was 25 mm over 12 hours, the second was 15 mm over 9 hours. Both were type II storms, with a rainfall intensity and distribution typical for this area (Leon *et al.*, 2002), and dry antecedent moisture conditions. In subwatersheds with extensive natural cover (forests, meadows or wetlands) or coarse textured soils, it was necessary to run larger volume rain storms, in order to generate runoff.

Fertilizer application rates and suggested availability factors were based on the results of a survey conducted for the Duffins Creek watershed in 1997 (JDE Ventures, 1998). This survey indicated that nitrogen and phosphorous applications varied with crop and soil types.

4.3 Analysis and Evaluation

To facilitate comparisons with Provincial Water Quality objectives dissolved phosphorus concentrations were converted to total phosphorus using regression relationships developed from long term (approximately 20 to 30 years) provincial water quality monitoring data for the two watersheds. Coefficients of correlation for phosphate and total phosphorus at the three stations monitored ranged from 0.68 to 0.98. Suspended sediment loads were converted from imperial tons to metric tons.

Spatial patterns in the relative predominance of non-point sources of sediment and dissolved phosphorus were evaluated using a trace source contribution (TSC) algorithm in the AGNPS model. The TSC analysis tool was used to calculate the percentage of outlet results that are derived from each grid cell within the watershed, and the results were displayed on maps to facilitate recognition of priority management areas. Assessments were made on a watershed and subwatershed basis.

5.0 FINDINGS AND INTERPRETATION

A summary of the AGNPS modelling results for the various storm events and land use scenarios evaluated in each study area are presented in **Tables 2 and 5.** Accompanying trace source contribution analysis maps for the sediment load and phosphate (soluble phosphorus) concentration are presented in **Appendix C** for each study area.

Table 2. Suspended sediment yield at the outlet cell of each study area under the various land use scenarios and rain events.

Watershed or Subwatershed	Storm Event	Sediment Yield (metric tons) *(Percent change compared to sediment yield under scenario 1 shown in parenthesis)*			
		Scenario1 - Existing	Scenario 2 - Official Plan (OP)	Scenario 3 - OP + Natural Heritage	BMP*
Reesor	15mm 9 hr 25mm 12 hr	22.4 45.8	21.6 (↓4%) 52.4 (↑14%)	5.2 (↓77%) 20.8 (↓55%)	- 28.3 (↓38%)
West	15mm 9hr 25mm 12hr	28.7 64.4	31.3 (↑9%) 72.1 (↑12%)	28.4 (↓1%) 63.4 (↓2%)	- 61.8 (↓4%)
East	15mm 9hr 25mm 12 hr 30mm 12 hr 35mm 12 hr 38mm 12 hr	2.3 4.8 38.8 43.0 -	2.6 (↑13%) 4.0 (↓17%) 44.5 (↑15%) 45.3 (↑5%) -	1.1 (↓52%) 1.0 (↓79%) 4.1 (↓89%) 5.7 (↓87%) 23.5	- - 29.7 (↓23%) 37.5 (↓13%) -
Ganatsekiagon	15mm 9hr 25mm 12hr 35mm 12hr 40mm 12hr	no runoff no runoff 1.2 16.0	0.86 11.4 32.6 (↑2617%) 36.9 (↑131%)	1.3 10.3 27.3 (↑2217%) 34.5 (↑116%)	 - 12.2 (↓24%)
Urfe	15mm 9hr 25mm 12hr 30mm 12hr 35mm 12hr 38mm 12hr 40mm 12hr	no runoff no runoff no runoff no runoff 7.23 7.26	1.01 7.55 - - 26.4 (↑265%) 29.5 (↑306%)	0.85 5.70 - - 18.1 (↑150%) 22.1 (↑204%)	- - - - 9.8 (↑36%) -
Miller	15mm 9hr 25mm 12hr	2.68 15.1	6.16 (↑130%) 18.7 (↑24%)	3.91 (↑46%) 10.5 (↓30%)	- 10.9 (↓28%)
Whole Duffins	15mm 9hr 25mm 12hr	31.6 84.2	40.5 (↑28%) 110.4 (↑31%)	28.9 (↓9%) 71.9 (↓15%)	- 73.4 (↓13%)
Whole Carruthers	15mm 9hr 25mm 12hr	2.69 12.5	1.80 (↓33%) 8.39 (↓33%)	no runoff 7.8 (↓38%)	- 11.1 (↓11%)

* "BMP" scenario simulated increased forest cover in "priority" grid cells determined from the trace source contribution analysis

5.1 Suspended Sediment Yield

Under existing conditions, the typical design storm events that were modeled (15mm and 25mm) result in no runoff in two of the study areas: Ganatsekiagon and Urfe. In comparison, under the OP scenario, even small-sized storms generate runoff in Ganatsekiagon and Urfe. This is attributed to the extensive increase in impervious area in these two subwatersheds; urban cover increases from approximately 2% under existing conditions in both subwatersheds to 43% and 32% under the OP in Ganatsekiagon and Urfe, respectively, with the development of the Seaton lands.

Storm events simulated under the official plan scenario (scenario 2) generally result in more sediment load than under existing conditions, particularly as storm size increases. A greater proportion of the sediment under the future scenarios is likely due to in-stream erosional processes, particularly in study areas such as Urfe and Ganatsekiagon with significant urban expansion, in contrast to overland erosion which is likely the dominant source of in-stream sediment from agricultural areas.

For most watershed areas, scenario 3 (official plan plus enhanced natural heritage) produces sediment yield levels equal to or better than existing conditions. Similarly, the BMP exercise of simulating increased forest cover in "priority management areas" (determined from the Trace Source Contribution analysis in scenario 1 for existing conditions) produced sediment yield levels that were approximately equal to or better than existing conditions in all but one study area (Urfe), and in several cases, were as good as the result obtained in scenario 3. The slight increase in sediment yield modeled in Urfe's BMP exercise (approximately 2 ton increase) is not considered to be significantly different than existing conditions. The results of the BMP exercise from the various study areas suggest that the location of "priority management areas" influences the magnitude of the water quality improvement (see **Appendix C** for maps illustrating the results of the trace source contribution analysis). For example, in the case of Urfe Creek the placement of the BMP exercise on "priority management areas" in the headwaters likely results in less runoff volume traveling to lower reaches, thereby reducing the dilution capacity of the stream. In subwatershed areas with extensive urban expansion planned through the OP, urban stormwater management facilities and retrofits of existing facilities will be extremely important in order to achieve the water quality improvements modeled in scenario 3 and the BMP exercise.

Major exceptions to the trend of maintained/ improved water quality conditions modeled in scenario 3 as compared to existing conditions occurred in (1) Ganatsekiagon and (2) Urfe. Sediment yield under scenarios 2 and 3 in these two study areas was significantly greater (by and order of magnitude) than scenario 1. This is likely due to the fact that the increase in natural heritage cover in scenario 3 is not that significant in these two subwatersheds. Scenario 3 is not that different from scenario 2 and this is reflected by similar water quality results for the two scenarios. In devising the land use scenarios, the Town of Pickering advised not to alter the secondary plan in advance of the Seaton land swap. Therefore it may actually be possible to achieve greater natural area protection and re-vegetation than was originally assumed for these subwatersheds in the modeled scenario 3.

The presence of the glacial Lake Iroquois shoreline, which cuts through both Ganatsekiagon and Urfe, may also have influenced the scenario 3 trend found in these subwatersheds, since the shoreline tends to have more sandy, erodible soils. With the increased flows that would occur with urbanization, it is likely that the susceptible soils would easily erode and contribute to the substantial increase in sediment load. In addition, Ganatsekiagon and Urfe are steep watersheds and the hydraulics within the channel may be such that greater energy in the form of stream power is available to transport sediment.

Significant improvements in suspended sediment yield between scenario 3 and existing conditions were found in two study areas in particular: (1) Reesor and (2) East. This is attributed to the extensive application of the enhanced natural heritage in these areas (i.e. large conversions of agricultural land to forest cover; see **Table 1**).

A comparison of the sediment yield generated by each subwatershed under the 25 mm storm event can provide insight to the relative significance of each individual study area to the water quality of the watershed as a whole. **Tables 3** and **4** provide this summary. The total loads of 84.3 and 113.8 tons, determined from the sum of the loads modeled from each subwatershed, are almost identical to the results modelled for the whole Duffins under the existing and official plan scenarios of 84.2 and 110.4 tons. On an individual basis, the West Duffins and Millers Creek study areas contribute 76% and 18% of the total sediment yield, respectively, under the existing land use scenario. In the West, the Reesor/Stouffville subwatershed area accounts for approximately 70% of the suspended sediment under the existing and future official plan scenario, but drops significantly to only 33% under the official plan plus enhanced natural heritage scenario. Therefore expansion of natural cover in the Reesor subwatershed area as defined in the enhanced natural heritage scenario can significantly improve conditions in the West Duffins. Under the future scenarios, the Ganatsekiagon and Urfe also contribute a large proportion of the sediment yield in the whole Duffins, particularly when the small area of these subwatersheds is taken into account.

Table 3: Comparing the sediment load from the West, East, Ganatsekiagon, Urfe and Millers subwatersheds as a percent of the total Duffins watershed yield.

Sub-watershed	Scenario 1: Existing		Scenario 2: OP		Scenario 3: OP+NH	
	Sediment Yield (tons)	Percent of Total	Sediment Yield (tons)	Percent of Total	Sediment Yield (tons)	Percent of Total
West	64.4	76%	72.1	63%	63.4	70%
East	4.8	6%	4	4%	1	1%
Gan	0	0	11.4	10%	10.3	11%
Urfe	0	0	7.55	7%	5.7	6%
Miller	15.1	18%	18.7	16%	10.5	12%
TOTAL	84.3	100%	113.75	100%	90.9	100%

Table 4: Comparing the sediment load from the Reesor/Stouffville subwatershed as a percent of the total West Duffins yield.

Sub-watershed	Scenario 1: Existing		Scenario 2: OP		Scenario 3: OP+NH	
	Sediment Yield (tons)	Percent of West	Sediment Yield (tons)	Percent of West	Sediment Yield (tons)	Percent of West
Reesor	45.8	71%	52.4	73%	20.8	33%

Table 5: Phosphate concentration results modeled with AGNPS from the outlet cell of each study area and the conversion to total phosphorus using the established relationship between PO_4 and Total P (as described in section 2.4.2).

Watershed or Subwatershed	Storm Event	Phosphate (PO_4) Concentration (mg/l)				Converted to Total Phosphorus (mg/l) Using Relationship Between PO_4 and Total P			
		Existing	Official Plan (OP)	OP + Natural Heritage	BMP	Existing	Official Plan (OP)	OP +Natural Heritage	BMP
Reesor	15mm 9 hr 25mm 12 hr	0.02 0.02	0.03 0.02	0.03 0.02	-0.02	0.06 0.06	0.08 0.06	0.08 0.06	-0.06
West	15mm 9hr 25mm 12hr	0.00 0.00	0.00 0.00	0.00 0.01	0	0.07 0.07	0.07 0.07	0.07 0.08	-0.07
East	15mm 9hr 25mm 12 hr 30mm 12 hr 35mm 12 hr 38mm 12 hr	0.15 0.11 0.09 0.08 -	0.15 0.12 0.11 0.09 -	0.15 0.15 0.10 0.09 0.09	- - 0.10 0.08 -	0.22 0.18 0.16 0.15 -	0.22 0.19 0.18 0.16 -	0.22 0.22 0.17 0.16 0.16	- - 0.17 0.15 -
Ganatsekiagon	15mm 9hr 25mm 12hr 35mm 12hr 40mm 12hr	no runoff no runoff 0.11 0.09	0.05 0.04 0.04 0.03	0.05 0.04 0.03 0.03	-0.09	no runoff no runoff 0.46 0.38	0.22 0.17 0.17 0.13	0.22 0.17 0.13 0.13	-0.38
Urfe	15mm 9hr 25mm 12hr 30mm 12hr 35mm 12hr 38mm 12hr 40mm 12hr	no runoff no runoff no runoff no runoff 0.01 0.01	0.05 0.04 - - 0.03 0.03	0.05 0.04 - - 0.03 0.03	0.01 -	no runoff no runoff no runoff no runoff 0.05 0.05	0.22 0.17 - - 0.13 0.13	0.22 0.17 - - 0.13 0.13	0.05 -
Miller	15mm 9hr 25mm 12hr	0.12 0.10	0.02 0.02	0.03 0.02	-0.08	0.19 0.17	0.09 0.09	0.10 0.09	-0.15
Whole Duffins	15mm 9hr 25mm 12hr	0.09 0.07	0.07 0.06	0.07 0.05	-0.07	0.16 0.14	0.14 0.13	0.14 0.12	-0.14
Whole Carruthers	15mm 9hr 25mm 12hr	0.10 0.08	0.03 0.03	no runoff 0.06	-0.08	0.17 0.15	0.10 0.10	no runoff 0.13	-0.15

* BMP tested simulated increased forest cover in "priority" grid cells determined from the trace source contribution analysis

5.2 Phosphate / Total Phosphorus Concentration

Model results for phosphate and total phosphorus concentrations are presented in **Table 5**. Four of the eight subwatershed study areas show no change or only a slight change in phosphorus levels across the four scenarios, including the study areas: (1) Reesor, (2) West, (3) East, and (4) Whole Duffins. These four study areas exhibited the least amount of land use change overall, and therefore changes in phosphorus sources would be expected to be minimal. Although phosphorus concentrations do not show much change over the various scenarios TRCA modelled, phosphorus loads in the watershed would likely show greater increases under the OP scenario due to the increased volumes of overland runoff associated with urban expansion.

Of the remaining four study areas that exhibited phosphorus level changes between scenarios 1 and 2, three had decreases, (1) Ganatsekiagon, (2)Miller, and (3) Whole Carruthers, and one increased, Urfe. The decreases are attributed to the significant conversion from agricultural land to urban land uses, which thereby removes a major source of phosphorus. For example, Miller's urban cover increased from 38% to 61% under scenario 2. Although Urfe also has extensive urban expansion under the OP scenario, the increase in phosphorus concentration in Urfe may be due to the presence of more sandy soils in this subwatershed, which is due to the extent and orientation of the glacial Lake Iroquois shoreline in this subwatershed. Sandy soils are less capable of binding phosphorus than clay/loam soils, so although sandy soils erode easily, they do not carry high phosphorus levels. There is less exposure of the Iroquois shoreline in the Ganatsekiagon subwatershed, as compared to Urfe, which may also explain the differences in phosphorus results between these two subwatersheds.

Relative to the overall dry weather/wet weather phosphorus Provincial Water Quality Objective (PWQO) of 0.03 mg/l, all modeled storm events that generate runoff fail to meet the objective. It should be noted, however, that water quality levels tend to be at their worst under storm conditions, and since phosphorus levels only marginally exceed the objective, it is possible that phosphorus concentrations averaged over both dry and wet weather conditions may meet the PWQO.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Predicted Water Quality Conditions

Sediment loads can generally be expected to increase in the Duffins and Carruthers watersheds as a result of urban growth under the OP scenario. Enhanced natural heritage cover can compensate for some of the negative impacts of urban growth by at least maintaining existing water quality conditions. This would suggest that greater improvements or watershed protection could be achieved by incorporating rural and urban stormwater management practices in all new developments. Natural heritage enhancement programs focused on priority management areas have roughly the same benefit as the enhanced natural heritage cover scenario. Some differences in these overall trends occur in subwatersheds that have one predominant land use.

6.2 The Role of AGNPS

The findings indicate that AGNPS is a useful model for evaluating surface water quality changes under varying land cover types, particularly when rural land uses make up a portion of the land cover because AGNPS utilizes the following broad land cover classifications: forests, crops, impervious, wetlands, bare ground, and water. Due to uncertainties in actual model load and concentration predictions, the strength of the model lies in a comparison of relative predictions among subwatersheds and alternative scenarios.

The key parameters of use in the evaluation included total sediment yield and phosphate (soluble phosphorus) for the subwatershed outlet of each study area. These parameters are useful because suspended sediment often indicates the presence of other contaminants that bind to the sediment particles. Dissolved phosphate is likely transported in a manner similar to that of other dissolved nutrients and is usually a limiting nutrient in the eutrophication process.

The model's module for Trace Source Contribution (TSC) analysis is a useful tool, which can assist TRCA by directing attention to watershed areas for stewardship/management activities. The simulation of additional forest cover (and conversely taking crop land out of production) in the areas identified through the TSC analysis was easily evaluated in the model. As with the various scenario evaluations, there is more confidence in the *relative* improvements of the BMP as opposed to the actual values predicted.

6.3 Recommendations

The following recommendations are provided for the Duffins and Carruthers watersheds:

1. Stormwater management practices should be incorporated into new and existing developments.
2. Rural stewardship should be focused on "priority management areas" (as determined through the trace source contribution analysis tool of the AGNPS interface). AGNPS results should be considered to assess the relative benefits of alternative management approaches, coupled with field inspections and determinations of landowner willingness to undertake the various best management practices.
3. Any natural heritage enhancement programs should be directed to priority areas, to achieve the greatest water quality benefit.

6.3.1 Future use of AGNPS in TRCA

Set-up of the AGNPS model for the Duffins and Carruthers Creek watersheds provides the basis for simulation of other land cover scenarios or Best Management Practices not analyzed in this study. It is recommended that this further analysis be undertaken to fully evaluate the utility of this model, and provide additional guidance to stewardship initiatives.

AGNPS could also be used in other rural subwatersheds of the TRCA, such as the Humber River and Rouge River watersheds, to predict water quality changes under a future Official Plan and enhanced natural heritage cover scenario as well as to identify key areas in those subwatersheds for stewardship/management activities. Similar preparation work would be required, including the preparation of base maps (e.g. update DEM for each area, generate land cover maps for alternative scenarios, update agricultural land use maps, etc.). Calibration data (i.e. event based stream flow and water quality data) would also need to be collected.

7.0 REFERENCES

Blinger, R.L. , C.E. Murphree, C.K. Mutcher, 1989. Comparison of Sediment Yields Models on Watersheds in Mississippi. *Transactions of ASAE* Vol. 32(2): March-April, 1989.

Booty W.G., G. S. Bowen, L. Leon and D.C.L. Lam, 2001 *Decision Support Technology Transfer for Non-Point Source Water Qaulity Modelling within Ontario Conservation Authorities. Program and Abstracts Thirty-Sixth Central Canadian Symposium on Water Pollution Research*.

Bowen, G. S., D.C.L. Lam, W.G. Booty and L. F. Leon., 1997. *Application of the Agricultural Non_Point Source Model (AGNPS) on a Catchment Draining the Oak Ridges Moraine. Workshop on Water Resource Investigations of The Oak Ridges Moraine: Geology and Hydrogeology.*

Finney, V. L., M.A. Cooke, S.T. Moorhead and J. Klug. 1998. *Nutrient Analysis of the Malibu Watershed using the AGNPS Model*. www.mother.com/vfinney/paper2/malnut.htm

Frere, M.H., Ross, J.D. and L.J. Lane. 1980. The nutrient submodel. In Knisel W. Ed. Creams, A Field Scale Model for Chemicals, Runoff and Erosion from Agricultural Managed Systems. *U. S. Dep. Agric. Conser. Res. Rep.* 26, Vol1,

JDE Ventures, 1998. *1998 Survey of Farming Practices and Fertilizer use in the Stouffville and Reesor Creeks Watershed for AGNPS Model Application,* A final report to the Ontario Ministry of the Environment, Standards Development Branch and the Toronto and Region Conservation Authority, 15pp.

Leon, L.F., W.G. Booty, G.S. Bowen, D.C.L. Lam, 2002 (in print). *Calibration of the AGNPS Model for Duffins Creek Watershed in Southern Ontario.*

Leon, L.F., 1999, *AGNPS Interface for RAISON/Windows.* University of Waterloo, Department of Civil Engineering.

Leon, L. F., 1999. *AGNPS Interface for RAISON/Windows: Tutorial Guidelines.* University of Waterloo, Department of Civil Engineering.

Leon , 1998. *Capabilities of AGNPS to include reservoirs, channel erosion, sewage treatment plants and riparian vegetative buffer strips.* Unpublished Memo.

Mostaghimi,S., S.W. Park, R. A. Cooke, and S.Y. Wang. 1997. Assessment of Management Alternatives On A Small Agricultural Watershed. *Wat Res.* Vol. 31. No. 8 p 1867-1878.

Toronto and Region Conservation Authority (TRCA), 2002a. *Carruthers Creek State of the Watershed Report.* Downsview, Ontario.

Toronto and Region Conservation Authority (TRCA), 2002b. *Duffins Creek State of the Watershed Report.* Downsview, Ontario.

Toronto and Region Conservation Authority (TRCA), 2003. *Technical Analysis and Integration Process Summary Report: Duffins and Carruthers Creek Watersheds Plan.* Downsview, Ontario.

Wischmeier, W. H and D.D. Smith 1978. Predicting rainfall erosion losses-a guide to conservation planning. *U.S. Department of Agriculture, Agriculture Handbook* NO. 537

Young, R.A., C.. Onstrad, D. Bosch and W. P. Anderson. 1989. AGNPS: A Non Point Source pollution model for evaluating agricultural watersheds. *J. Soil Wat. Conser.* Vol 44. Number 2. P 168 -1173.

Young, R.A., C.. Onstrad, D. Bosch and W. P. Anderson. 1994. *Agricultural Non-Point source Pollution Model, Version 4.03, AGNPS User's Guide*. U.S. Department of Agriculture

Young, R.A., C.. Onstrad, D. Bosch and W. P. Anderson. 1997, *AGNPS Agricultural Non-Point source Pollution Model. A Watershed Analysis Tool*. U.S. Department of agriculture, Conservation Research report 35, 80 p.

Appendix A

Land Cover Scenarios in the Duffins and Carruthers Watersheds

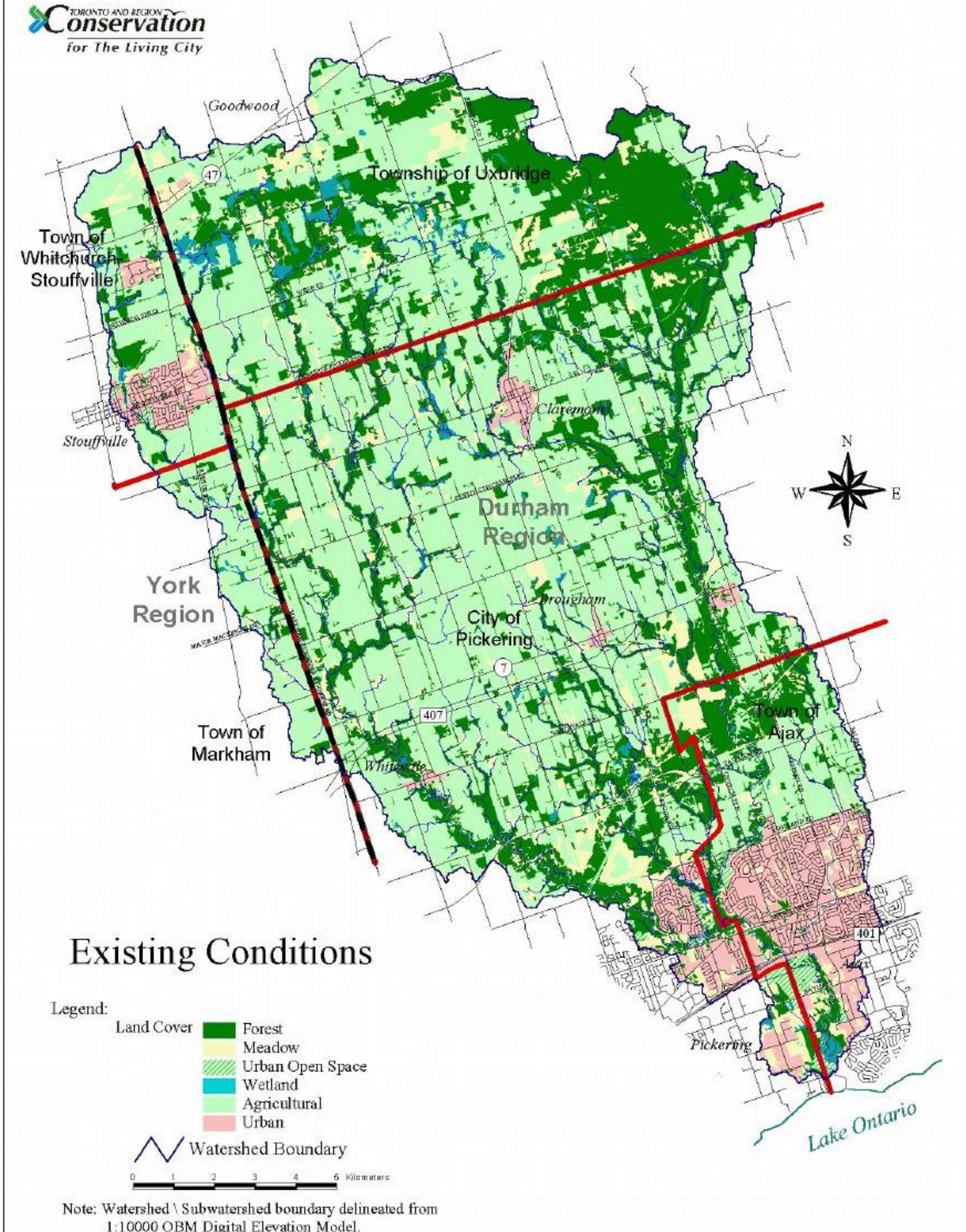

Figure A1: Land cover in Duffins Creek under existing conditions

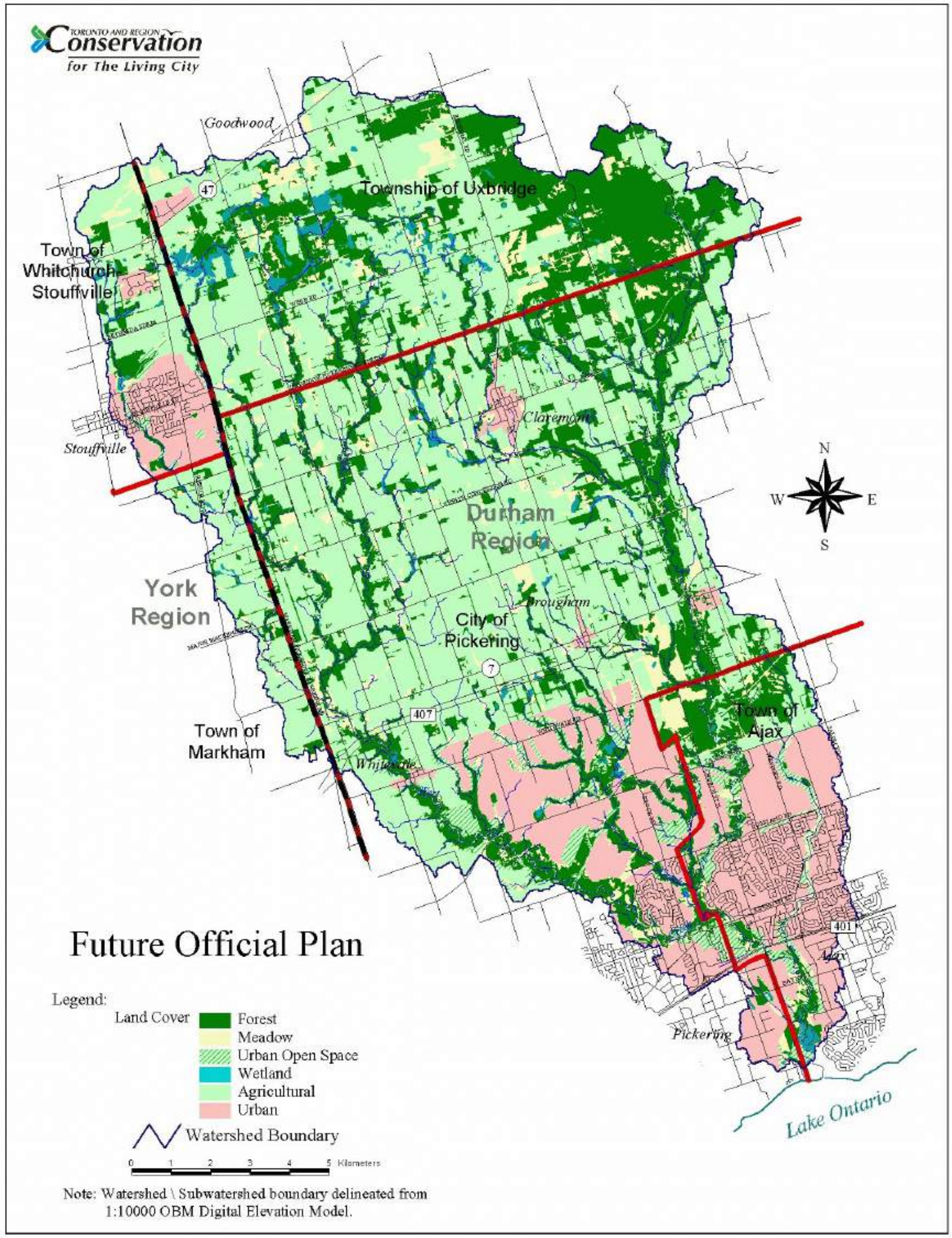

Figure A2: Land cover in the Duffins Creek under the future Official Plan

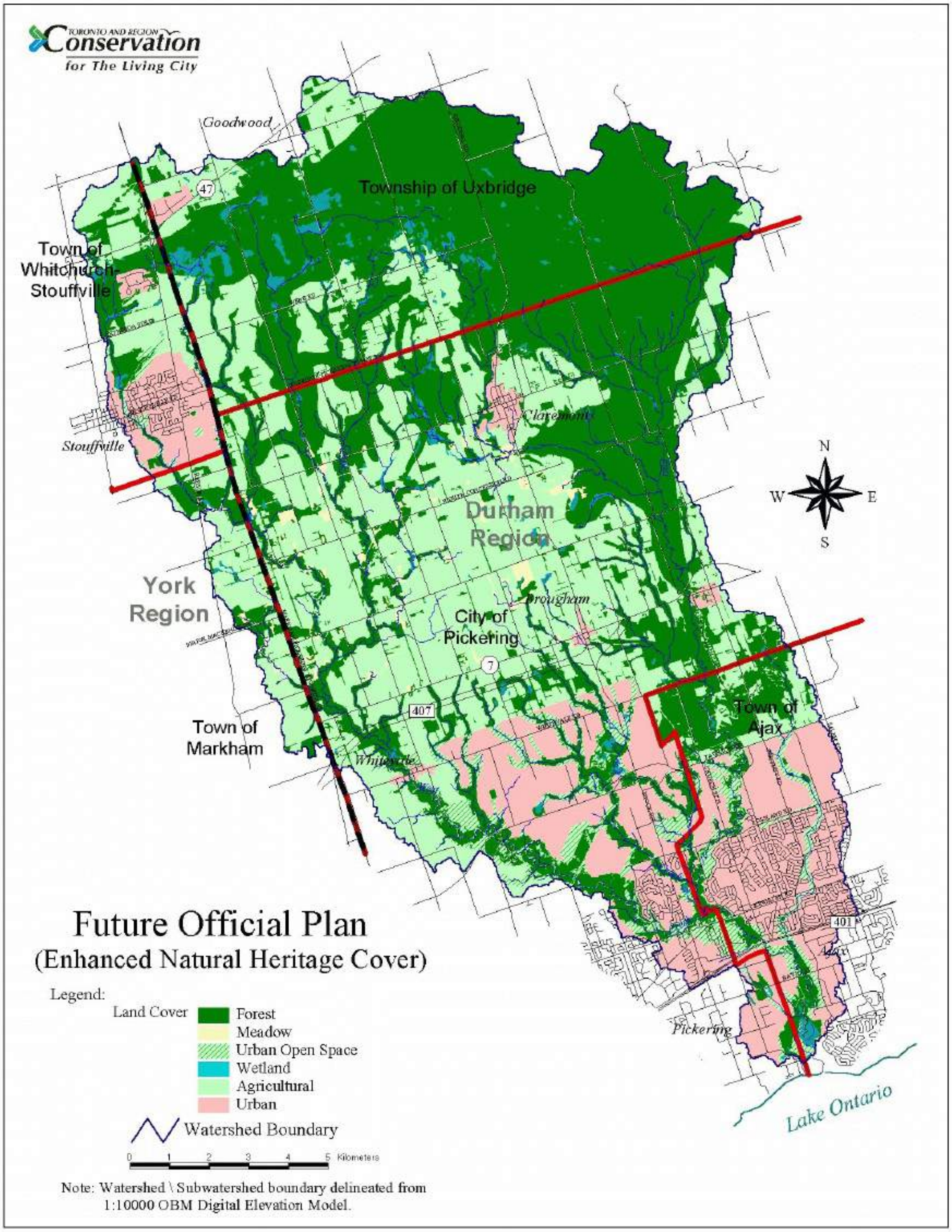

Figure A3: Land cover in the Duffins Creek watershed under the future Official Plan with enhanced natural heritage cover.

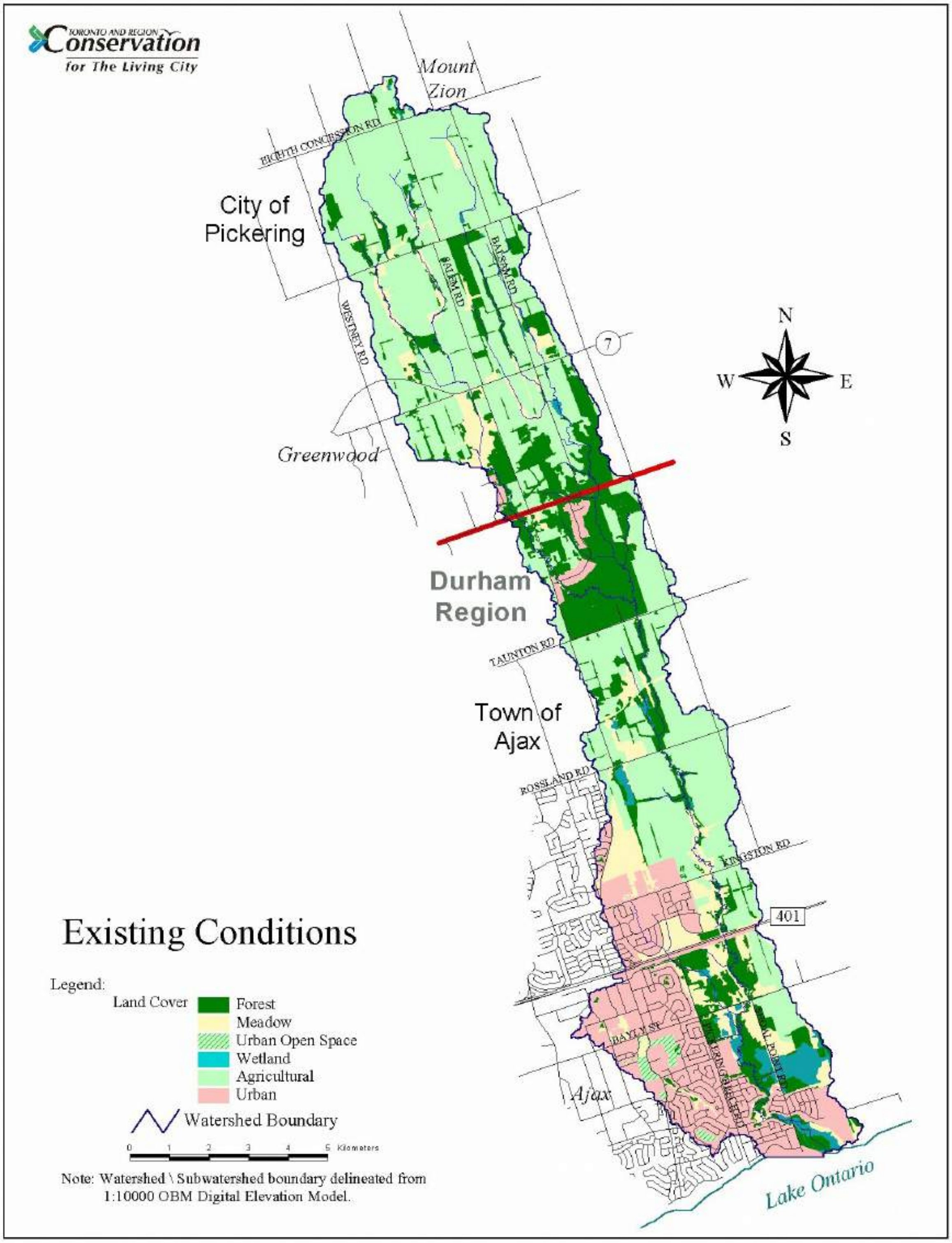

Figure A4: Land cover in the Carruthers Creek watershed under existing conditons

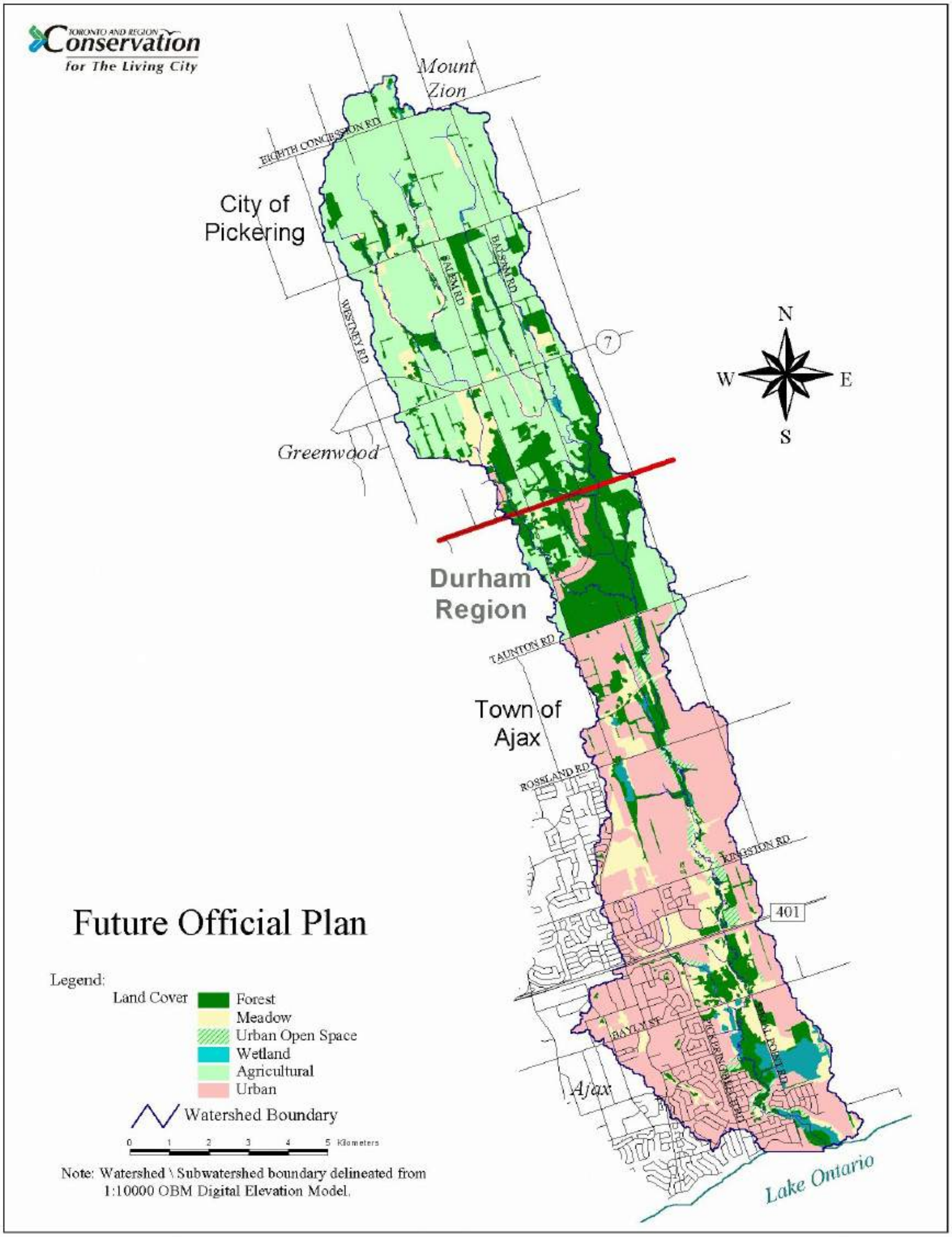

Figure A5: Land cover in the Carruthers Creek watershed under the future Official Plan

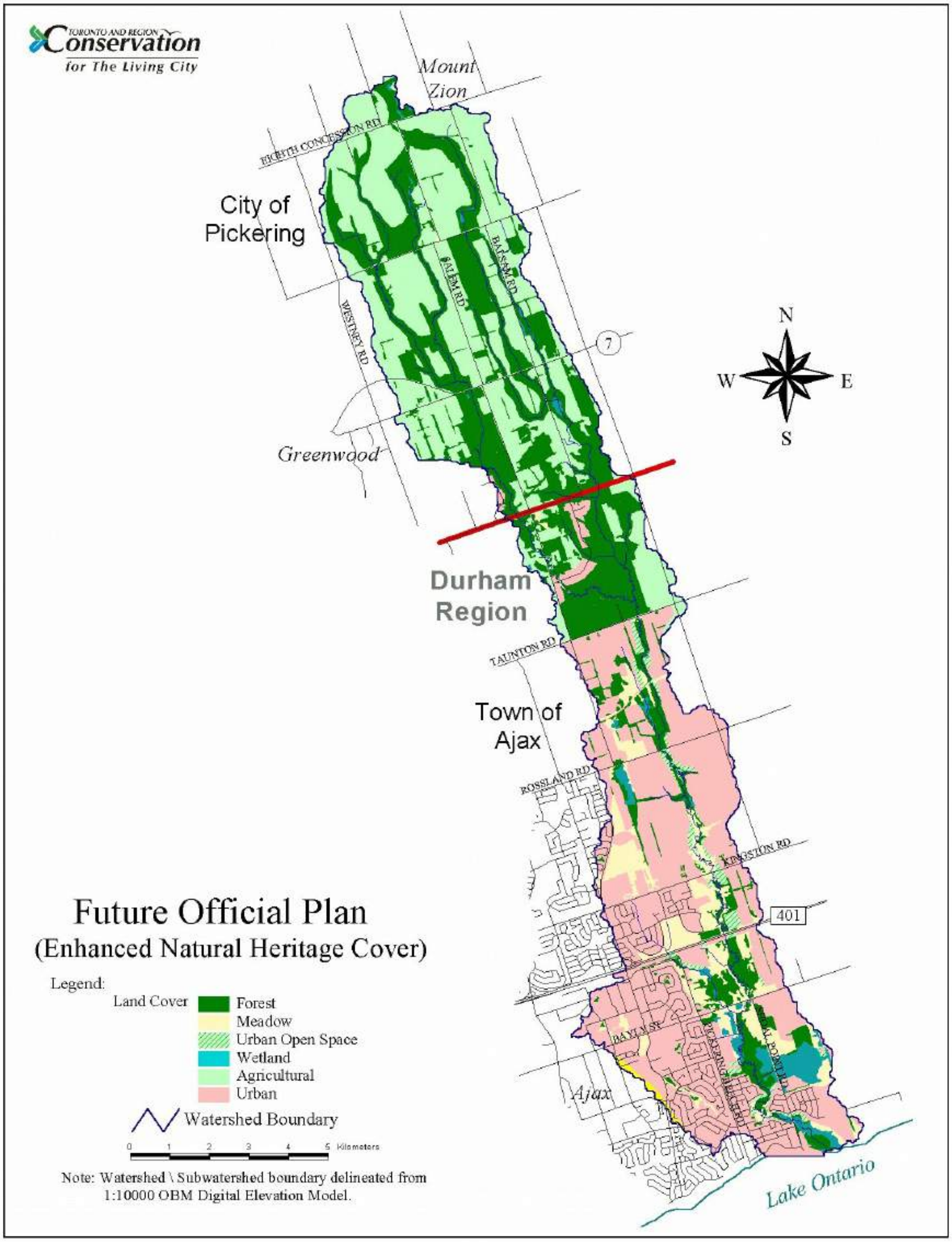

Figure A6: Land cover in the Carruthers Creek watershed under the future Official Plan with enhanced natural heritage cover

Appendix B

AGNPS Calibration Report for the Duffins Creek Watershed

Calibration of the AGNPS Model for Duffins Creek Watershed in Southern Ontario

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Abbreviations List

AGNPS – Agricultural Non-Point Source
AMC – Antecedent Moisture Content
API – Antecedent Precipitation Index
BMPs – Best Management Practices
CE – Coefficient of Efficiency
DEM – Digital Elevation Model
GIS – Geographic Information System
NPS – Non-Point Source
SCS – Soil Conservation Service

ABSTRACT: As part of an integrated watershed management study for watersheds of Southern Ontario, the Agricultural Non-Point Source (AGNPS) model was interfaced with a decision support system that drastically reduces time-consuming data input steps and scenario testing. Research was carried out to define appropriate model inputs for sensitive input parameters for the region as well as defining a protocol for model calibration at the subwatershed and watershed scale. In this study, the model has been evaluated for a wide range of storm events and it provided realistic estimates of nutrien t loads in runoff water. ***.*** *Both the peak flows for tested grid sizes and historic runoff values are quite well reproduced by the AGNPS model. Very high Coefficient of Efficiency (CE) values of 0.821 and 0.919, for the 1x1 and 2x2 km grids respectively, and of 0.713 for the runoff volumes were obtained. The CE values for nutrient loads are extremely high, 0.990 for nitrogen and 0.965 for phosphorus.* ***.*** *The model was found to be well suited to applications in southern Ontario, and with its new interface, a very useful tool for watershed management by conservation authorities who are responsible for watershed management programs in the region.*

Key words: nonpoint source modeling, calibration protocol, decision support.

INTRODUCTION

The input of nutrients to the Great Lakes from non-point sources has been a concern for many years. The International Joint Commission study of Pollution From Land Use Activities Reference Group (PLUARG) was completed in 1978 and was the basis for much of the policy on non-point source pollution control in the Great Lakes and elsewhere. The Great Lakes Water Quality Agreement (GLWQA) signed by the U.S and Canada specifies key provisions for control measures for phosphorus and critical pollutants. Section 4 emphasizes the importance of demonstration projects on urban and rural watersheds to advance knowledge and enhance information.

In 1994 the Ontario Ministry of the Environment (MOE) and the National Water Research Institute (NWRI) of Environment Canada initiated a collaborative study to investigate rural water quality with the Duffins Creek watershed, which drains into Lake Ontario. Non-point source (NPS) pollution is a major component of the study. A wide range of available NPS models were evaluated and the Agricultural Non-Point Source (AGNPS) model was selected. The model is particularly well suited to evaluate best management practices (BMPs) because of its ability to concurrently simulate water quantity and quality in different parts of a watershed. It also lends itself well to interfacing with GIS systems to expedite data input and display/interpret model results.

An interface has been developed for the AGNPS model using the RAISON for Windows Decision Support System (Lam and Swayne, 1993) that drastically reduces time-consuming tasks and provides good input data based on the digital information of the watershed. Research was carried out to determine the appropriate ranges for sensitive input parameters for optimum performance of the model in southern Ontario. The model was calibrated so that conservation authorities within southern Ontario, who are responsible for watershed management, may now use it effectively.

One of the challenges that watershed managers face in southern Ontario is a declining knowledge base on rural water quality conditions. Due to funding constraints, water quality monitoring programs were reduced across the province in the 1990's. The objective of this research was to develop modelling capabilities that would fill this information gap and provide watershed managers with a tool that would enable them to design and target best management practices that would be effective in improving water quality conditions in rural watersheds.

The AGNPS model was conceived on the basis of the CREAMS model, which was developed with the intention of minimizing the calibration efforts. The model has been applied and validated in many parts of the United States. Validation of the model for sediment and runoff was shown by Koelliker and Humber (1989) for five watersheds in Kansas. Sugiharto *et al.* (1994) applied the AGNPS model to evaluate 20 management practices dealing with sediment and phosphorus yields from 4 ha fields in a watershed dominated by dairy farms. Best management practices were evaluated for watersheds in southern Iowa (Tim *et al.* 1994) and coastal watersheds in South Carolina (Choi and Blood, 1999). It has being used in different circumstances to calculate sediment and nutrient loading due to nonpoint source pollution in watersheds (Bingner *et al.*, 1989, Young *et al.*, 1989, Finney *et al.*, 1995, Mostaghimi *et al.*, 1997).

In Canada, the AGNPS model has had much less use. Perrone and Madramootoo (1999) evaluated the model in a small Quebec watershed for its applicability and performance with respect to hydrologic conditions in that province. In this paper, the AGNPS model has been calibrated and validated for use in southern Ontario at both subwatershed and watershed scales. The intention is to present a set of guidelines in order to properly run the AGNPS model and select the appropriate values for the parameters and coefficients. It also presents the measured data from the field studies where data was collected for three years with the intention to calibrate the model.

MATERIALS AND METHODS

The AGNPS Model

The AGNPS model (Young *et al*., 1994) is a distributed model that simulates agricultural watersheds for a single storm event assuming uniform precipitation patterns. Version 5.0 of the AGNPS model was used in this study. Watersheds modeled by AGNPS must be divided into homogenous square working areas called cells. The hydrology in the model is calculated by the Soil Conservation Service (SCS) curve number approach. With this method, the infiltration is calculated simply by subtracting the runoff from the amount of rainfall with the runoff being calculated using the SCS curve numbers for each cell.

The Universal Soil Loss Equation (USLE) is used for predicting soil erosion which is predicted for five different particle sizes (sand, silt, clay, small and large aggregates). The AGNPS model simulates the soil loss and sediment yield in a two-step process. First, the soil erosion is calculated and then compared to the sediment transport capacity of the flow. The eroded sediment is then routed based on a steady-state continuity equation for sediment transport and deposition described by Foster *et al*. (1980). Among the factors in the USLE, the soil erodibility factor is a measure of potential erosion of the soil and is a function of the soil texture; the vegetative cover factor estimates the effect of ground cover conditions and accounts for the effect of vegetation and land management on erosion rates resulting from canopy protection (reduction of rainfall energy effect).

The pollutant transport part of the model estimates transport of nitrogen, phosphorous and chemical oxygen demand (COD) throughout the watershed. It is divided into one part handling soluble pollutants and another part for sediment based pollutants. The methods used to predict nitrogen and phosphorus yields were developed by Frere et al. (1980).

As in most nonpoint source pollution models, the equations are based on the CREAMS model (Knisel, 1980). The nitrogen and phosphorus estimates are performed using relationships between chemical concentration, sediment yield and runoff volume. Soluble nitrogen and phosphorus in runoff waters represent the effects of rainfall, fertilization, solid waste and leaching from the soil in each cell. The contributions of soluble nutrients from each cell are calculated first within the cell and routed downstream. Once soluble nutrients reach concentrated flow, they are assumed to remain as constants. That is, the amount arriving in the overland flow from any particular cell is simply added to what is already present in the channel, with no losses of soluble nutrients allowed, except for the nutrient decay within the cell.

Nitrogen concentration occurring in precipitation varies between 0.8 and 1.2 ppm, which is not agronomically significant for cropland but could be for unfertilized and forested areas. The value used in the model is the recommended value in the AGNPS documentation (Young *et al.*, 1994) of 1 ppm. Other sources of nutrients are the fertilizers. Normally nitrogen fertilizers are quite water soluble and phosphate fertilizers are moderately soluble. Consequently, water from the soil and light rain dissolves the granules. Only part of the rainfall leaves the field as runoff. The part of the rain that does not run off fills the surface layer and leaches soluble nutrients deeper into the soil. In the AGNPS model a leaching rate is calculated through the use of extraction coefficients for soil and runoff.

The AGNPS Interface

The AGNPS is a robust and well tested model. Mostaghimi *et al.*, (1997) found that, based on several simulations, the AGNPS model was suitable for a watershed scale simulation. At the same time, they also noted that the most difficult task was the input data preparation for the model, a very time consuming process and pointed out the difficulties for determining the accuracy of such input values. The AGNPS model has previously been interfaced with GIS systems such as GRASS (He et al. 1993), SPANS (Rode and Frede, 1997) and ARC/INFO (Hession and Huber, 1989). However, these GIS systems have a large learning curve to master and we wanted a system that would allow rapid and easy training for a wide range of users.

Data needed for the model is classified into two categories: *Watershed Data* include information applying to the entire watershed such as watershed size, number of cells, and if running for a single event, the storm type, duration and intensity. *Cell Data* includes information on the parameters based on soil type, land use, and management practices within the cell. Any attempts to improve NPS modelling capabilities need to be combined with the application of new technologies to resolve problems associated with ease of model use. This will allow the user to track the decision-making processes through the model to obtain a better understanding of the simulation. An integrated approach is achieved in this research with the linkage of the AGNPS model with the RAISON decision support system. Interactive programs were created to assist in processing data, initiating model simulations, and analyzing model results.

Interfaces were built (Leon, 1999) to allow interaction with the model by intercepting input and output and to connect them to the database in the system. Work was done to create communication links between the AGNPS model and RAISON. The interface created in the present research, drastically reduces the time required to prepare input data for the model based on automatically extracting parameter values from digital information of the watershed. The pre-processing tools provide easy data compiling for the models. Using DEM (Digital Elevation Model), soil type, and land use maps in vector formats, procedures are designed to automate as much input of data as possible. Design of a control panel for model operation helps in the setup and operation of the model. Post-processing for output by means of graphical and statistical tools also assists with the interpretation of model results. Also, techniques to analyze the sensitivity associated to the model were evaluated and included in the system.

Study Location

This application focuses on Duffins Creek, a 293 km^2 watershed draining into Lake Ontario at Ajax, 10 km east of Metropolitan Toronto. The headwaters originate in the northern regions of the watershed in the Oak Ridges Moraine where sub-surface drainage predominates (Bowen *et al.*, 1995). The land use is mainly non-intensive agricultural with growing urban areas in the lower parts of the watershed at Pickering and Ajax. Only 10% of the watershed is developed. Agricultural practices in the watersheds have changed over the past 30 years in response to expropriation to build a new international airport in the 1970's by the Provincial and Federal governments. Current agricultural practices include cash crops, market gardens, sod farms, diary and beef operations, and orchards. Also scattered throughout the watershed are riding stables and hobby farms. A large percentage of the operations in the watershed are based on tenant farming.

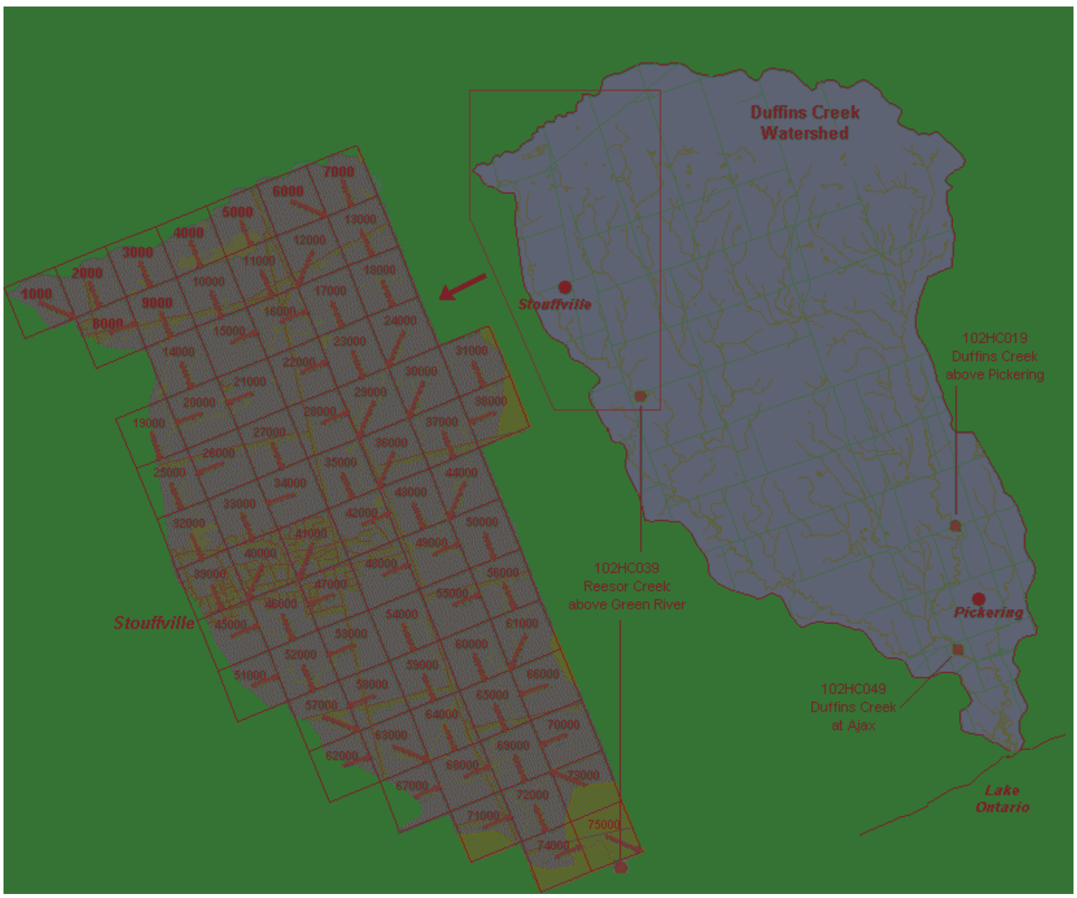


Figure 1. Reesor Creek subwatershed, showing model grid and flow directions.

In the northwestern corner of the Duffins Creek watershed is the Reesor Creek sub watershed (Figure 1). It is 38.9 km^2 in area with a flood control reservoir and a sewage treatment plant that discharge into the Duffins Creek west river system. Originally the Duffins watershed was chosen for three reasons: i) the Federal and Ontario governments are major owners of the land, expropriated in the 1970s to build an international airport, ii) the watershed has a comprehensive environmental database to work with and iii) project plans proposed the need for non-point source pollution modeling in the watershed.

Data Collection

Despite the fact that the Duffins Creek watershed is one of the most highly monitored watersheds in Canada, data collected were not designed for use in an event-based non-point source model. Consequently, it was decided that additional event-based monitoring for flows and water chemistry should be initiated for parts of the watershed. During 1997, hourly samples were collected and loads were calculated hourly for several events and then totaled to determine the event loads at the Reesor Creek station. In 1999, rising limb, descending limb and composite event samples were collected at Reesor, Uxbridge and Leaskdale Creek sampling stations. Additionally, Provincial and Federal monitoring data for 1995 and historic records in Duffins were used for hydrologic calibration of the model.

When an event takes place in the watershed, an ISCO sampler turns on when the water level rises to a predetermined level. Every 10 minutes, a pump turns on and fills, in sequence, a one liter bottle. The sampler continues filling 24 bottles over 24 hours from the time it is activated. The field technician determines from the hydrograph when the event started and when the peak flow occurred. Composite samples are prepared for the rising and descending limbs of the hydrograph as well as a volume weighted event composite sample. This method reduced the number of samples for analysis and was developed by the Lake Simcoe Conservation Authority and the MOE. The analysis were completed by the MOE at their main laboratory. The results for the rising and descending limbs are used to calculate loads for the event. The average of the load estimates and the composite load estimate is divided by the total runoff for the event to yield the event mean concentration.

While the primary focus of the AGNPS model is to simulate surface runoff and nutrient transport for rainfall events, information on water quality concentrations during baseflow conditions for all seasons of the year are also required. Once each month, grab samples were collected for analysis. A survey of farming practices and fertilizer use in the Stouffville and Ressor Creek sub watershed of the Duffins Creek Watershed (JDE Ventures, 1998) was commissioned by the Ontario Ministry of Environment and Toronto Region Conservation Authority in 1998 in support of the AGNPS model applications.

Preliminary Sensitivity Analysis

In order to define the variables that require special attention during the calibration work, a preliminary sensitivity analysis was performed. Understanding the sensitivity of a model provides a better comprehension of the accuracy needed for the input data and the results become more defensible and credible. Most of the discussion of sensitivity analysis is based on the assumption that the computed responses are smoothly varying in a lineal mode. A common application involves changing the parameter values in both directions (increase and decrease a small percentage) of the base case value and tracing the resulting response gradient.

The normalized sensitivity coefficients and its ranking using average gradients are the methods chosen to perform the sensitivity analysis in this research. A preliminary analysis was performed, using 32 possible input parameters, changing 10% for both low and high variations. After conducting the 64 model runs involved in the process by automatic batch mode, the numerical results where extracted from the database. A summary of the normalized sensitivity gradients is shown in Table 1; a zero value means no response.

Table 1. Summary of the Normalized Sensitivity Gradients for the AGNPS Model

Parameter	TRV	PRR	TSY	NS	NR	SNC	PS	PR	SPC	CODr	CODc
Initial Data											
Precipitation	3.16	2.90	0.93	0.50	0	-1.00	1.00	0	-5.00	2.19	-0.80
Nitrog_Rain	0	0	0	0	0	0.67	0	0	0	0	0
EI_Rfactor	0	0	0.74	0.50	0	0	1.00	0	0	0	0
KCoeff_PerRunoff	0	0	-1.31	-1.50	0	0	-2.00	0	0	0	0
General Cell Data											
SCS_No	8.16	7.92	2.53	2.00	0	0.33	2.00	0	5.00	7.19	-1.26
LandSlope	0	0	0.54	0.50	0	0	0	0	0	0	0
SlopeLength	0	0	0.22	0.50	0	0	0	0	0	0	0
K_Factor	0	0	0.73	0.50	0	0	1.00	0	0	0	0
C_Factor	0	0	0.74	0.50	0	0	1.00	0	0	0	0
P_Factor	0	0	0.37	0	0	0	0	0	0	0	0
COD_Factor	0	0	0	0	0	0	0	0	0	0.94	0.99
Soil Related Data											
Soil_Nitro	0	0	0	1.00	0	0	0	0	0	0	0
Soil_Phos	0	0	0	0	0	0	1.00	0	0	0	0
PoreW_Nitro	0	0	0	0	0	0	0	0	0	0	0
PoreW_Phos	0	0	0	0	0	0	0	0	5.00	0	0
ExtR_Nitro	0	0	0	0	0	0.33	0	0	0	0	0
ExtR_Phos	0	0	0	0	0	0	0	0	5.00	0	0
ExtL_Nitro	0	0	0	0	0	-0.67	0	0	0	0	0
ExtL_Phos	0	0	0	0	0	0	0	0	-5.00	0	0
Fertilizer Related Data											
Applied_Nitro	0	0	0	0	2.0	0.33	0	0	0	0	0
Applied_Phos	0	0	0	0	0	0	0	2.0	5.00	0	0
AvFac_Nitro	0	0	0	0	0.2	0.33	0	0	0	0	0
AvFac_Phos	0	0	0	0	0	0	0	0.2	5.00	0	0
Channel Related Data											
Chan_Slope	0	0.16	0.06	0	0	0	0	0	0	0	0
Chan_SideSlope	0	0	0.02	0	0	0	0	0	0	0	0
Chan_ManningN	0	0	-0.43	-0.50	0	0	0	0	0	0	0
Decay_Nitro	0	0	0	0	-5.00	-3.33	0	0	0	0	0
Decay_Phos	0	0	0	0	0	0	0	0	-5.00	0	0
Decay_COD	0	0	0	0	0	0	0	0	0	-2.50	-2.41

Variable description: TRV-Total Runoff Volume,PRF-Peak Runoff Rate, TSY-Total Sediment Yield, NS-Nitrogen in Sediment, NR-Nitrogen in Runoff, SNC-Soluble Nitrogen Concentration, PS-Phosphorus in Sediment, PR-Phosphorus in Runoff, SPC-Soluble Phosphorus Concentration, CODr-COD in Runoff, CODc-COD Concentration.

These results show which of the parameters are more likely to produce important variations in the output variables. For the hydrology, represented by the total runoff volume and peak rate output values, the precipitation and curve number are the most sensitive to the outcome. For sediment and nutrients, the parameters that produce the largest variations in the output are land slope, rainfall intensity energy, the soil erodibility, the cover factor, curve numbers and the decay coefficients. Additionally, during the calibration work, it was noted that there were two additional factors that influence the hydrologic response of the model: (i) the antecedent moisture condition and (ii) the storm type to use as the triangular hydrograph to calculate the peak flow in the model.

Initial Watershed Data

Among the initial watershed data required for the model, the moisture condition and the storm type for the event have to be selected. The runoff curve numbers depend on the soil water content (moisture condition) and as shown in the sensitivity analysis the curve numbers are one of the parameters that affect the runoff and peak flow rates substantially. The antecedent soil moisture condition (AMC) represents the watershed soil moisture content and the runoff curve numbers depend on the AMC as described by the SCS as condition I for dry soils but not to the wilting point, II for average moisture condition (general case for annual floods) and III for nearly saturated soils.

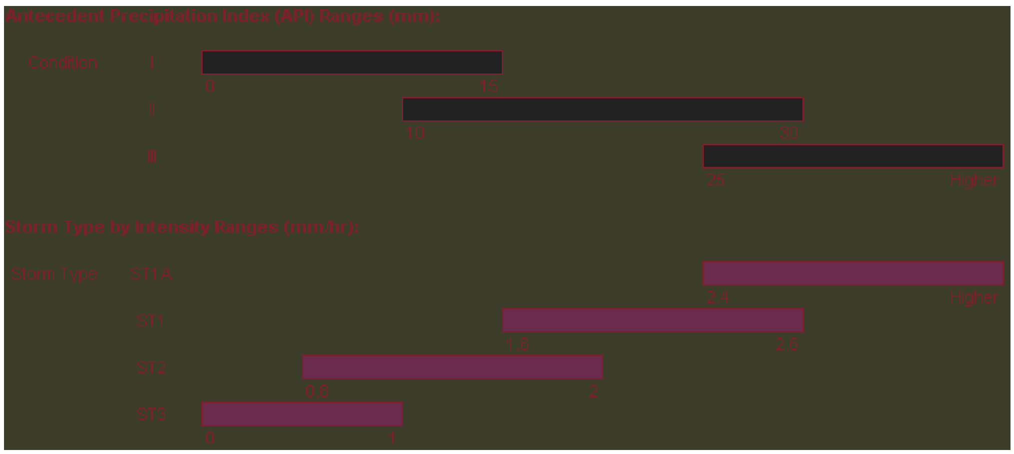


Figure 2. Criteria to select AMC and Storm Type for the AGNPS model.

With respect to the storm type, the SCS method uses the convolution of a triangular hydrograph to route excess rainfall. The area under the unit hydrograph equals the unit volume of the rainfall excess. The storm type is a value to represent the type of synthetic 24-hour rainfall distribution being simulated. The values were developed by the SCS to represent the rainfall intensity distributions. Type IA is the least intense and type II the most intense short duration rainfall. In the present work, using the antecedent precipitation index (API) and the storm intensity, criteria for selecting appropriate values for the AMC and the storm type was developed. The API is calculated as presented in Perrone and Madramootoo (1998) by a $\sum K^i P_i$ where P_i are the precipitation values for 1, 2, ...n days prior to the event and K is a constant (n=14 and K=0.85). Figure 2 presents the adopted criteria to select AMC and the storm type based on the API and storm intensity values.

Model Setup

Two different grid sizes were created in order to run AGNPS for Duffins Creek. The first grid is a 1x1 km cell size with 205 cells, while the second grid is a 2x2 km cell size with 57 cells. The AGNPS manual suggests single cell resolutions between 10 km^2 to 162 km^2, with more detailed sizes of 200 x 200m recommended for watersheds < (8 km^2) and 400 x 400m for watersheds > 8000 km^2. AGNPS has been used successfully with cell sizes up to 1x1 km. The 2 km size used in this application was selected to exceed these recommendations and test the assumption that more accurate results can be obtained by reducing the cell size.

The data extraction for both grids was accomplished using the DEM (250m resolution file) for the elevation, slopes and flow directions. Digital maps for the Duffins area (soil and land use layers) were used to extract the soil and land cover dependent data. Figure 1 shows the stream-flow gauges where the comparison between calculated and measured flows was made. Once the simulations were completed, the peak flows were recorded for the outlets of Reesor Creek subwatershed and Duffins Creek watershed to be compared with the Water Survey of Canada stations.

All the model factors used in the USLE were calculated automatically, with the use of the interface; from soil and landuse digital maps and they were kept unchanged for the calibration process. The model defines the sediment transport capacity for each of the five particle size classes: clay, silt, sand, small and large aggregates, and then computes deposition. The only option that was changed during the calibration work was choosing *all* or *none* to define which particle sizes were allowed to be scoured within the cell.

The required input, for cells where fertilizer has been applied, include the level of fertilization and the availability factors for N and P. These refer to the percentage of fertilizer left in the surface layer of soil at the time of the storm. The fertilizer rates and availability factors used in the model were obtained from the JDE Ventures survey of 1998. The interface was used to propagate the rates as a function of the landuse coverage. The only parameters that were modified for the calibration of nutrient concentrations were the decay factors.

RESULTS AND DISCUSSION

Hydrology

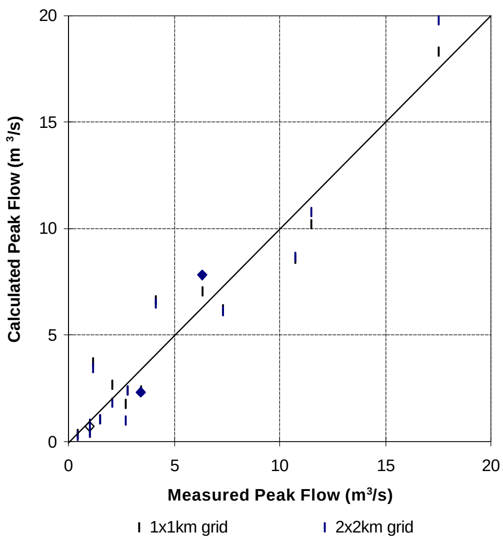
Table 2 presents the calibration results for the two grids (1 and 2 km) used in the study for the 1995 event data. Additional events were selected from the historical streamflow and meteorological archives to test for computed runoff.

Table 2 AGNPS Results (1 and 2 km grids†)

Event	Rainfall (mm)	Duration (hrs)	Peak Meas (m^3/s)	Calc 1x1km (m^3/s)	Calc 2x2km (m^3/s)	Gauge Station
25-29 Apr/95	16.5	18	11.50	10.24	10.77	Duffins Creek at Ajax
(AMC-III)			1.72	3.76	3.44	Reesor Creek above Green River
16-20 May/95	20.0	15	17.50	18.32	19.79	Duffins Creek at Ajax
(AMC-III)			4.14	6.64	6.50	Reesor Creek above Green River
1-6 Jun/95	10.7	20	3.40	2.40	2.30	Duffins Creek at Ajax
(AMC-II)			1.00	0.70	0.39	Reesor Creek above Green River
13-18 Jul/95	24.4	10	7.34	6.20	6.14	Duffins Creek at Ajax
(AMC-II)			2.70	1.77	0.98	Reesor Creek above Green River
2-6 Aug/95	18.1	20	2.79	2.42	2.37	Duffins Creek at Ajax
(AMC-II)			1.01	0.43	0.85	Reesor Creek above Green River
2-10 Sep/95	14.2	15	1.51	1.06	1.06	Duffins Creek at Ajax
(AMC-II)			0.40	0.38	0.28	Reesor Creek above Green River
4-16 Oct/95	26.9	13	10.70	8.61	8.65	Duffins Creek at Ajax
(AMC-II)			2.06	2.71	1.84	Reesor Creek above Green River
8-12 Nov/95	29.7	14	69.40	49.98	55.36	Duffins Creek at Ajax
(AMC-III)			6.29	7.03	7.84	Reesor Creek above Green River

†1km grid in lat/long is 1x1.37km (1.37km^2) and a 2km grid in lat/long is 2x2.85km (5.69km^2)

Figure 3 shows the graphs for measured and calculated peak flows together with the measured and calculated runoff values for the historic events. In calculating peak flows, there appears to be no improvement in accuracy by using the more detailed 1 km grid. It is important to note that because the peak flow rate in AGNPS is used to calculate sediment transport, errors in peak flow calculations also affect both sediment bound as well as soluble nutrient yields. These results match our knowledge of watershed response, where it is known to take 15 mm of rain with moist soil conditions to generate runoff.



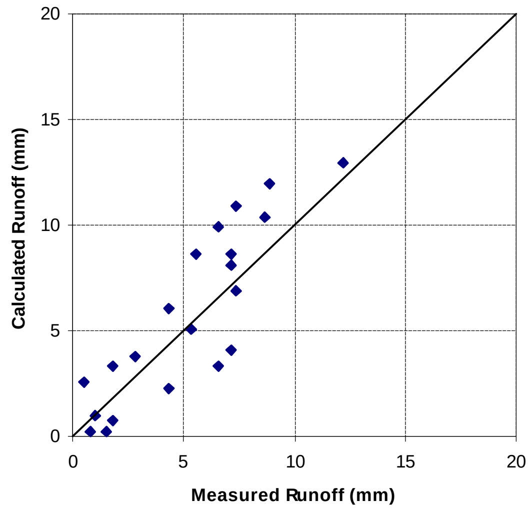


Figure 3 AGNPS results: (left) measured and calculated peak flows at the gauging stations for 1995 data, (right) measured and calculated runoff for historical events.

With respect to the goodness of fit of the measured and predicted data, we calculated the coefficients of efficiency proposed by Nash and Sutcliffe (1970) and described by Rode and Frede (1997) in their application of AGNPS in two watersheds in Germany. The coefficient of efficiency (*CE*), is dimensionless and provides a good indication of how precise the model simulates specific variables. If the observed variable is exactly simulated by the model, then *CE*=1. If *CE*<0, the precision of the model is lower than when the mean of the measured values is used.

Both, the peak flows for the two tested grids and the historic runoff values are quite well reproduced by the AGNPS model. This good match is confirmed by very high *CE* values of 0.821 and 0.919, for the 1x1 and 2x2 km grids respectively, and of 0.713 for the runoff volumes. From the monitoring program for flows and water chemistry during 1997-99, 17 events were used to further calibrate the AGNPS model in Reesor Creek. Table 3 presents the complete profile with the model results and the measured parameters from the campaign. The peak flow comparison at Reesor Creek subwatershed outlet gauge is shown in Figure 4.

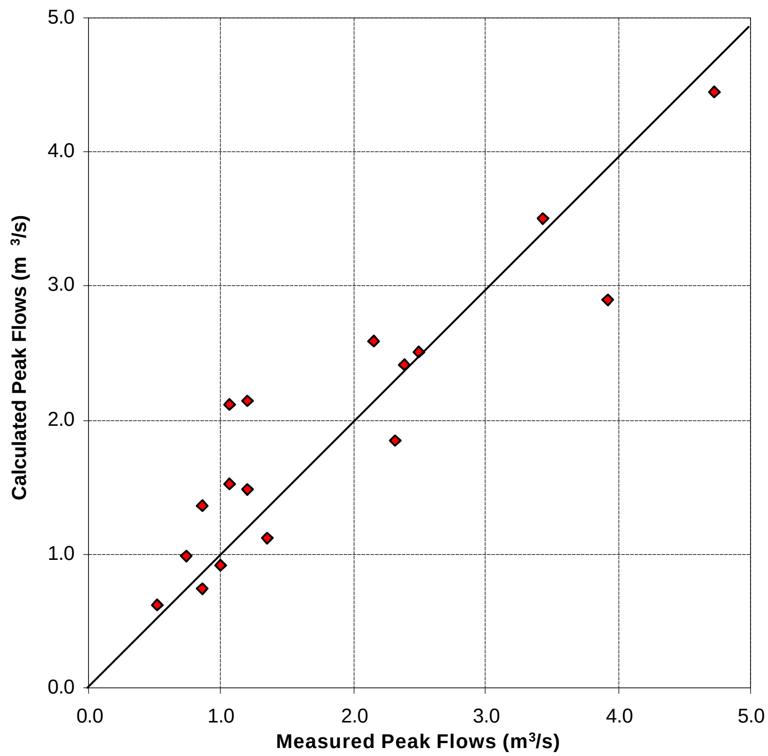


Figure 4. Measured and calculated peak flows at Reesor Cr. for the 1997-99 events.

Again, a satisfactory agreement between measured and calculated values for peak flow was achieved with a *CE* value of 0.753. To compare the good fit in this study, it is worth comparing these numbers with the work of Rode and Frede in Germany (Rode and Frede, 1997). For two catchments where AGNPS was applied, they calculated *CE* values of 0.81 and 0.89 for runoff, and 0.34 and 0.69 for peak flow rates. It is important to note that the peak flow rates are used to also estimate the sediment yield and nutrient concentrations in soluble form. So to have a good estimation of the peak flow will also provide a better agreement in soil erosion and nutrient loads. A summary of the *CE* for all the runs performed in this study is presented in Table 4, including the Reesor Creek calibration parameters values for peak flows, sediment and nutrients for the 17 events in 1997-99.

Table 3. Complete profile for the events selected from the 1997-99 sampling campaign and model results for Reesor Creek

Reesor Creek	Base	75 cells							Outlet Cell : 75	N rain = 1 ppm								
Event	**#**	**1**	***9*** [‡]	**10**	**11**	**13**	**14**	***15*** [‡]	**19**	**20**	**21**	**23**	**25**	**26**	**43**	**51**	**53**	**55**
Date	d-m-y	25/3/97	21/6/97	8/7/97	15/8/97	20/8/97	8/3/98	9/3/98	10/5/98	26/6/98	6/7/98	7/8/98	24/8/98	7/10/98	19/5/99	7/9/99	29/9/99	13/10/99
5day AMC	mm	3.2	*27.4*	14.4	12.5	22.8	13.2	*50.5*	8.5	1	11.9	11.4	7.4	0	8.2	22.1	9.1	21.8
14 API	mm	6.8	*28.2*	9.8	8.5	14.1	13.6	*52.1*	8.1	3.5	12.6	10.6	6.3	3.4	10.3	25.8	10.6	32.6
AMC/API	-	I	*II*	II	I	II	I	*III*	I	I	I	I	I	I	II	II	II	III
Precipitation	mm	17.2	*26.6*	11.1	19.9	10.8	11.0	*22.5*	25.4	14.1	19.1	14.0	43.7	18.8	12	12.5	39.4	26.6
Duration	hrs	9	*8*	5	5	9	4	*15*	14	6	8	6	5	7	9	8	15	10
Intensity	mm/hr	*1.9*	*3.3*	*2.2*	*4.0*	*1.2*	*2.8*	*1.5*	*1.8*	*2.6*	*2.6*	*2.6*	*8.7*	*2.7*	*1.3*	*1.6*	*2.6*	*2.7*
EI	-	1.83	*3.03*	1.58	2.34	1.17	0.75	*4.54*	3.27	0.97	1.47	0.94	12.46	1.58	1.41	1.11	8.13	2.57
Decay (N/P)	%	(5/30)	(8/26)	(7/25)	(5/20)	(8/20)	(6/23)	(7/27)	(7/30)	(5/20)	(6/26)	(10/26)	(8/26)	(5/20)	(10/26)	(9/25)	(10/30)	(12/35)
Storm Type	-	ST1	*ST1A*	ST2	ST1A	ST2	ST1A	*ST2*	ST1	ST1A	ST1A	ST1A	ST1A	ST1A	ST2	ST2	ST1	ST1A
AGNPS Results																		
Runoff	mm	na	*2.54*	na	na	na	na	*8.4*	na	na	na	na	3.3	na	na	na	4.6	5.8
Sediment-all[¶]	kg	9378	14286	4572	9429	3404	12243	48526	8667	9073	8352	9094	12619	8657	4318	4968	17882	28825
Sediment-no[¶]	kg	4958	5720	2855	5324	2286	8057	28774	4379	3465	3637	2378	8840	3841	2317	2113	12904	21682
Nitro Conc	ppm	3.73	*1.84*	4.20	3.41	3.79	4.40	*3.20*	2.38	4.19	3.16	2.46	2.21	3.54	3.02	3.41	2.34	3.55
Phos Conc	ppm	0.01	*0.05*	0.03	0.03	0.05	0.03	*0.06*	0.01	0.04	0.02	0.02	0.05	0.04	0.03	0.04	0.06	0.08
Peak Flow	m3/s	2.41	*1.84*	0.92	1.37	0.99	2.58	*4.45*	1.12	2.11	1.49	2.15	2.50	1.52	0.74	0.62	2.89	3.51
Nitro load[§]	kg	935.9	*157.8*	94.6	88.3	86.7	417.8	*930.2*	225.2	211.0	216.6	121.2	256.9	113.2	101.7	53.8	376.7	730.2
Phos load[§]	kg	1.76	*3.94*	0.77	0.88	1.14	2.85	*17.44*	0.95	2.01	1.37	0.99	5.81	1.28	1.01	0.63	9.66	16.45
Measured Values																		
Peak Flow	m3/s	2.39	*2.32*	0.99	0.86	0.74	2.15	*4.73*	1.35	1.06	1.20	1.20	2.50	1.06	0.86	0.52	3.92	3.43
Runoff	mm	7.14	2.13	0.64	0.74	0.66	2.69	5.77	2.69	1.42	1.96	1.40	2.08	0.91	0.96	0.45	3.89	6.45
Sediment	kg	8474	10874	2271	4741	1229	10593	43530	4323	3150	4809	4691	9900	7305	2089	2317	16830	26944
Nitro Conc	ppm	3.33	2.96	3.96	3.75	3.54	4.12	4.27	2.31	4.50	3.18	2.67	2.91	3.81	3.06	3.24	2.28	3.05
Phos Conc	ppm	0.006	0.038	0.0384	0.0608	0.0386	0.0326	0.0434	0.01	0.0385	0.025	0.018	0.027	0.0385	0.0325	0.046	0.067	0.068
Nitro load	kg	907.6	242.8	97.1	105.6	88.3	425.7	943.8	238.0	246.6	237.3	143.0	232.6	132.6	112.1	38.5	339.0	752.7
Phos load	kg	1.64	*3.59*	0.94	1.71	0.96	3.37	*18.41*	1.03	2.11	1.86	0.97	2.16	1.34	1.19	0.79	9.98	16.81
Partial Values for Total N																		
Nitrates	ppm	1.83	1.56	2.62	2.16	2.40	2.32	2.32	1.18	1.65	1.71	1.15	0.94	1.18	1.93	1.85	0.93	1.59
Nitrite	ppm	0.05	0.08	0.09	0.01	0.01	0.05	0.04	0.05	0.05	0.03	0.02	0.02	0.03	0.14	0.03	0.04	0.05
NTK	ppm	1.44	1.32	1.25	1.58	1.13	1.75	1.91	1.08	2.80	1.44	1.50	1.96	2.60	0.98	1.36	1.30	1.40
Nitrates load	kg	499.5	127.8	64.3	60.8	59.7	239.6	513.1	121.5	90.4	127.5	61.7	74.7	41.0	70.9	14.6	138.8	393.0
Nitrite load	kg	15.0	6.4	*2.3*	0.2	0.3	5.1	8.7	5.4	2.8	2.5	1.0	1.4	1.1	5.3	0.5	6.6	13.6
NTK load	kg	393.1	108.6	30.5	44.6	28.2	181.0	422.1	111.2	153.4	107.4	80.4	156.5	90.4	35.9	23.3	193.6	346.1

[‡]Events 9 (June 1997) and 15 (March 1998) with hourly data (radar precipitation, flows and sediments)

[§]If the AGNPS calculated runoff values <0.25mm, then the measured runoff was used to calculate the nitrogen and phosphorus loads

[¶]Ithe sediment all and no, refers to allowing all or none of the particle sizes to be scoured

Table 4. Coefficients of Efficiency (CE) for all Events in Duffins and Reesor Creeks

Event	Mean	$\Sigma(X_s-X_m)^2$	$\Sigma(X_o-X_s)^2$	CE
Duffins Creek (16 events)				
Peak flow 1x1km grid (m^3/s)	7.666	2242.548	401.623	0.821
Peak flow 2x2km grid (m^3/s)	8.035	2784.763	226.663	0.919
Duffins Creek (23 historic events)				
Runoff volume (mm)	6.140	1195.728	343.225	0.713
Reesor Creek (17 events)				
Peak flow (m^3/s)	1.953	17.198	4.244	0.753
Sediment yield-all (kg)	12604	1419.654	181.494	0.872
Sediment yield-none (kg)	7863	919.691	128.281	0.861
Nitrogen concentration (ppm)	3.225	9.188	3.877	0.578
Phosphorus concentration (ppm)	0.038	0.006	0.002	0.643
Nitrogen load (kg)	301	1348.192	14.155	0.990
Phosphorus load (kg)	4.056	462.714	16.029	0.965

Sediment and Nutrient Transport

As described earlier, for the sediment yields, two options were available to select for the calibration runs; allow all or none of the particle sizes to be scoured in the grid channel. As shown in the summary (Table 3), two runs for each event were performed, one allowing all the particle sizes to be scoured and the second one with none of them being allowed for channel scouring. This creates a range for the maximum and minimum values of sediment yield. The results from the model calculations for sediment yield are presented in Figure 5 with the dashed lines representing such a boundary range.

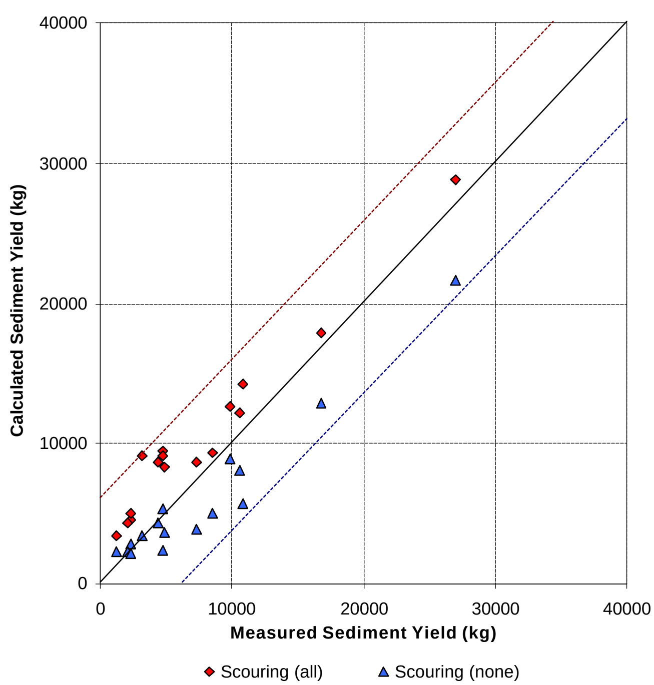


Figure 5. Measured and calculated sediment yield for the 1997-99 events.

As presented in Table 4, the *CE* values for sediment yield, when all of the particle sizes were selected for scouring is 0.872, and 0.861 when none is selected. As also noted in the work by Rode and Frede, such high values of *CE* (i.e. 0.85 and 0.93 for their two tested watersheds) show that the AGNPS model predicts the sediment yield quite satisfactorily.

The small difference between the values for full or no scouring, implies that either the overestimation or underestimation that this selection will produce on the sediment yield values, depending on allowing a particular aggregate size or not to be scoured, is roughly the same in absolute value. It is fairly safe to recommend that by running the model with the two options, the model will predict the range in which the real value of the sediment yield will fall.

In order to test the nutrient component with values as close as possible to the observed values, more accurate fertilizer rates for nitrogen and phosphorus had to be used as source for the nutrient input data. As mentioned in the data collection section, a survey of the farming practices and fertilizer use in Reesor Creek sub-watershed was commissioned by the Ontario Ministry of Environment and Toronto Region Conservation Authority in 1998 in support of the AGNPS model applications. The fertilizer rates and availability factors used in the model were obtained from this survey. Table 5 shows a summary of the lookup tables for the fertilizer rates values. These rates were propagated in the model grid as a function of the landuse coverage. As described earlier, the only parameters that were modified for the calibration runs on nutrient concentrations were the decay factors.

Table 5. Lookup Table for Fertilizer Values from the Reesor Cr. Survey (1998)

Fertilizer Lookup Table Land cover	Nitrogen Application (kg/ha)	Phosphorus Application (kg/ha)	Nitrogen Availability (%)	Phosphorus Availability (%)
Corn	110	22	60	50
Golf Course	90	17	30	30
Hay & Pasture + Idle	45	22	70	70
Red Clover	22	22	60	60
Residential	45	5	20	20
Soybeans	0	33	0	50
Winter Wheat	75	12	90	50
Woodlot	0	0	0	0

As noted from the summary table (Table 3), the resulting ranges for the nitrogen decay are between 5 and 12% and for phosphorus between 20 and 30%. These values were obtained by trial and error until a good match was obtained with the model. Nevertheless, the resulting decay coefficients are consistent with the recommendations in the AGNPS manual, which suggests percentages below 50% for both nutrients. In fact it was encouraging to find such a good agreement for all of the different events with such a small range of variation for the decay percentages. Due to the fact that just a few of the events produced enough calculated runoff, the nutrient loads for the rest of the events were calculated using the measured runoff. The comparison of measured and calculated concentrations and loads for both nitrogen and phosphorus is presented in Figures 6 and 7 respectively.

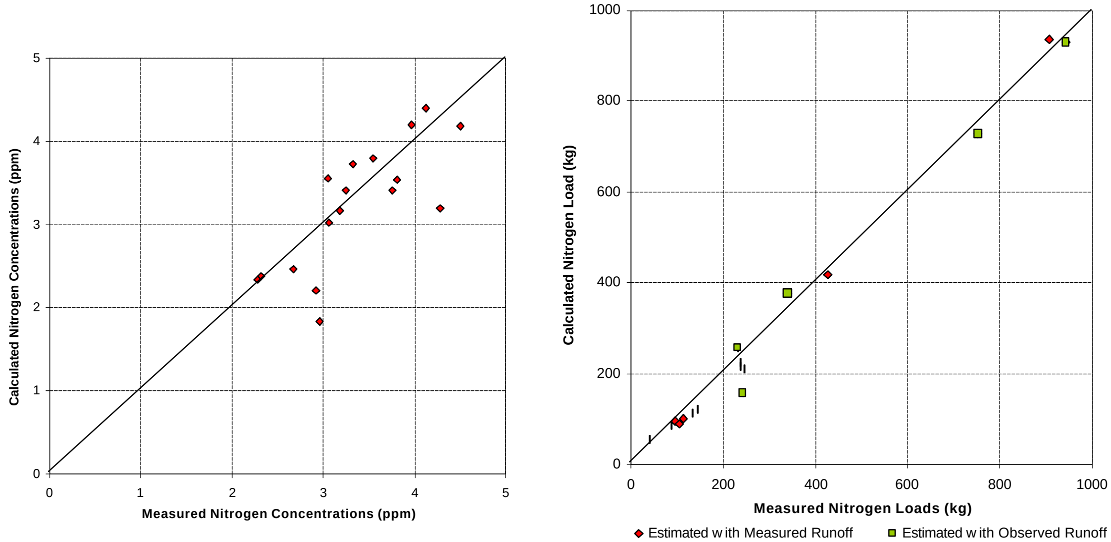


Figure 6. Nitrogen measured vs. calculated concentrations and loads.

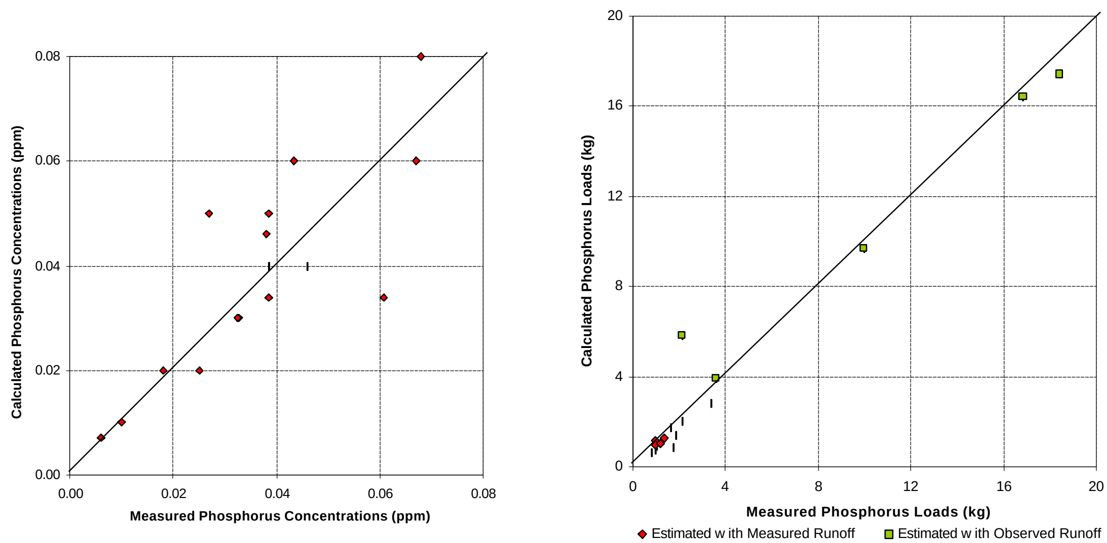


Figure 7. Phosphorus measured vs. calculated concentrations and loads.

The *CE* values for nutrient loads, as presented in the summary for the coefficients of efficiency (Table 4), are extremely high, 0.990 for nitrogen and 0.965 for phosphorus. This excellent agreement contrasted with the evident dispersion on the concentration values, with *CE* values of 0.578 and 0.643 for nitrogen and phosphorus respectively. This can be explained by the small numeric values of the concentrations and then improving, showed by the narrowing between observed and measured load values, when the nutrient loads are calculated with a better predicted or observed runoff value and by increasing the numeric quantity as a result of including the drainage area as part of the loads estimation process.

CONCLUSIONS

Typically, the best use for nonpoint source models is for comparative analysis between different scenarios. This involves modifying parameters to account for the desired change in conditions. The capability to undertake rapid “what if” scenarios, in defining and managing future land use, will be critical in maintaining the ecological function of urbanizing watercourses. It is not expected to be able to predict accurate concentrations of nutrients as it is an event model that is highly sensitive to antecedent conditions.

Nevertheless, with these restrictions in mind, it is capable of predicting realistic estimates if the parameter values are assigned correctly. This means that the model can be used to confidently evaluate the changes in watershed hydrology, sediment yield and nutrient loads caused by modifications in land use. In this study, the model has been evaluated for a wide range of storm events and provided realistic estimates of nutrient loads in runoff water.

By linking the model to a decision support system with a user-friendly technical interface, the model can be applied very efficiently to different types of watersheds and for a wide range of planning scenarios and to evaluate best management practices. The combination is much more useful than just linking the AGNPS to a GIS system.

The model appears to be well suited to applications in southern Ontario and should prove to be a valuable tool in watershed management. It can be used to gain an understanding of current water quality/runoff conditions in watersheds lacking monitoring data and as a useful tool to design and evaluate BMPs. The user-friendly interface has already allowed conservation authorities within southern Ontario to be able to apply the model very quickly and effectively for watershed management studies.

ACKNOWLEDGEMENTS

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REFERENCES

Bingner, R.L., C.E. Murphree and C.K. Mutchler. 1989. Comparison of sediment yield models on watersheds in Mississippi. Transactions of the ASAE 32(2): 529-534.

Bowen,.G., Kay D., Lam D.C., and Booty, W.G.. (1995). Environmental Databases Duffin’s Creek Watershed. Duffin’s Creek Project Technical Report 95-2, MOEE.

Choi, K.S., and E. Blood. 1999. Modeling developed coastal watersheds with the Agricultural Non-Point Source Model. Journal of the American Water Resources Association. Vol. 35, No. 2, 233-244.

Finney, V.L., Cocke, M.A., Moorhead, S.T., Klug, J. (1995). Nutrient Analysis of the Malibu Watershed Using the AGNPS Model. Animal Waste and the Land-Water Interface, Ed. Kenneth Steele, Lewis Publishers, pp. 305-312.

Foster, G.R., Lane, L.J., Nowlin, J.D., Laflen, J.M., and Yountg, R.A., (1980). A Model to Estimate Sediment Yield from Field-Sized Areas: Development of the Model. In: Knisel, W.G. (ed.) 1980. *CREAMS:* A Field Scale Model for Chemicals, Runoff, and Erosion from Agricultural Management Systems, USDA, Cons. Research Report No. 26, pp. 36-63.

Frere, M.H., J.D. Ross, and L.J. Lane. 1980. The Nutrient Submodel. In: CREAMS, A Field Scale Model for Chemicals, Runoff, and Erosion from Agricultural Management Systems. U.S. Dept. Agric., Conservation Research Report 26, pp. 65-85.

He, C., J.F. Riggs, and Y.T. Kang. 1993. Integration of Geographic Information Systems and a Computer Model to Evaluate Impacts of Agricultural Runoff on Water Quality. Water Resources Bulletin, Vol. 29, No. 6, 891-900.

Hession, W.C. and K.L. Huber. 1989. BMP effectiveness using AGNPS and a GIS. American Society of Agricultural Engineers, 1989 International Winter Meeting. Paper No. 89-2566.

JDE Ventures, 1998. 1998 Survey of Farming Practices and Fertilizer use in the Stouffville and Reesor Creeks Watershed for AGNPS Model Application, A final report to the Ontario Ministry of Environment, Standards Development Branch and the Toronto Region Conservation Authority, 15p.

Koelliker, J.K. and C.E. Humbert. 1989. Applicability of AGNPS model for water quality planning. ASAE Paper No. 89-2042.

Knisel, W.G. 1980. CREAMS: A field-scale model for chemicals, runoff and erosion from agricultural management systems. Conservation Research Report No. 26. USDA-SEA: Washington, D.C.

Lam, D.C.L. and D.A. Swayne. 1993. An expert system approach of integrating hydrological database. Models and GIS: application of the RAISON system. In: Kovar, K., Nachtnebel, H.P. (Eds.), Application of GIS in Hydrology and Water Resources Management. IAHS Publication No. 211, Wallingford, UK, pp.23-33.

Leon, L.F., (1999). Integral System for Nonpoint Source Pollution Modeling in Surface Waters, Ph. D. Thesis, Civil Engineering, University of Waterloo, Waterloo, Canada.

Mostaghimi, S., Park, S.W., Cooke, R.A., and Wang, S.Y. (1997). Assessment of Management Alternatives on a Small Agricultural Watershed, Wat. Res. Vol. 31, No 8, pp. 1867-1878.

Nash, J.E., and V. Sutcliffe. 1970. River flow forecasting through conceptual models, I. A discussion of principles. J. Hydrol. (Amsterdam) 10: pp.282-290.

Perrone, J. and C.A. Madramootoo. 1998. Improved curve number selection for runoff prediction, *Can. J. Civ. Eng*. 25, pp. 728-734.

Rode, M., and H.G. Frede. 1997. Modification of AGNPS for Agricultural Land and Climate Conditions in Central Germany, J. Environ. Qual., 26:pp.165-172.

Sugiharto, T., T.H. McIntosh, R.C. Uhrig, and J.J. Lardinois. 1994. Modeling alternatives to reduce dairy farm and watershed nonpoint source pollution. J. Environ. Qual. 23: 18-24.

Tim, U.S. and R. Jolly. 1994. Evaluating agricultural nonpoint-source pollution using integrated geographic information systems and hydrologic/water quality model. Journal of Environmental Quality 23: 25-35.

Young, R.A., C.A. Onstad, D.D. Bosch, and W.P. Anderson. 1989. Agricultural nonpoint source pollution model for evaluating agricultural watersheds. Journal of Soil and Water Conservation 44(2):168-173.

Young, R.A., C.A. Onstad, D.D. Bosch, and W.P. Anderson. 1994. Agricultural Nonpoint Source Pollution Model, Version 4.03, AGNPS User's Guide. St. Paul, Minn. Pollution Control Agency and USDA-ARS: Washington, DC.

Appendix C

Priority Source Area Maps for Suspended Sediment and Phosphorus Under Existing Conditions

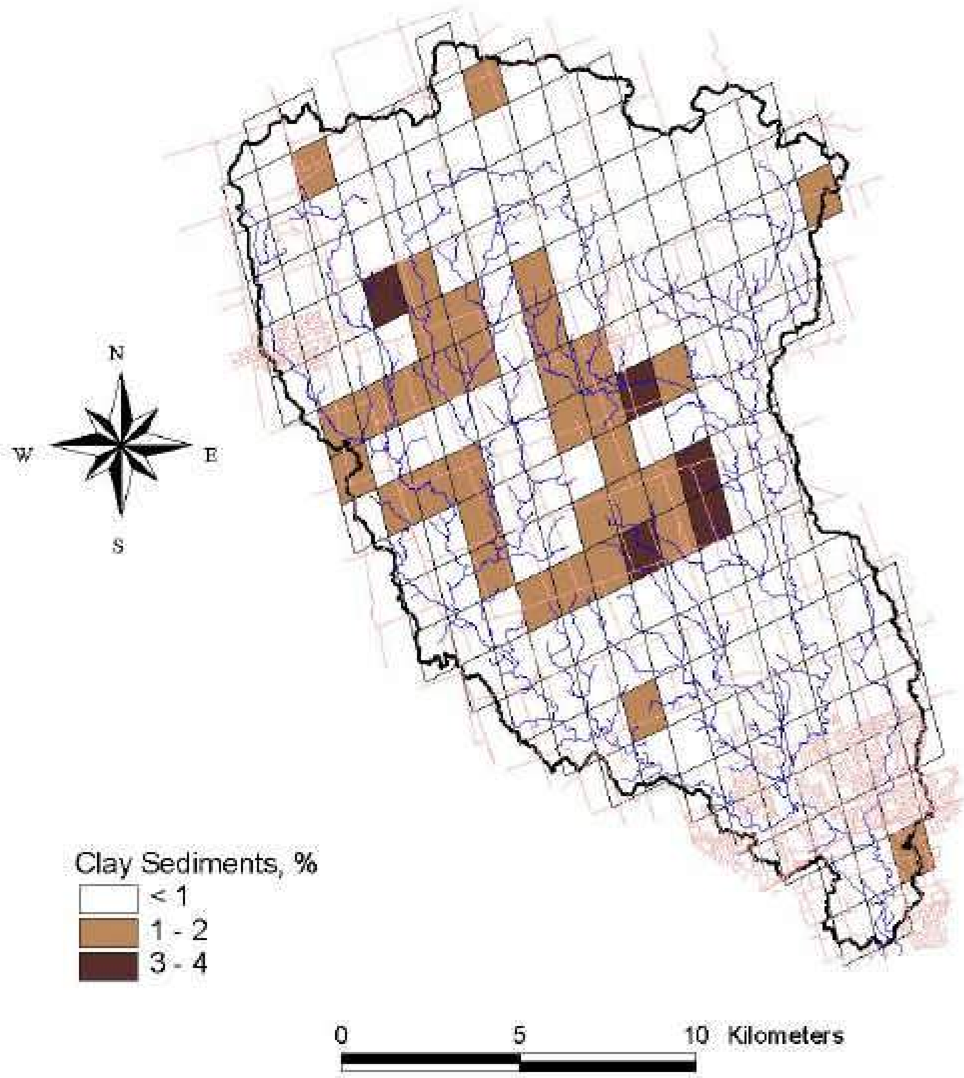

Figure C1: Whole Duffins Watershed: Predominant source areas for clay-sized sediment particles, which make up the largest proportion (80%) of the total sediment load. The trace source contribution analysis is based on a 25 mm, 12-hour storm event.

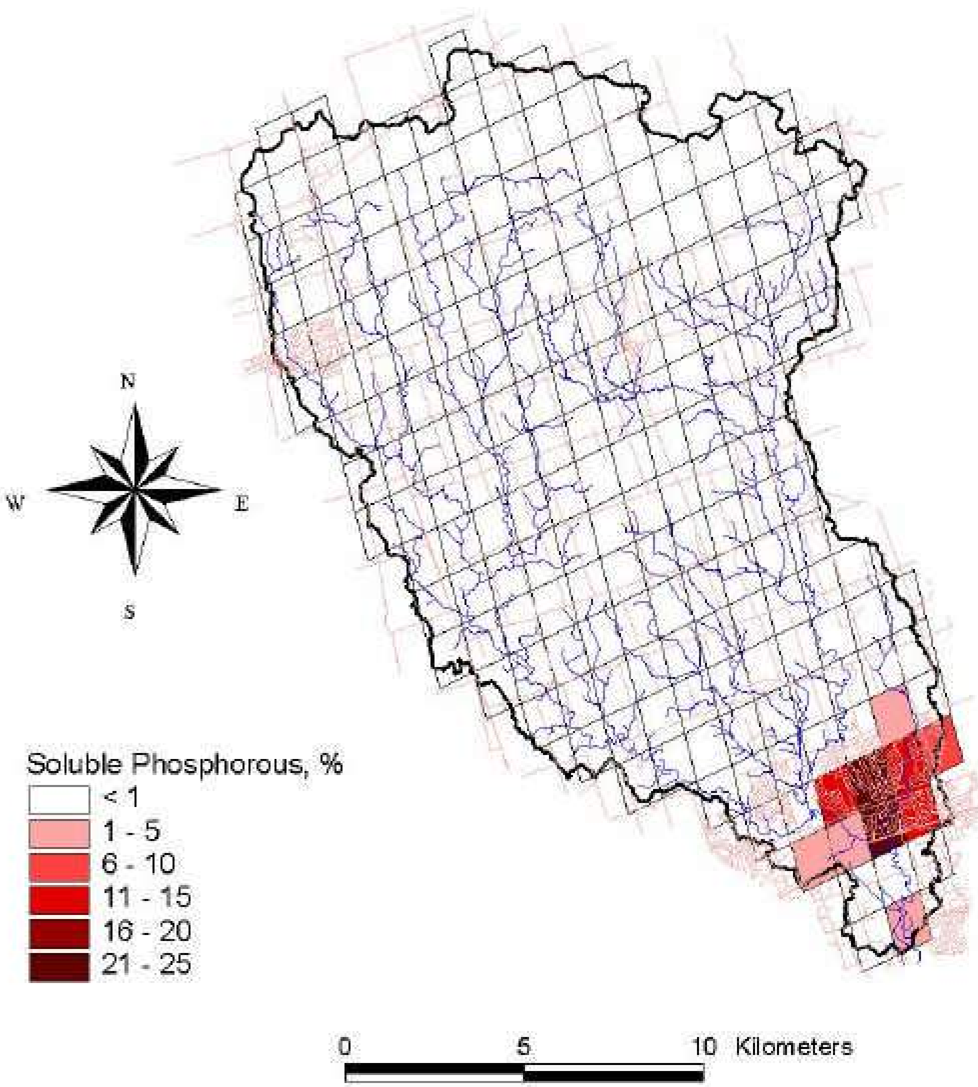

Figure C2: Whole Duffins Watershed: Predominant source areas for phosphate (soluble phosphorus). The trace source contribution analysis is based on a 25 mm, 12-hour storm event.

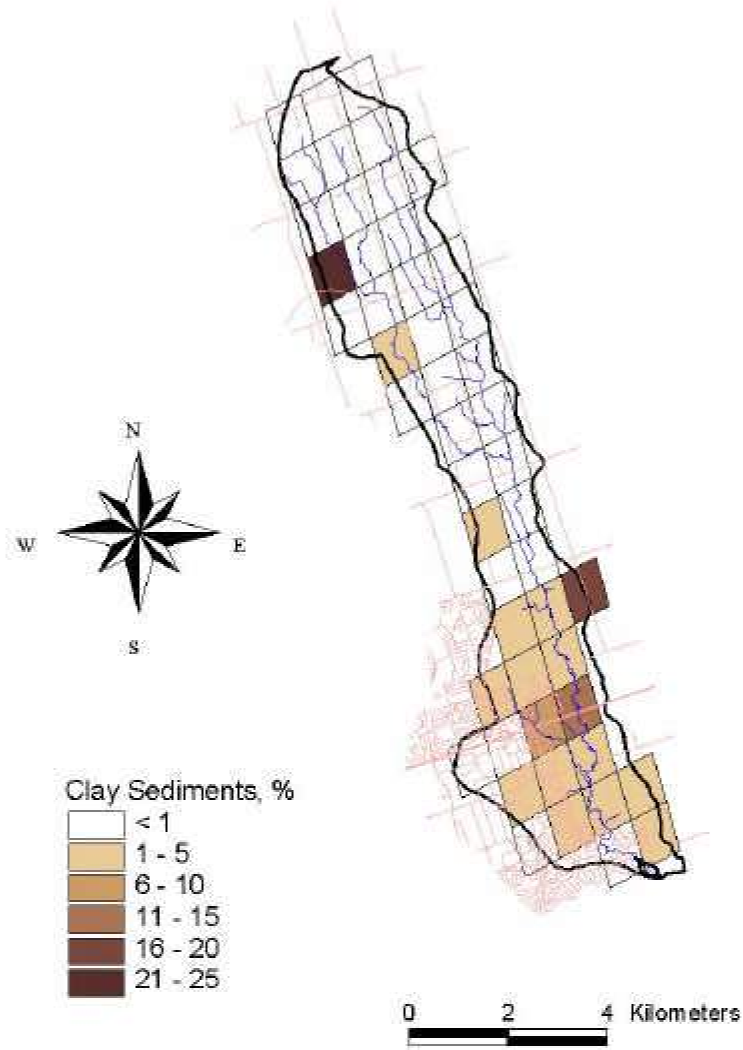

Figure C3: Whole Carruthers Watershed: Predominant source areas for clay-sized sediment particles, which make up the largest proportion (40%) of the total sediment load. The trace source contribution analysis is based on a 25 mm, 12-hour storm event.

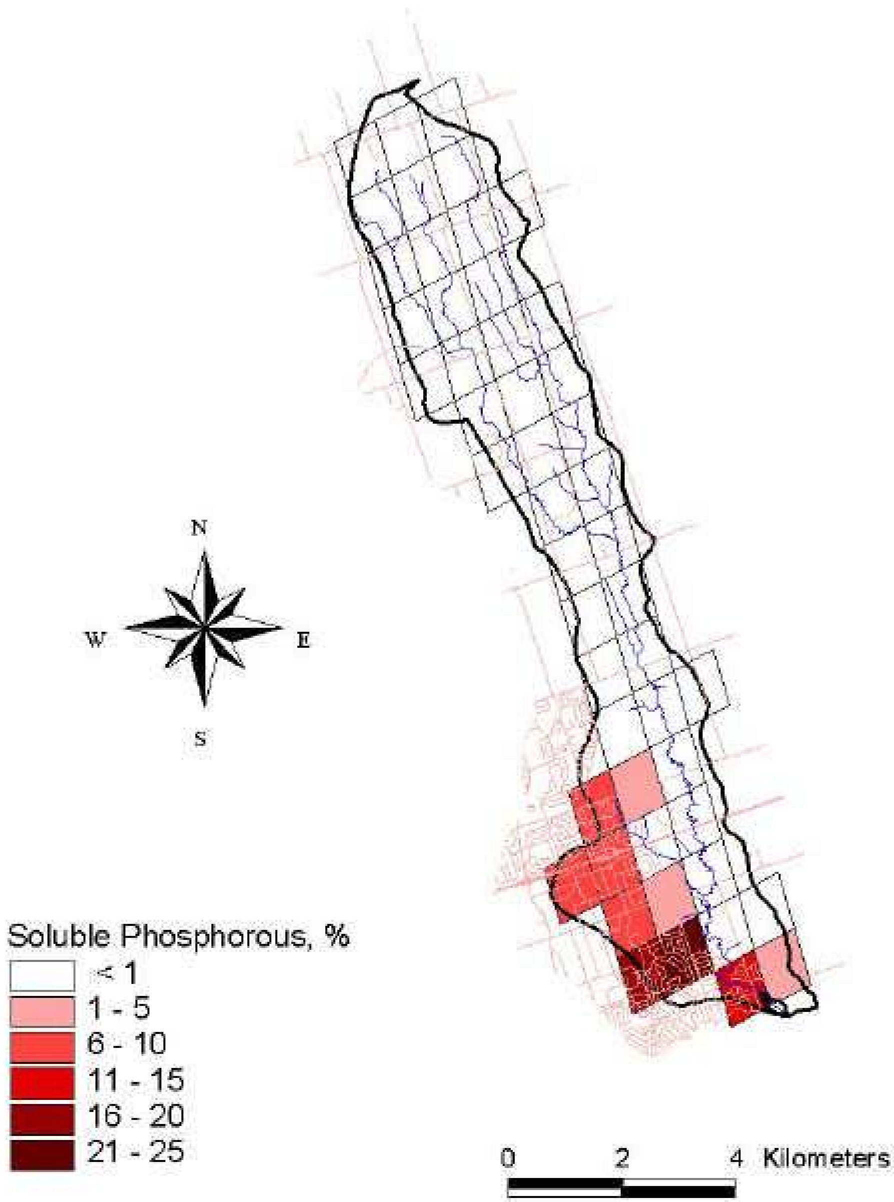

Figure C4: Whole Carruthers Watershed: Predominant source areas for phosphate (soluble phosphorus). The trace source contribution analysis is based on a 25 mm, 12-hour storm event.

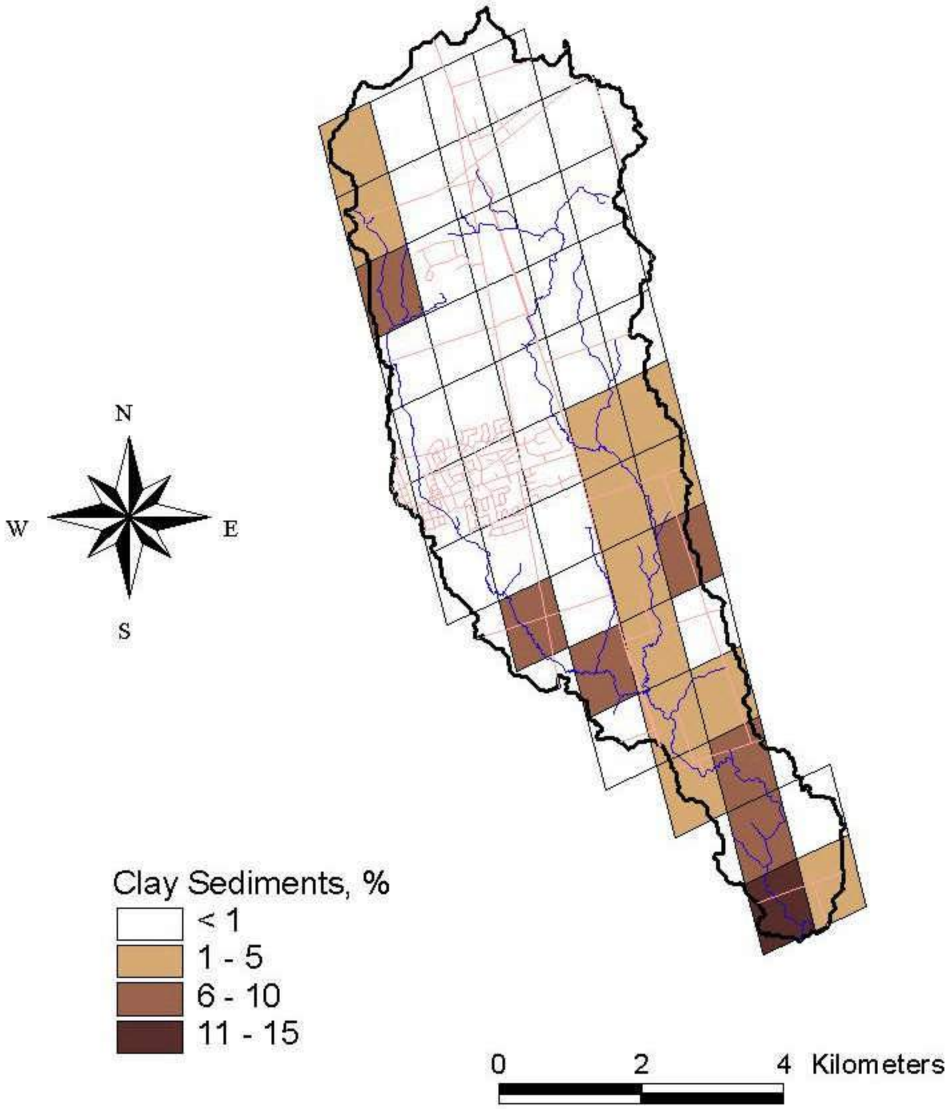

Figure C5: Reesor-Stouffville Subwatershed: Predominant source areas for clay-sized sediment particles, which make up the largest proportion (55%) of the total sediment load. The trace source contribution analysis is based on simulation of a 25 mm, 12-hour storm event.

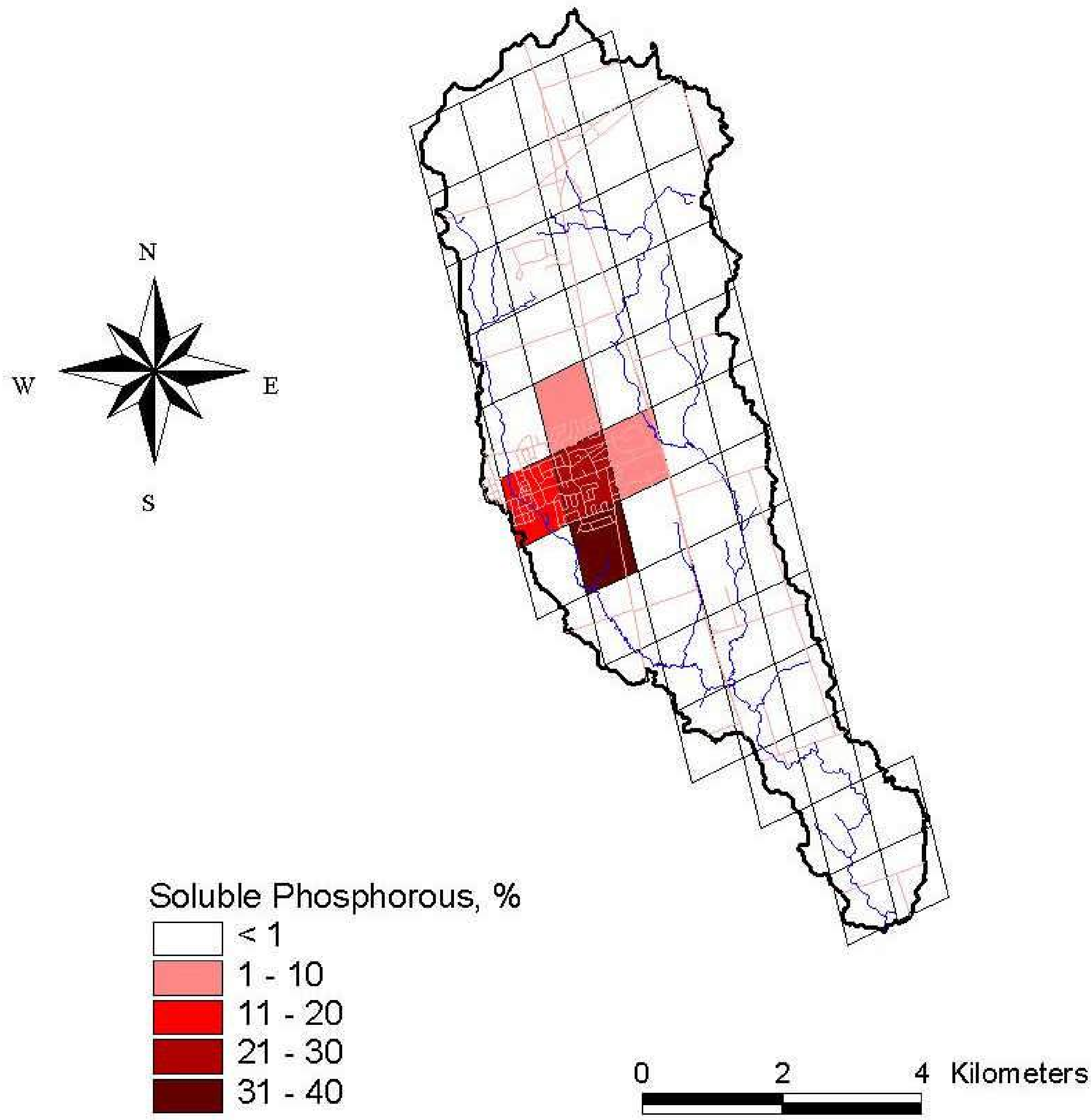

Figure C6: Reesor-Stouffville Subwatershed: Predominant source areas for phosphate (soluble phosphorus). The trace source contribution results are based on simulation of a 25 mm, 12-hour storm event.

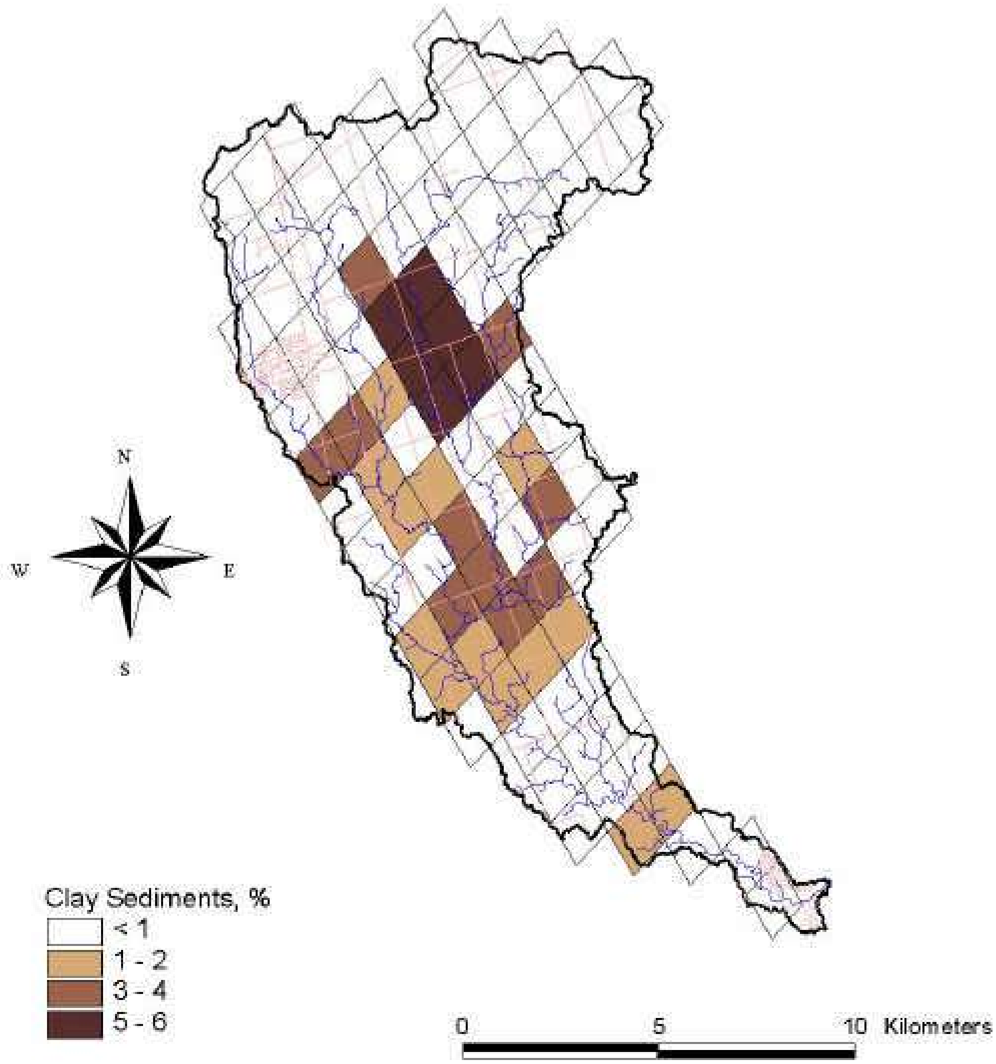

Figure C7: West Duffins Subwatershed: Predominant source areas for clay-sized sediment particles, which make up the largest proportion (54%) of the total sediment load. The trace source contribution analysis is based on simulation of a 25 mm, 12-hour storm event.

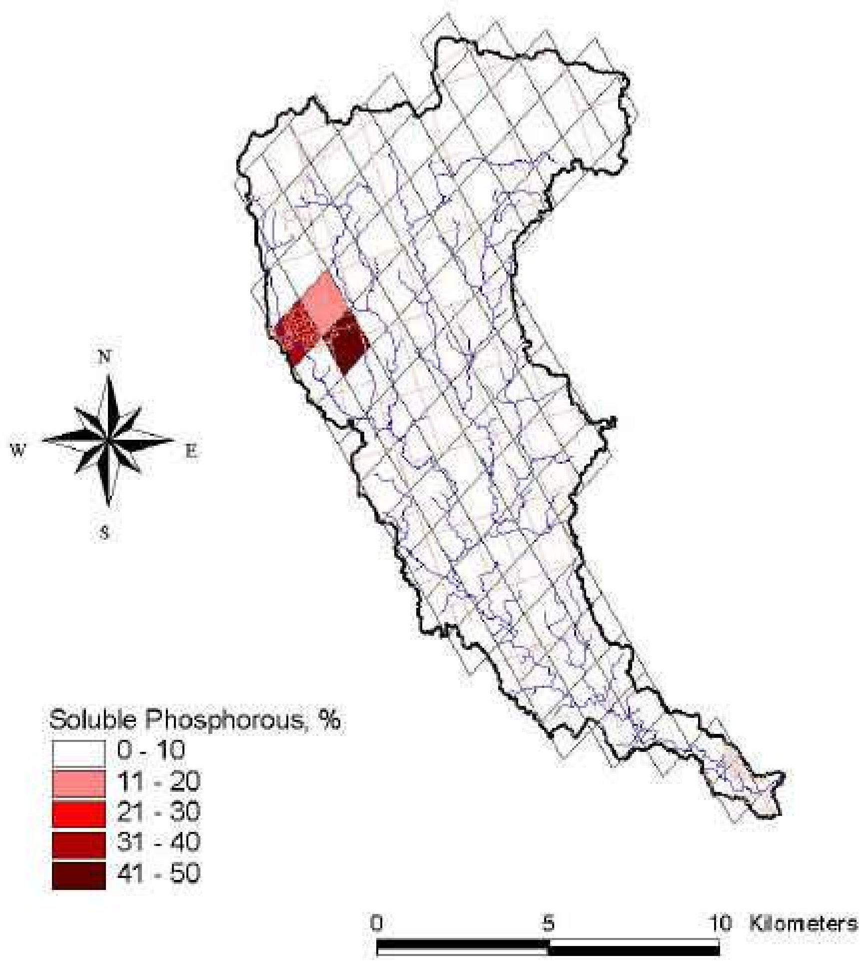

Figure C8: West Duffins Subwatershed: Predominant source areas for phosphate (soluble phosphorus). The trace source contribution analysis is based on the 25 mm, 12-hour storm event.

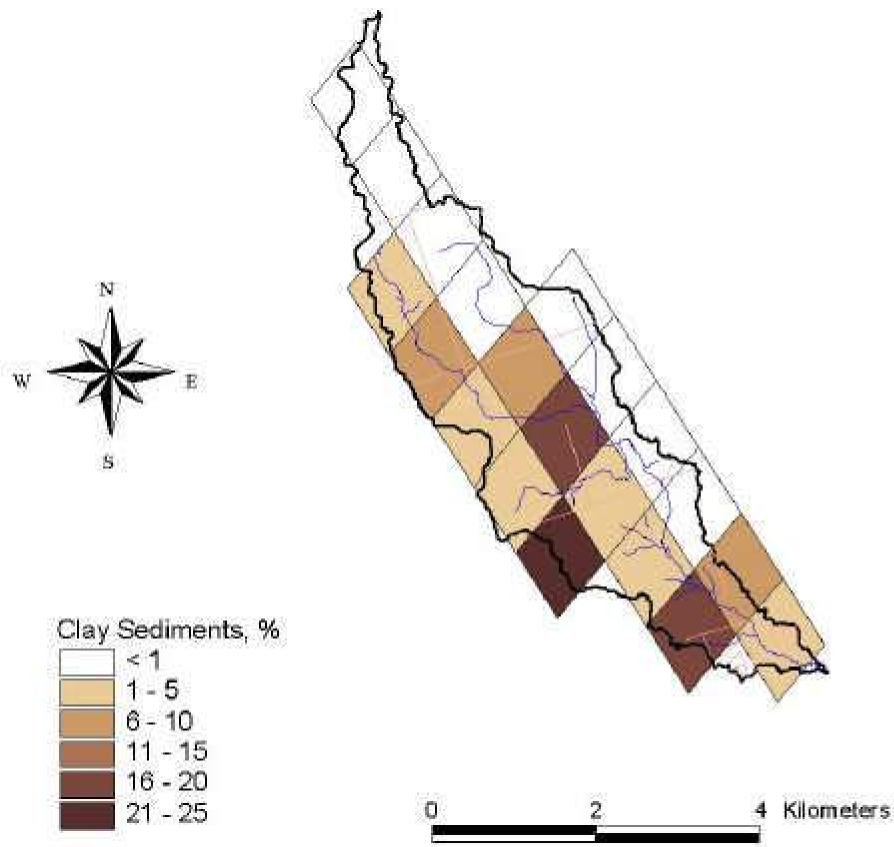

Figure C9: Ganatsekiagon Subwatershed: Predominant source areas for clay-sized sediment particles, which make up the largest proportion (87%) of the total sediment load. The trace source contribution analysis is based on the 40 mm, 12-hour storm event.

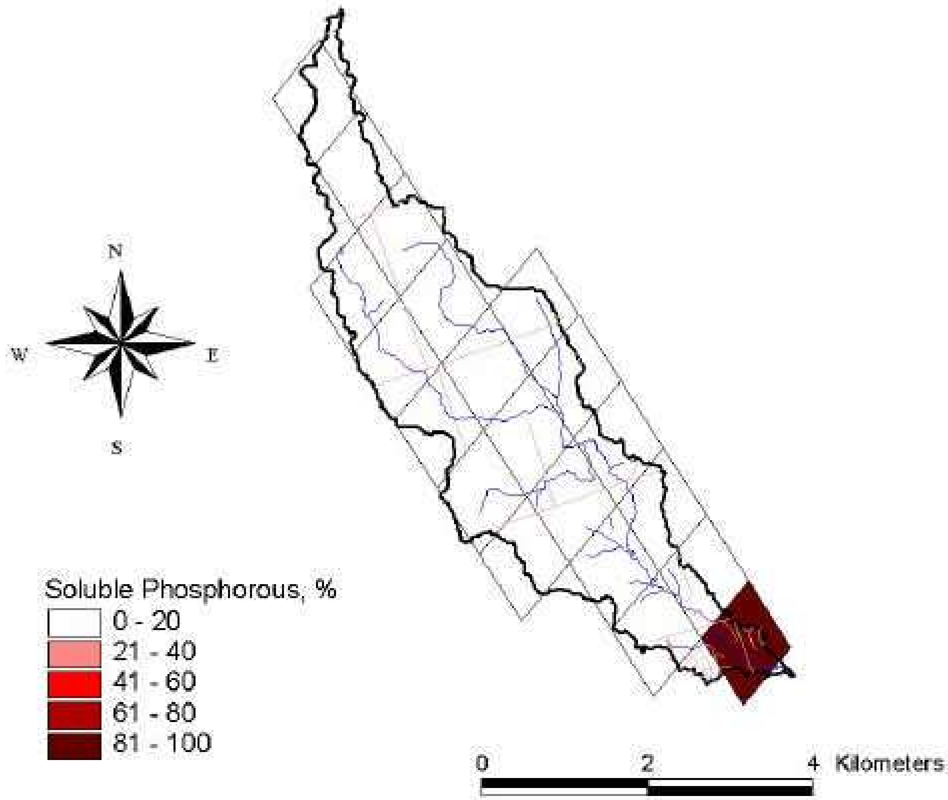

Figure C10: Ganetsekigon Subwatershed: Predominant source areas for phosphate (soluble phosphorus). The trace source contribution analysis is based on simulation of a 40 mm – 12-hour storm event.

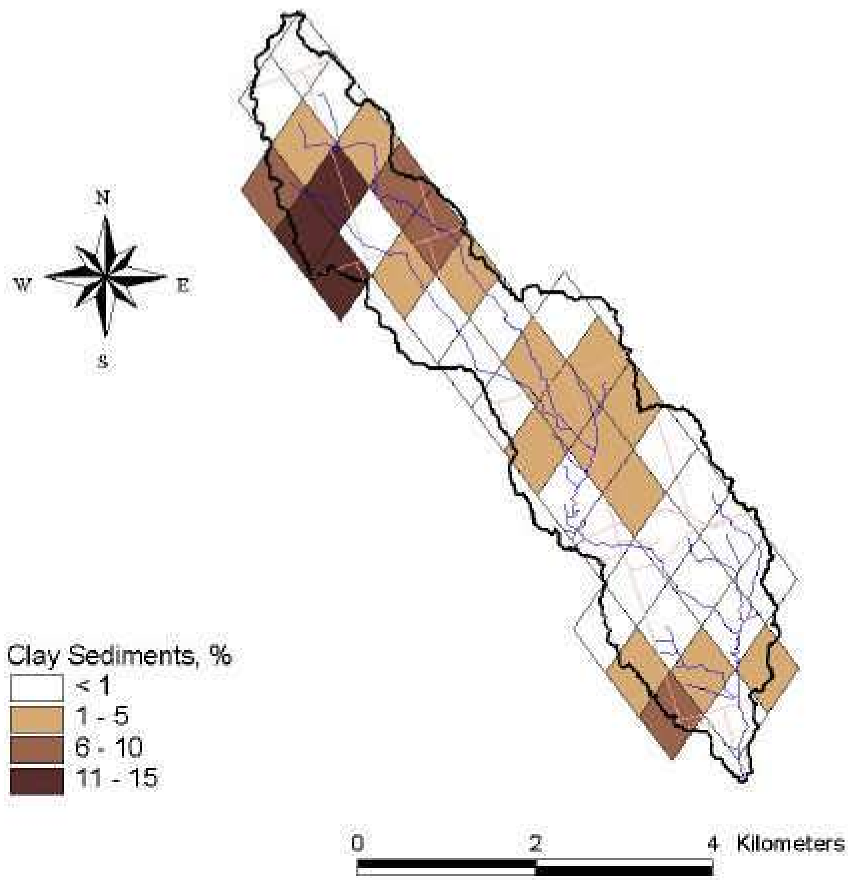

Figure C11: Urfe Subwatershed: Predominant source areas contributing to the clay-sized sediment particles, which make up the largest proportion (68%) of the total sediment load (7.2 tons). Based on the trace source contribution results of the 38 mm – 12-hour storm event.

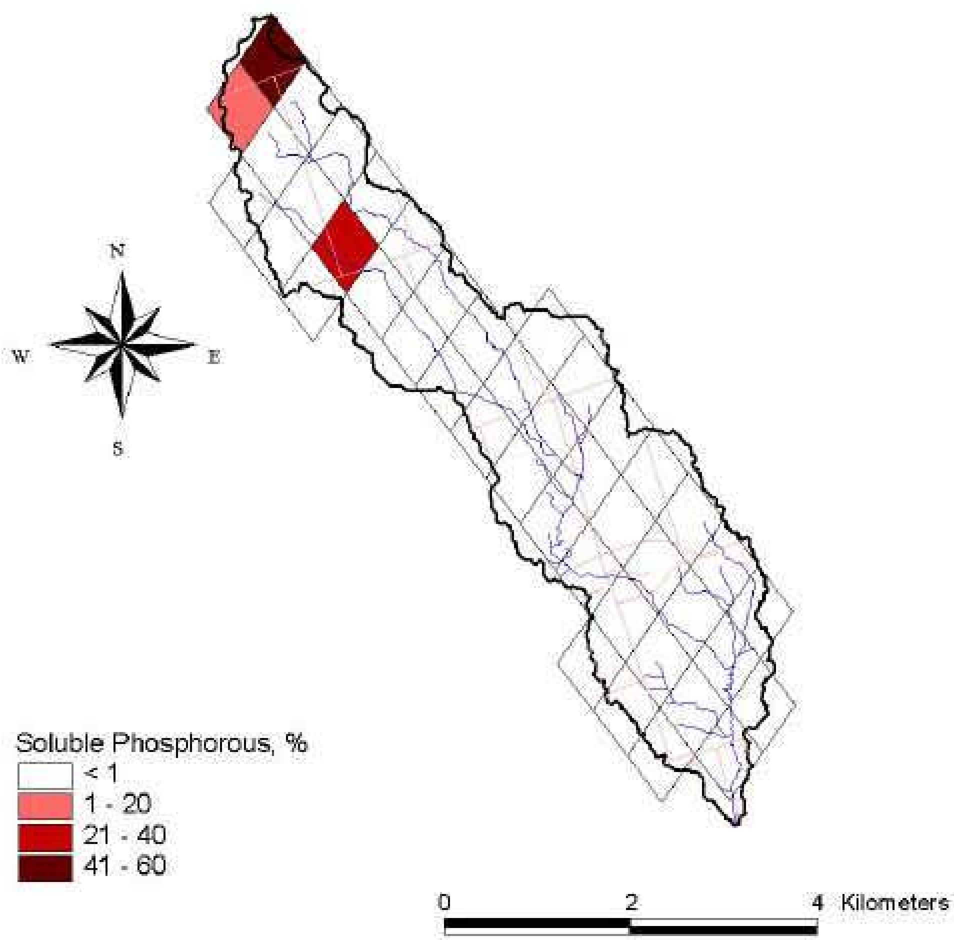

Figure C12: Urfe Subwatershed: Predominant source areas for phosphate (soluble phosphorus. The trace source contribution analysis is based on simulation of a 40 mm, 12-hour storm event.

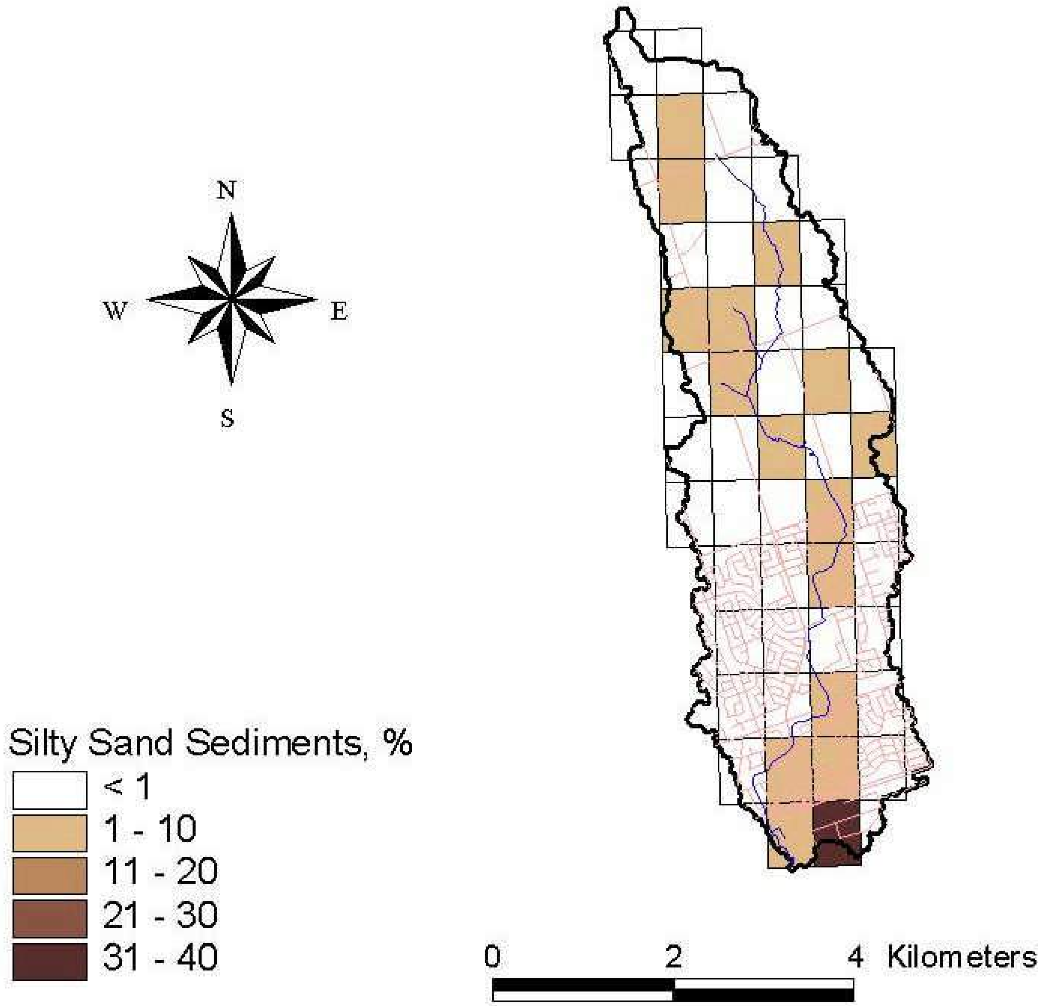

Figure C13: Millers Subwatershed: Predominant source areas for silty-sand sized sediment particles, which make up the largest proportion (31%) of the total sediment load. The trace source contribution analysis is based on a 25 mm, 12-hour storm event.

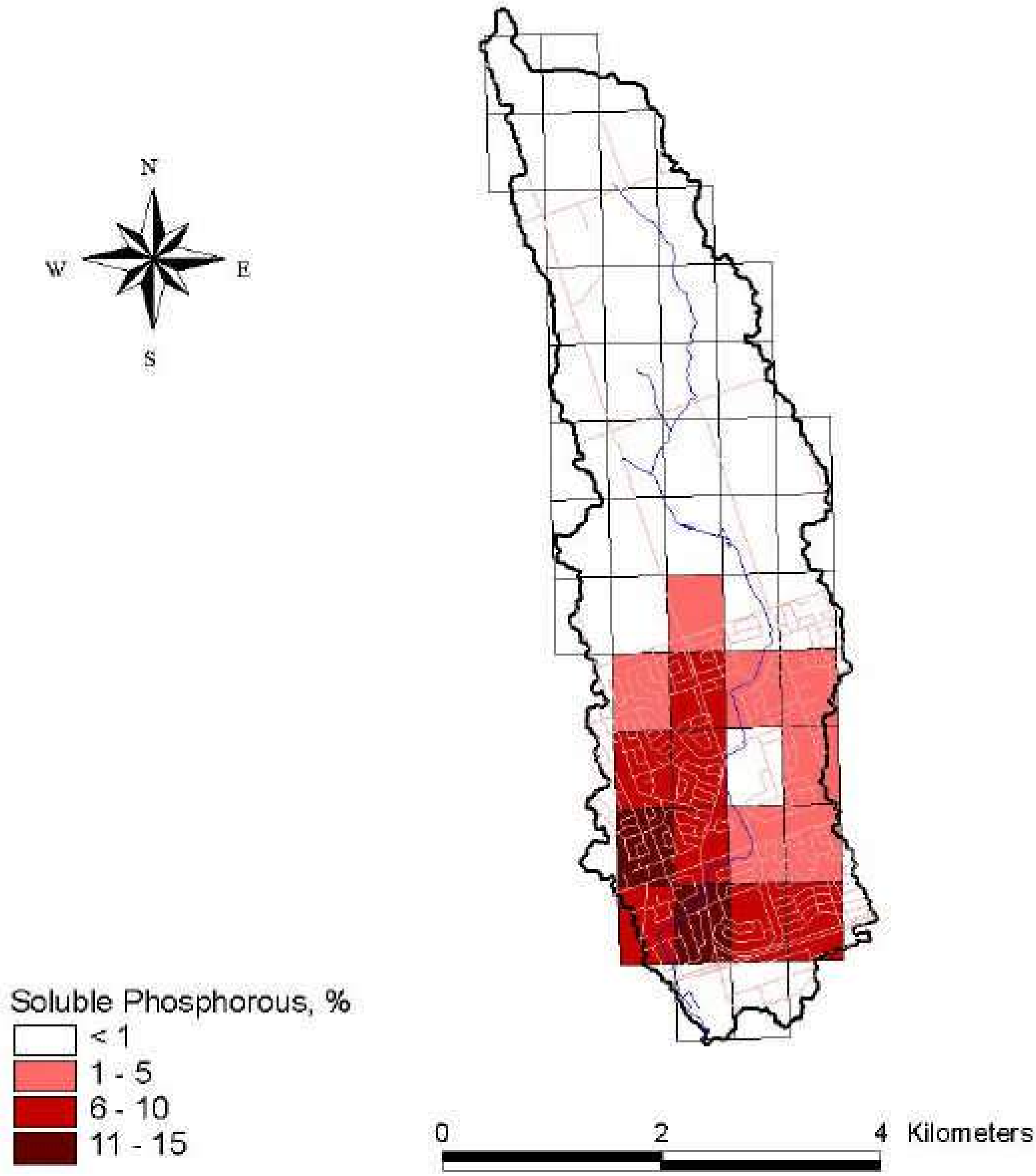

Figure C14: Millers Subwatershed: Predominant source areas for phosphate (soluble phosphorus). The trace source contribution analysis is based on simulation of a 25 mm, 12-hour storm event.

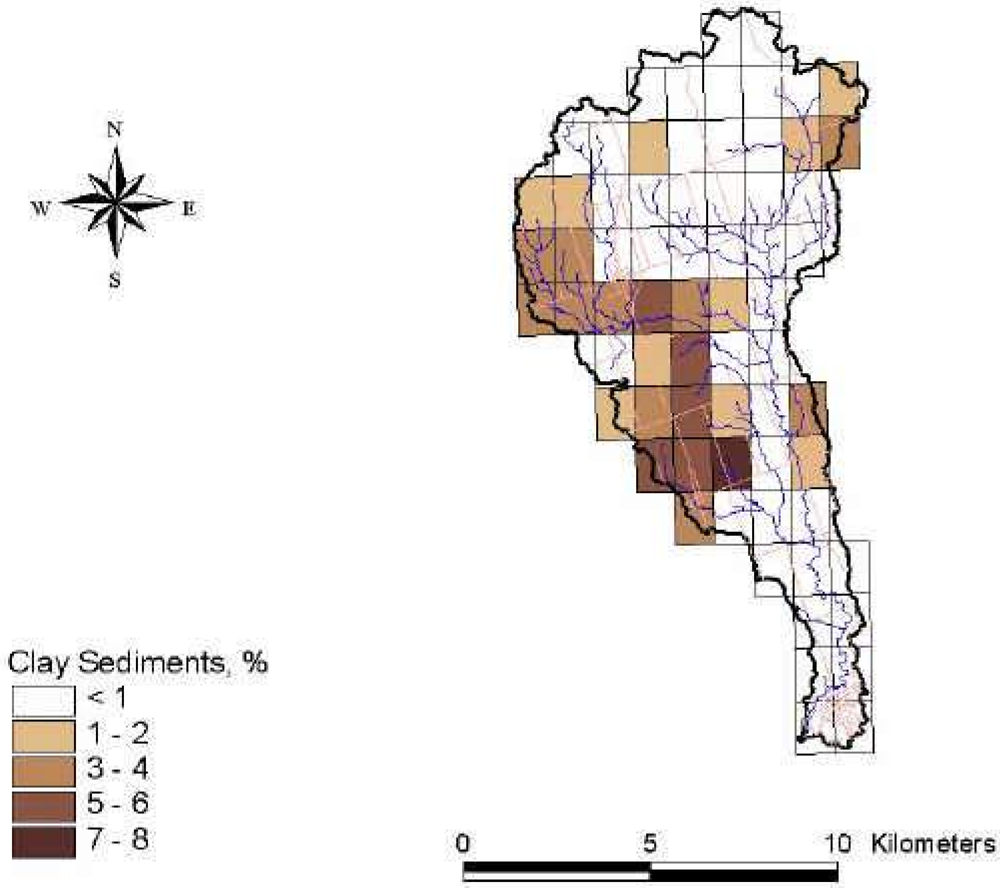

Figure C15: East Duffins Subwatershed: Predominant source areas for clay sized sediment particles, which make up the largest proportion (71%) of the total sediment load. The trace source contribution analysis is based on a 30 mm, 12-hour storm event.

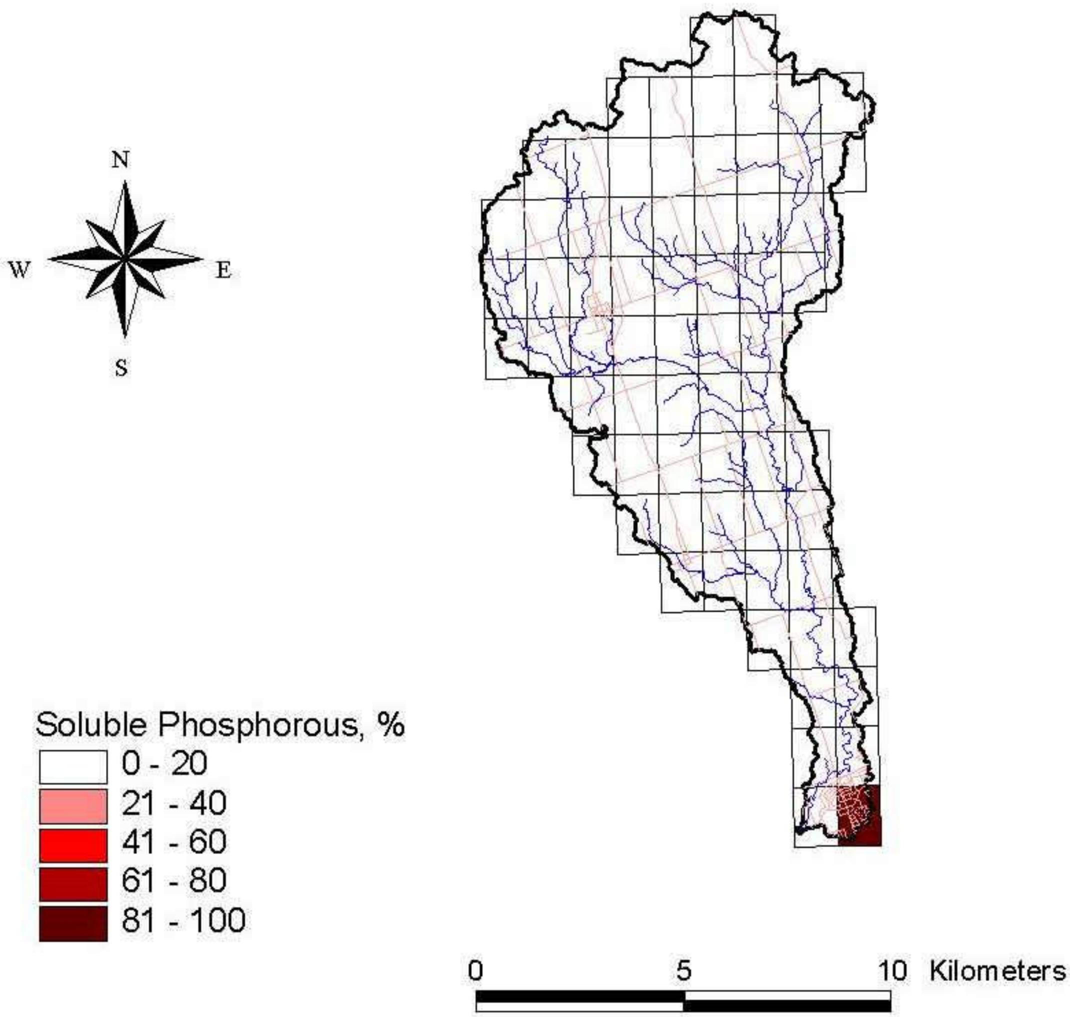

Figure C16: East Duffins Subwatershed: Predominant source areas for phosphate (soluble phosphorus). The trace source contribution analysis is based on simulation of a 30 mm, 12-hour storm event.

DUFFINS AND CARRUTHERS CREEKS

LOW FLOW MANAGEMENT

T.R.C.A

February 14, 2003

DUFFINS CARRUTHERS
LOW FLOW MANAGEMENT

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APPENDICES

DUFFINS AND CARRUTHERS CREEKS
LOW FLOW MANAGEMENT

1)____TRCA ROLE/INTEREST IN LOW FLOW

The Toronto and Region Conservation Authority (TRCA) is a watershed based natural resource management agency with an interest in understanding and working with our partners in managing aspects of the Hydrologic Cycle.

The flow regime within a watershed can be viewed as having two stages, " High Flow " and " Low Flow ". When a rainfall or snowmelt event occurs, additional water is introduced into the surface watercourses resulting in higher flows, velocities and water levels. These High Flow conditions tend to result in erosion and flooding conditions. During the majority of time however, the flow sustained in our rivers and streams is supplied from ground water or discharge from wetlands. This portion of the flow regime is referred to as Low Flow, or is often referred to as " Baseflow "..

The development of an understanding of the connections between the ground water system and the surface system is required to be fully able to manage the overall watershed system.

1.1) BACKGROUND

During the past decade, the role of the Authority has evolved from mangers of Flood Control within our watersheds to one of Watershed Managers based more on an ecosystem approach. To fulfill this role, issues related to all aspects of the flow regime within our rivers and streams and the interconnections to all aspects of the hydrologic cycle need to be included in the development of our watershed management strategies and policies.

The traditional role and strategies of the Authority for dealing with high flow extremes over the last 40 years has become entrenched within the land use planning and development process. Designing new development projects to ensure protection against flooding is well understood by our client groups.

The Authority in keeping with an ecosystem approach, has also recognised the need to develop a strategy to deal with the significant component that low flows represent in terms of the bulk of total stream discharge. The development of an understanding of these flows on a watershed basis and the range in fluctuation of these flows is necessary in order for the Authority to be in a position to fully manage our water resources.

The development of a Plan and component strategies related to managing the low flow resources on a watershed basis and to develop the level of client understanding and compliance we have related to the flood issues, will require an ongoing effort.

1.2) MANAGEMENT COMPONENTS

The development of a comprehensive Low Flow Management Plan begins with the identification of the principle components and issues pertinent within the watershed. The following represents a generic listing within the Duffins and Carruthers Creek's watersheds.

- an understanding of the location and mechanisms of ground water recharge areas within the watershed,
- an understanding of the location and mechanisms of ground water discharge within the watercourses of each watershed,
- the location, use and quantity of all significant water taking's within each watershed,
- the development of a water budget for each watershed at an applicable scale to allow for the assessment of hydrologic impacts (re: recharge amounts) associated with proposed land use change.,
- the development of a calibrated ground water model, linking recharge to discharge, in order to link land use change impacts to potential changes in low flow.
- a drought management plan to deal with events affecting the watersheds ability to sustain low flows (ie: future water needs assessment),
- a plan to manage water quantity within the watershed,
- an understanding of the connection of low flows to aquatic habitat and species.

All of the above components are required to form a comprehensive Low Flow Management Plan. Components such as the water budget, ground water model and defining recharge areas are components being undertaken as part of the overall Duffins and Carruthers Creek watershed strategy. However, input from these activities have been integrated within the final watershed Low Flow Management Plan.

2) RECHARGE/DISCHARGE OF GROUND WATER

The two principal components to understanding the watershed low flow system relate to how water from rainfall or snowmelt enters, is stored and moves within the sub-surface geology and where, and at what rate it is released into the surface watercourses. An understanding of these process's is required to effectively manage the low flow regime within the Duffins and Carruthers watersheds

2.1.1) Recharge

In the Duffins and Carruthers Creek watersheds, a comprehensive model of how the ground water system operates has been developed through a separate initiative. This modelling is based upon an understanding of the surficial soils and the underlying geology to define the aquifer systems which collect and allow for the movement of ground water between the Oak Ridges moraine and Lake Ontario. The detailed understanding of this process allows for the;

- identification of key recharge areas by watershed(watershed geology/soils),
- investigation of options related to protection of these areas through processes such as land use planning, acquisition, stewardship etc..
- investigation of options related to managing or mitigating impacts associated with land use change. (re: maintaining infiltration volumes)

2.1.2) Discharge

Lowflow monitoring and mapping was undertaken to provide an indication of stream reaches receiving groundwater discharge or flow losses, through either natural processes (i.e. recharge) or human induced water withdrawals.

This observed baseline data and mapping, under existing land use conditions, was used as a reference in:

- interpreting the predicted changes from future land use scenarios,
- evaluating the impacts of water withdrawals and;
- investigation of options related to protection of or management of these areas (ie: land use planning, acquisition, stewardship etc.)

2.1.3) Low Flow Assessment Duffins and Carruthers Creek's

Baseflow measurements were undertaken by Authority staff on the Carruthers Creek watershed in 2000, based upon Water Survey of Canada flow measurement standards and a sampling protocol originally developed by the Geologic Survey of Canada (GSC) during its sampling program on the Duffins Creek watershed in 1995 and 1996. The GSC sampling protocol was used by TRCA, to ensure that a baseflow condition existed following any precipitation event. Given the hydrologic response of the TRCA watersheds, a 72 hour period was established as the minimum time to wait following any rainfall event, prior to beginning any sampling (Appendix C).

Sampling sites were chosen from headwaters to mouth on topographic maps prior to field reconnaissance at major and minor road crossings. Locations were chosen with consideration for accessibility to field staff and opportunity to develop a stage-discharge relationship (e.g. at road crossings). Once a transect location was chosen, the channel was broken into 20 panels. These panels were measured for depth, width, and water velocity. The collected measurements were recorded and calculated to give a total discharge of the stream segment sampled. The final discharge figure was then referenced with the closest upstream discharge and compared for accuracy and continuity.

Using TRCA's baseflow measurements at a total of 19 sites on Carruthers Creek (2000 data) and GSC's 1995-96 data for 131 sites on Duffins Creek, a set of maps were developed to show the existing baseflow distribution within the two watersheds. An assessment of the distribution, at watershed and subwatershed scales was undertaken to better understand the existing system in terms of significant discharge areas and potential recharge areas. The maps also provided an understanding of the relative local subwatershed inputs on a reach basis. An understanding was also developed of the stressors that exist, including natural processes, such as losses or gains due to geologic features (i.e. Lake Iroquois shoreline) and water takings (i.e. known withdrawals as per the Ministry of the Environment's Permit to Take Water (PTTW) data base).

2.1.3.1) Duffins Creek

At the watershed scale, Duffins Creek shows that the majority of the overall system baseflow is split between the East Branch of the creek (57 %), with the West Branch (38 %), with the tributaries of the Urfe, Ganatsekiagon and Millers contributing the remaining flow (5 %) (Figure 1.1).

In addition to the overall watershed assessment, the data was further analysed on each of the subwatersheds to define the distribution within each. Mapping products based upon a percent contribution were developed assuming that the outflow measurement from the basin represented 100 percent. The reaches were then shown in as a percentage in terms of their contribution to the outlet flow. These maps are useful in defining reach's which are key contributors to either enhancing or reducing base flows. It is also at this scale that surface water taking's may be identified providing that the measurements reflect a condition where water taking was underway. Unfortunately, the manner that the field data is collected, as a one time measurement, at any location does not guarantee that all water taking's are captured by the data. Geologic conditions that create significant gains or losses, are however reflected the data. The Lake Iroquois shoreline shows consistently as a loss in the upper portions and an increase in discharge along the toe of the shoreline feature. The Oak Ridges Moraine is reflected as the predominant source of flow within the East and West branches.

The following descriptions reflect the baseflow distribution within each of the five key sub-watersheds within the Duffins Creek watershed.

The West branch of Duffins Creek with its headwaters within the South slope of the Oak Ridges Moraine drains an area of approximately 135 square kilometres, flowing from the Village of Whitchurch-Stouffville south to its confluence with the east Branch just north of Highway # 2 in the Town of Ajax. As noted previously, the West branch provides approximately 38 % of the base flow found within the Main branch, with approximately 75 % of its flow being contributed from the Oak Ridges Moraine within the upper reaches of the basin. A map describing the distribution of flow within the West branch is attached as figure 1.2.

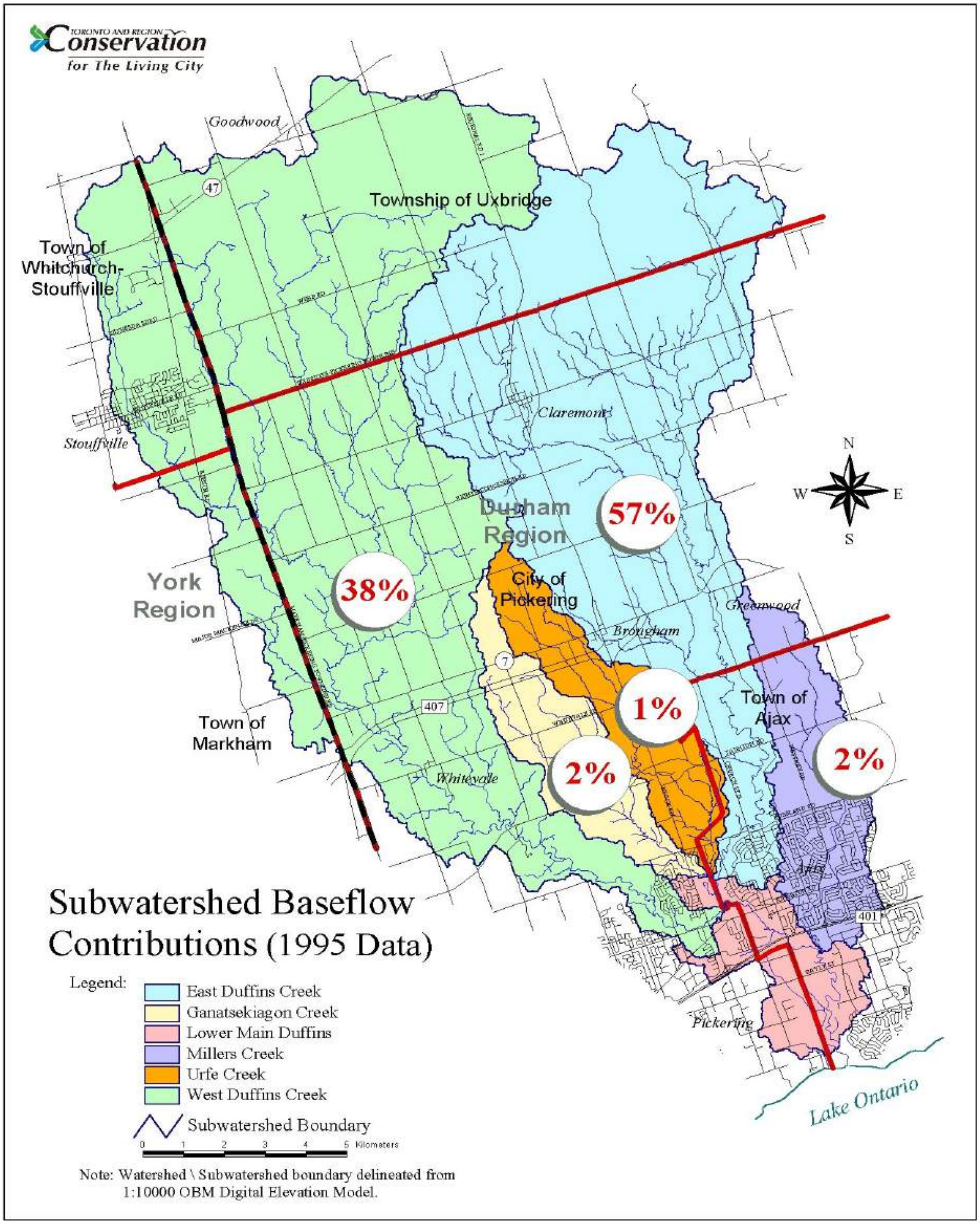


Figure 1.1 - Subwatershed contributions to overall baseflow

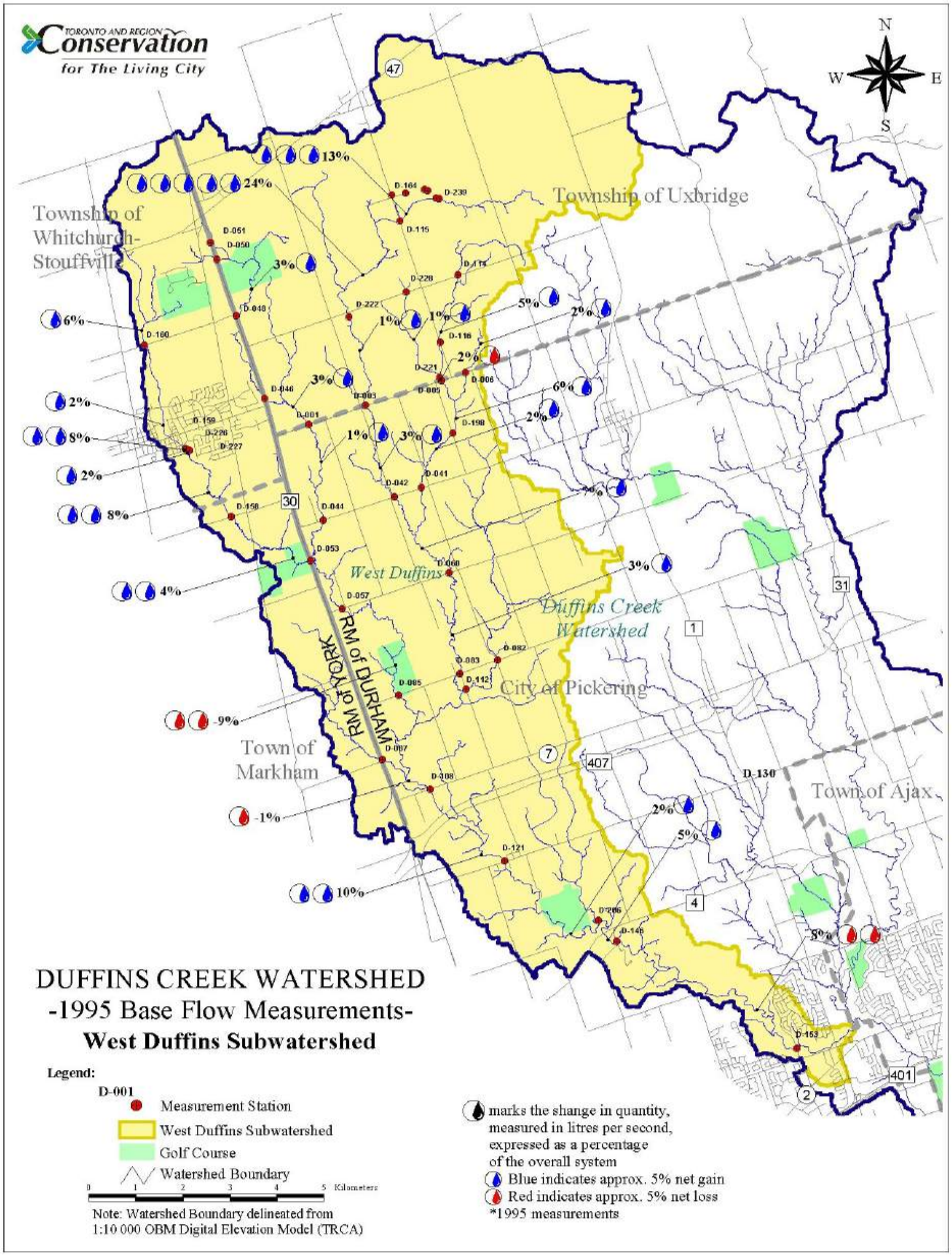


Figure 1.2 - West Duffins Creek Baseflow Distribution

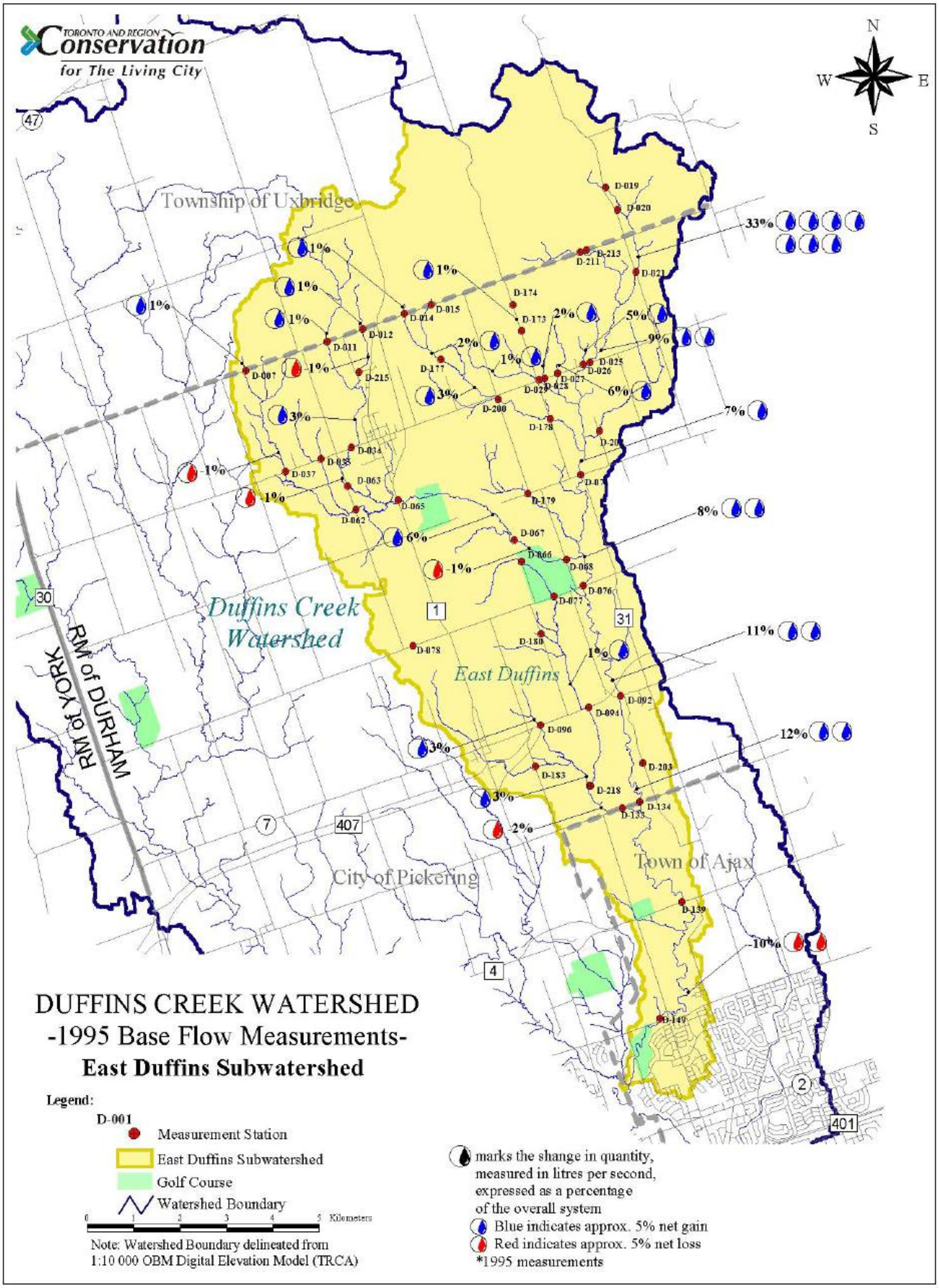


Figure 1.3 - East Duffins Creek Baseflow Distribution

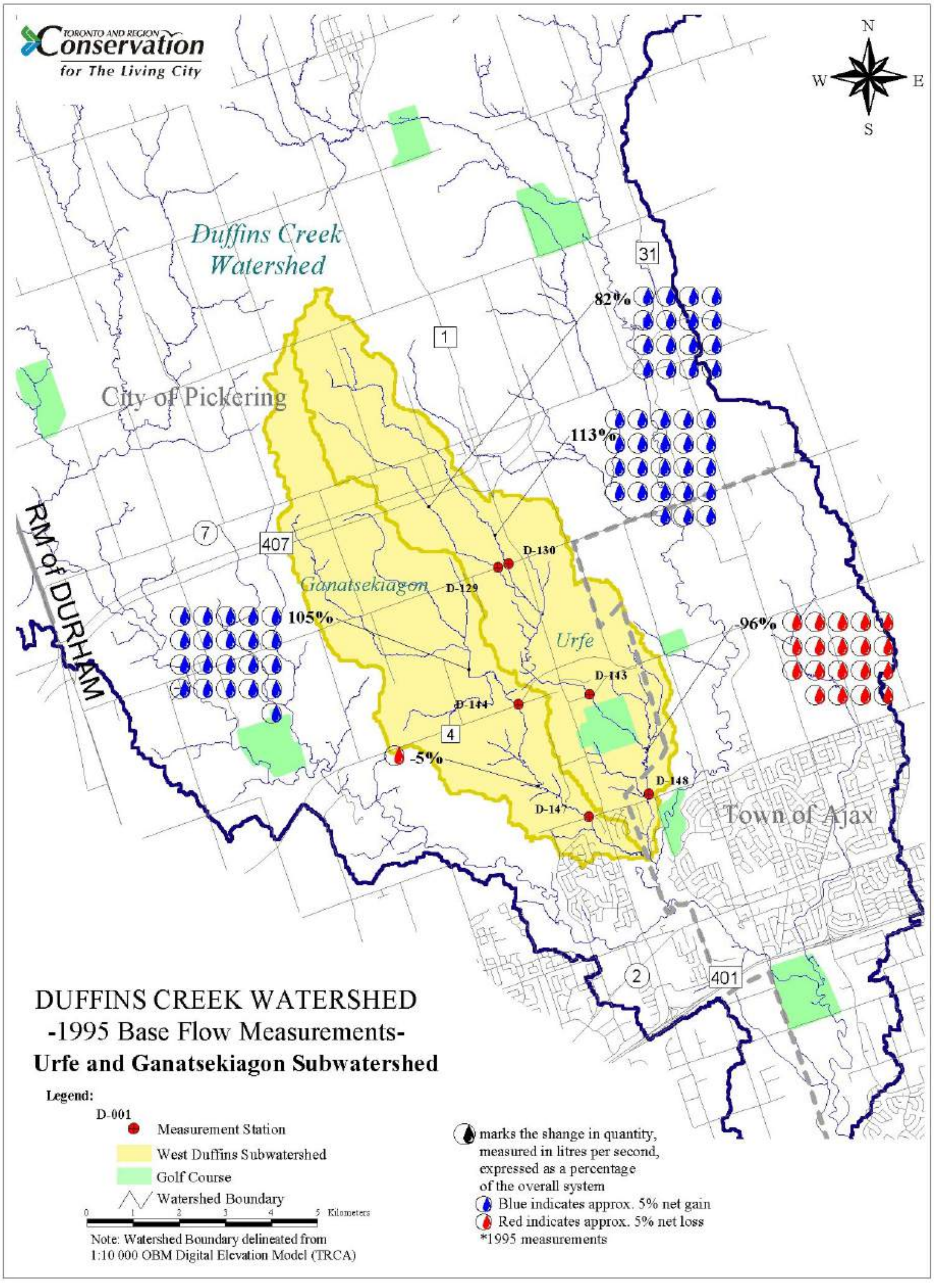


Figure 1.4 - Urfe and Ganatsekiagon Subwatersheds Baseflow Distribution

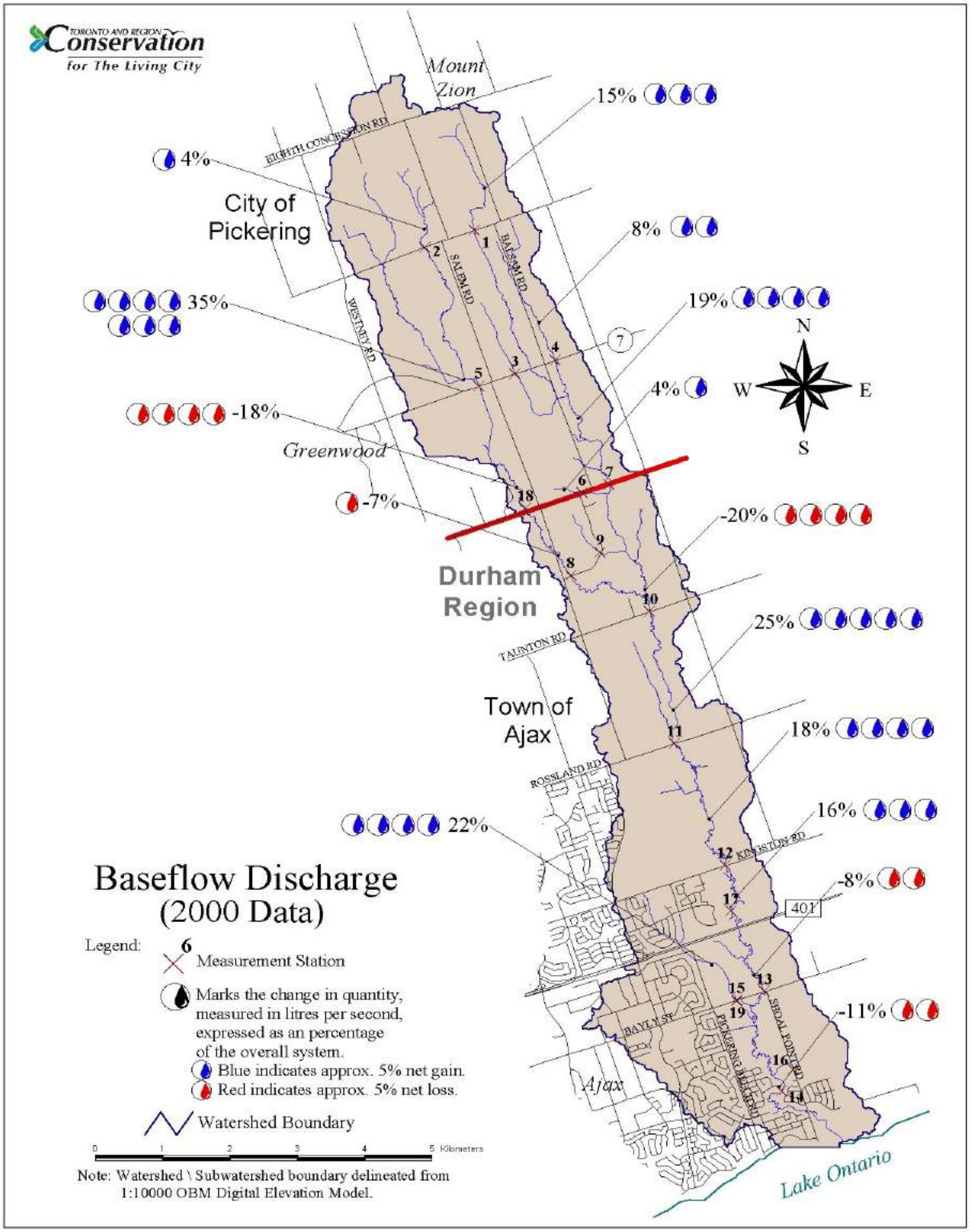


Figure 1.5 - Carruthers Creek Baseflow Distribution

provide a significantly higher percentage). A more uniform input of baseflow occurs between the base of the Lake Iroquois shoreline and Highway 401. (in the range of an additional 30 %, based upon 2000 data). As the watercourse crosses the Highway, the slope diminishes and the system enters an area of online wetland features, down to its outlet into the Carruthers Creek marsh at Lake Ontario. Within this reach flows are attenuated and base flow amounts either decrease or stay very close to the inputs to this reach. The existence of the wetlands in addition to the urban nature of the landform within this area of the watershed would appear to add little additional flows above what is being lost to evapotranspiration and surface routing.

From the baseflow data collected and mapped, it appears that in wet years, the upper portion of the basin can supply additional baseflow that can range up to 40 % of the total watershed flow. In drier years, this number is expected to be reduced significantly. The significance of these seasonally available baseflow is not presently known.

The distribution of base flows along the Carruthers Creek are shown on Figure 1.5

2.2) WATER TAKINGS

The Ministry of Environment is the Provincial agency responsible for permitting the removal of water from any surface or ground water source. Within the TRCA watersheds , active water taking permits are in place for a number of activities including but not limited to potable water supply, industrial use, golf course operations, agricultural use, sod farming, nursery operations, and for pits and quarry operations. By far the largest single use is for municipal and private potable supply, all of which are water taking's from the ground water systems or directly from Lake Ontario. With the development of appropriate knowledge and tools to understand and model the ground water system across all the TRCA watersheds, the ability to link the ground water system with our surface systems will be accomplished. These tools will allow us to understand and more actively manage the impacts related to ground water taking's by relating sub-surface changes to impacts within our watercourses. While ground water modelling tools will allow us to more effectively understand and manage ground water taking's and the impacts of land use changes, issues still exist related to surface water taking's. In order to develop more effective surface water taking management, the following actions are underway or are required through a cooperative effort with MOE.

- ground truthing of the existing M.O.E.E., GIS data base and mapping of all known water taking's (PTTW)
- investigation of the impacts and issues related to the cumulative impacts related to water taking's(integrate with water budget and ground water modelling results.)
- development of an aquatic ecosystem based procedure to define minimum flow rates for water taking's
- development of a proactive methodology to allow for the retrofit of existing permits in a manner protecting the aquatic ecosystem. (Appendix C)

Of the above action items, work has begun on the GIS data base of PTTW. Early analysis of the data to date has identified some significant issues including a lack of information related to the current state of the water taking's listed, and a general lack of information related to specific information on each taking, such as use and amounts in some instances. While this has limited the effective use of the data base, it does provide a good starting point for examination of the base flow data in terms of attempting to explain flow discrepancies measured in the field.

In addition to the data base work, work external to this process is still underway to attempt to define a protocol related to establishing a low flow threshold based upon ecological need. In the absence of such a protocol, the TRCA and MOEE Central Region have cooperated to define a process which allows the current Central Region's current threshold flow based upon the 60 % duration summer flow to be re-located from the nearest appropriate stream gauge site to the physical water taking location and establish the method and intake elevation required to protect the aquatic system. This process utilizes the distribution of low flow measured by the TRCA or the proponent, as opposed to an areal reduction and defines how the elevation of the intake is to be established. TRCA permit requirements are then used to ensure that the intake is constructed along the side of the watercourse, not as a weir or small dam and is constructed in a manner to ensure that the proper elevation of the sill is built in a manner which can not be easily manipulated. (Appendix C)

2.2.1) PTTW, Duffins Creek Watershed

A review of the PTTW data base surface water taking's within the Duffins Creek reveal a total of 10 active permits, all located within the West Duffins Creek and upper east tributary. A review of the overall data base reflects 29 permits for surface water taking's previously issued within the watershed (Figure 2.1). Of the ten active permits, three are for on line storage related to wetland creation projects and therefore would not reflect a significant loss from the system. The difficulties in use of this data is that we have no confirmation that any or all of the expired permit holders have stopped pumping, as the system is set up to be user specific in terms of initiating the update process upon expiry of the permit.

However, based upon the active permits within the West Duffins, 5 of the 6 are within the Reesor Creek sub-watershed. Based upon the amounts of water allocated to be removed by these permits, and the total baseflow outputs for this sub-watershed developed through the groundwater model, approximately 16 % of the total baseflow volume could be removed on an annual basis. With most of these permitted taking's being seasonal, the percentage of baseflow being lost on any given day when all taking's could be underway could represent closer to 30 %. In fact, when a second set of measurements were taken within the Reesor Creek in 2001, a pumping event was measured which reflected closer to an 80 % reduction, far in excess of what exists within the valid permits.

The remaining valid permit is well downstream within the West Duffins Creek, and is for industrial use. The industrial use is located close to Taunton Road , and has a valid permit to take approximately 2,725,200 l/day, which represents an average taking of 31.5 l/s.. This taking is reflected in measured data, which drops by 24 l/s through this reach. The permitted taking at this one site represents close to 10 % of the measured baseflow.

From an entire watershed perspective, the valid permitted taking's represent approximately 17 % of the total baseflow within the West Duffins Creek and 10 % of the total watershed baseflow.

Other taking impacts related to any illegal taking's as well as taking's not requiring a permit within the watershed are currently unknown. Table 1.1 reflects the PTTW data and the analysis undertaken.

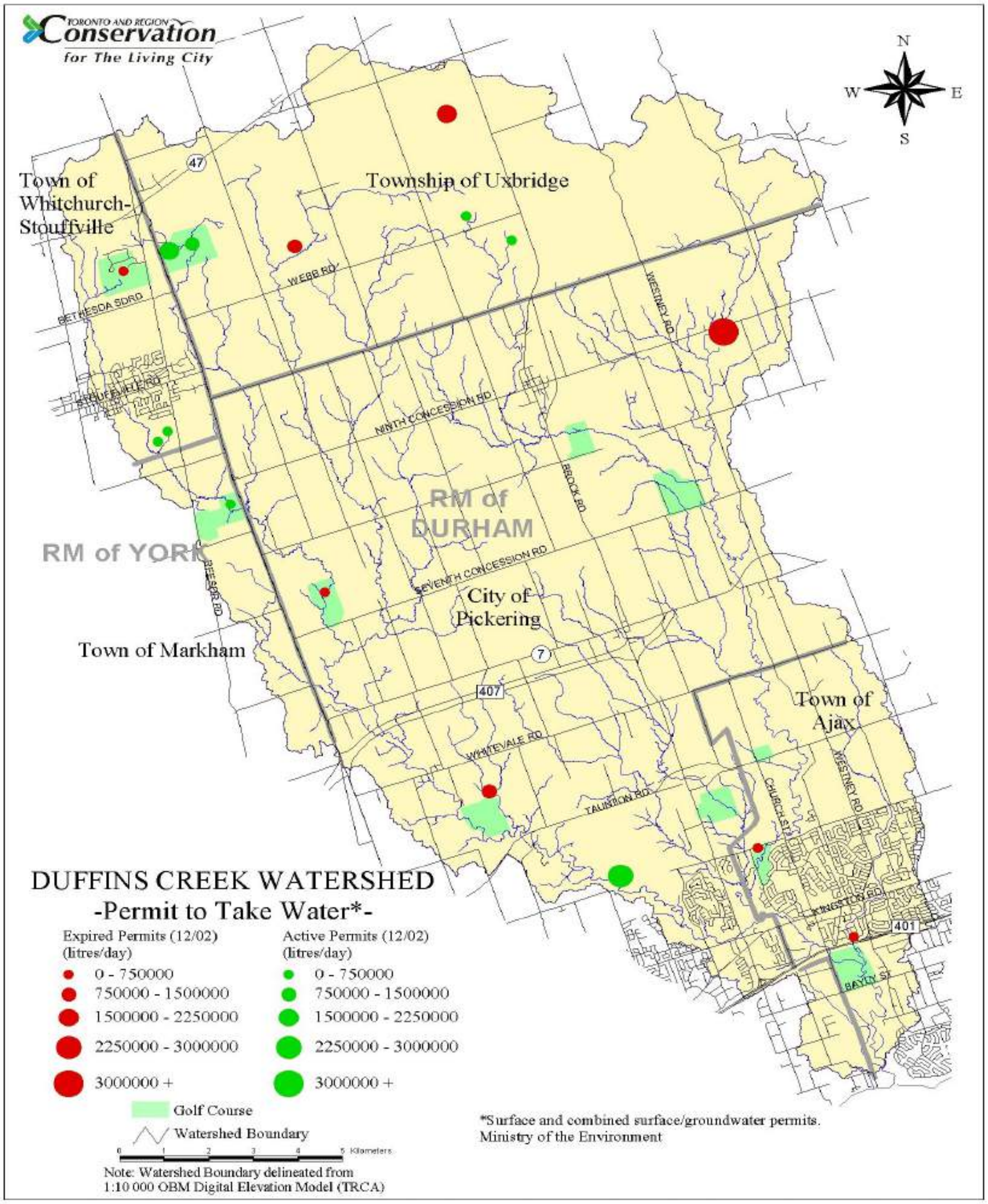


Figure 2.1 - Duffins Creek Permit To Take Water Distribution

2.2.2) PPTW, Carruthers Creek

While several private wells are recognised within the Ministry of Environment and Energy's Permit to Take Water (PTTW) data base, only one significant surface water taking exists. This PTTW is located within the reach below the Lake Iroquois shoreline which supplies the a large percentage of the overall system baseflow. The water taker is a large golf course operation, currently taking water from a series of on line ponds. Based upon the current methods of taking's for this site, the withdrawals will exceed the total yearly or daily baseflow from the Carruthers Creek. While the taking, which uses on line ponds, will undoubtedly collect more than just baseflow, this application could significantly impact the Carruthers Creek aquatic system. The analysis of the Carruthers Creek PTTW and baseflow is shown on Table 1.1.

Table 1.1

Estimated Surface Water Withdrawals as a Proportion of Total Annual Baseflow

Watershed/ Subwatershed	#PTTW (both active and expired)	Maximum permitted annual water takings (L/yr)	Total annual Baseflow volume (L/yr)	Percent of total annual baseflow available to be withdrawn (%)
Duffins Creek watershed	29	4,721,067,580	47,395,980,000	10.0
West Duffins Creek	17	3,347,918,320	19,870,965,000	16.8
Reesor Creek	9	924,203,200	5,765,175,000	16.0
East Duffins Creek	10	1,258,100,100	10,783,980,000	11.7
Ganatsekiagon Creek	0	n/a	n/a	n/a
Urfe Creek	0	n/a	n/a	n/a
Millers Creek	2	23327880	729180000	3.2
Carruthers Creek watershed	2*	1458136080	1056456000	138

*current PTTW applications

2.3) WATER BUDGET ANALYSIS

To be in a position to clearly understand the allocation of water resources within a watershed or sub-watershed, the distribution of the total volume of water which is input to the basin is required. This allocation is commonly defined as a water budget, and distributes the total input of rain and snow which falls into components of surface runoff, infiltration to ground water and the amounts that are lost to evaporation and transpiration. Flood and erosion control strategies related to the surface runoff component can be developed using tools which do not need a detailed understanding of the annual or seasonal water budgets. However, to effectively develop models to monitor and analyse the movement of ground water resources, all components of the water budget are necessary. Therefore as part of any comprehensive Low Flow Management Plan, an understanding of the water budgets are required. It is therefore necessary to;

- adopt a water budget procedure to be implemented on each watershed.
- define sensitivities and management issues requiring detailed analysis based on water budgets

Of the actions noted above, both have taken place within the Duffins Creek watershed. A water budget model was developed and calibrated at the existing stream flow gauging stations within the watershed. The calibrated models were further discretized based upon the hydrologic sub-basin breakdown (figure 2.2) and parameters for evapotranspiration (ET), surface runoff (RO) , and ground water inputs (GWI) developed for existing watershed conditions. The water budget model was then used to reflect changes to be expected within the model outputs due to changes in land use related to both the Municipal Official Plan (OP), the TRCA natural heritage objectives and a further urbanization beyond the OP.

Based upon changes within the GWI numbers generated by modelling these land use changes, it is possible to reflect anticipated impacts to baseflow within each of the main sub-watersheds. Table 1.2 reflects the changes in GWI between existing conditions and the future OP.

Table 1.2
Duffins Creek Modflow Discharge Analysis

Percent reduction in ground water discharge	Scenario 1 (Existing Conditions) ground water discharge in cubic metres/day	Scenario 2 (Future OP Conditions) ground water discharge in cubic metres/day
	132026	0
Total Duffins Creek Watershed		
3.314%		
Millers Creek % Reduction in Low Flow		
4.073%	4051	0
Urfe Creek % Reduction in Low Flow		

13.680%	4927	0
Ganetskiagon Creek % Reduction in Low Flow		
17.019%	6522	0
East Duffins Creek % Reduction in Low Flow		
0.965%	59911	??
West Duffins Creek % Reduction in Low Flow		
2.750%	??	??

Figure 2.2 - Duffins Creek Watershed Sub Basin Breakdown

2.3.1. Land Use Impacts to Baseflow

An interpretation of impacts on baseflows due to potential land use changes can be defined in the Duffins Creek watershed, based on results from the Water Budget Model and the Ground water Flow Model. The Ground water Model was used to predict changes in the amount of water being shown as discharge, in response to changes in ground water infiltration volumes (GWI) generated from the Water Budget Model.

Under the Future Official Plan scenario, the modelled reductions in baseflows would range from 0 to approximately 26 percent when viewed on an individual drainage basin basis. Baseflow reductions by sub-watershed are modelled as; the Lower Duffins (26%), Ganatsekiagon (17%), Urfe (14%) and Millers Creeks (4%). Little change would be anticipated within the East (1%) or West branches (3%) which generate the bulk of the overall system baseflow. With the majority of the watersheds baseflow being from the East and West branches, no significant impacts to overall baseflows would be expected within the lower reaches of the watershed.

2.4) DROUGHT MANAGEMENT

In keeping with the Provincial Low Water Response Plan (Appendix D), the Conservation Authorities within the Greater Toronto Area have recognised the need to develop a process to respond to a drought event and set up appropriate Low Water Response Teams (LWRT). While initially envisioned as being set up upon a watershed basis, the number of watersheds involved within the GTA C.A.'s and the obvious overlap of municipal involvement decreed a different approach within our watersheds. The GTA Authorities agreed to establish these Teams based upon a procedure developed as part of a flood forecasting and warning working group to streamline our communications and response procedures with our municipalities.

In doing this, our teams were set up based upon Regional Municipal boundaries for the most part with some minor additions of peripheral Municipalities. The current process and the teams developed represent a program in its initial stages and based upon feedback from these groups across the Province, the role and expectations of these teams will undoubtedly be revised over time. At present, these teams are set up to respond in the event of a drought developing and reaching a predefined set of conditions based upon precipitation and stream flow. The working of these groups is based upon attempting to gain a consensus of actions by water users in a voluntary sense such as watering restrictions and cut backs, as well as issuing appropriate Press Releases to assist in achieving this goal. Under the existing legislations dealing with Water Taking's, only the Province through MOE can order a reduction or elimination of water taking's under a valid permit to take water.

The LWRT within Durham Region was established in 2001 and covers an area which includes both the Duffins and Carruthers Creek watersheds. This team has met on three occasions, once in 2001 and twice in 2002 to discuss and to issue a drought message. The terms of reference for this group are included within Appendix D. Discussions related to creating a more effective response are ongoing.

3) LOW FLOW MANAGEMENT STRATEGIES

3.1) Duffins Creek

- *establish long term monitoring / indicator sites within the Duffins Creek to develop trend analysis to define and monitor base flow conditions, as well as the effectiveness of management activities.*

- *work with MOEE in a proactive manner through the renewal of the PTTW program to modify the on line water taking for golf courses and other users to allow for an uninterrupted passage of base flows to support the aquatic ecosystem.*

- *define recharge areas which supply the systems base flows and develop recharge protection strategies to protect the sustainabilty of base flows within the Duffins Creek Watershed.*

- *fill data gaps within sub-watersheds (re: Urfe, Millers and Ganatsekiagon)*

3.2) Carruthers Creek

- *establish long term monitoring / indicator sites within the Carruthers Creek both above and below the Lake Iroquois shoreline to develop trend analysis to define importance of seasonal base flow inputs to Carruthers Creek and to monitor the effectiveness of watershed management activities.*

- *work with MOEE in a proactive manner through the renewal of the PTTW program to modify the on line water taking for golf courses and other users to allow for an uninterrupted passage of base flows to support the aquatic ecosystem.*

- *develop a ground water model for the Carruthers Creek watershed.*

- *define recharge areas which supply the systems base flows and develop recharge protection strategies to protect the sustainabilty of base flows within the Carruthers Creek Watershed.*

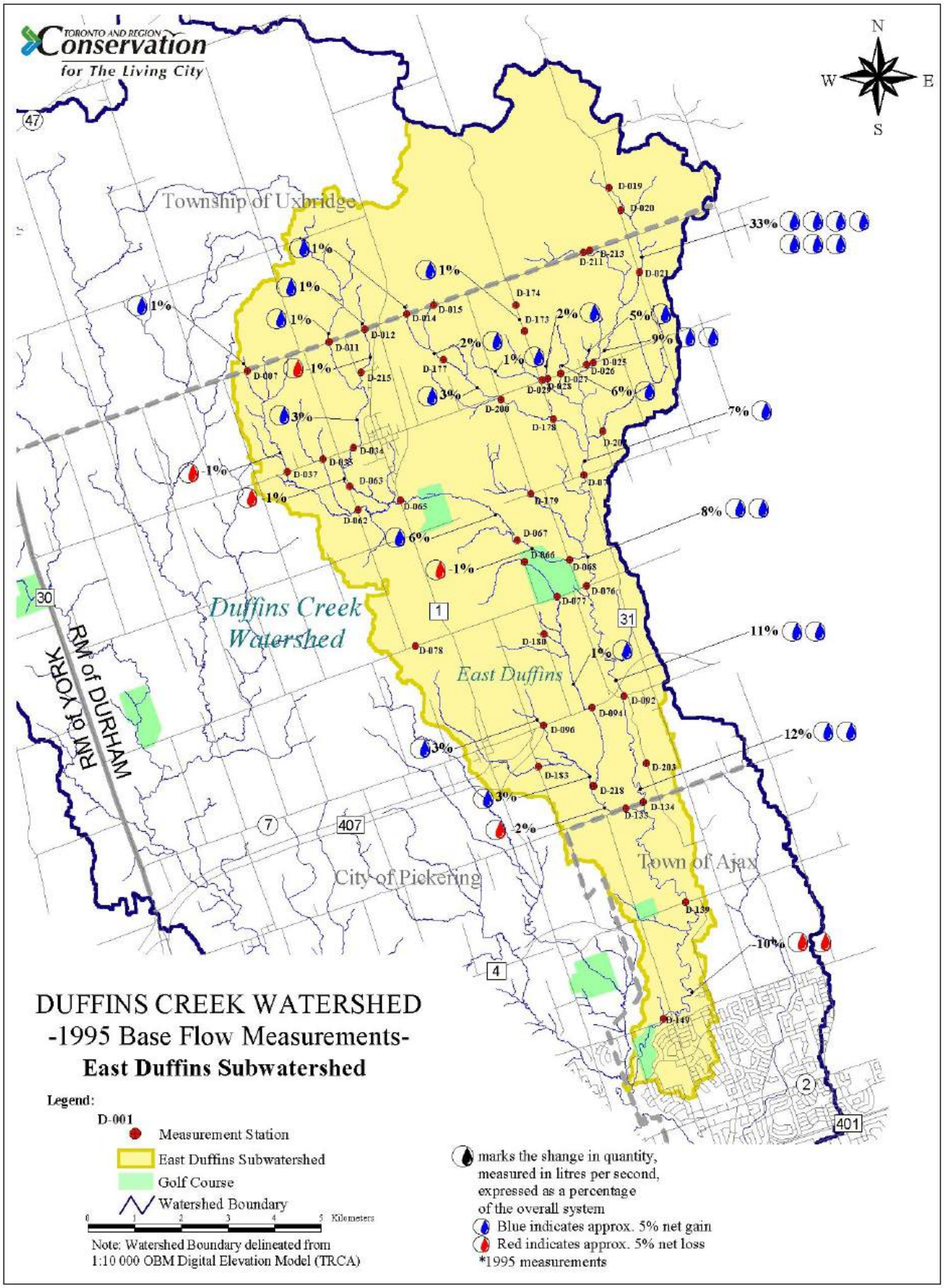
4.0) INTEGRATION

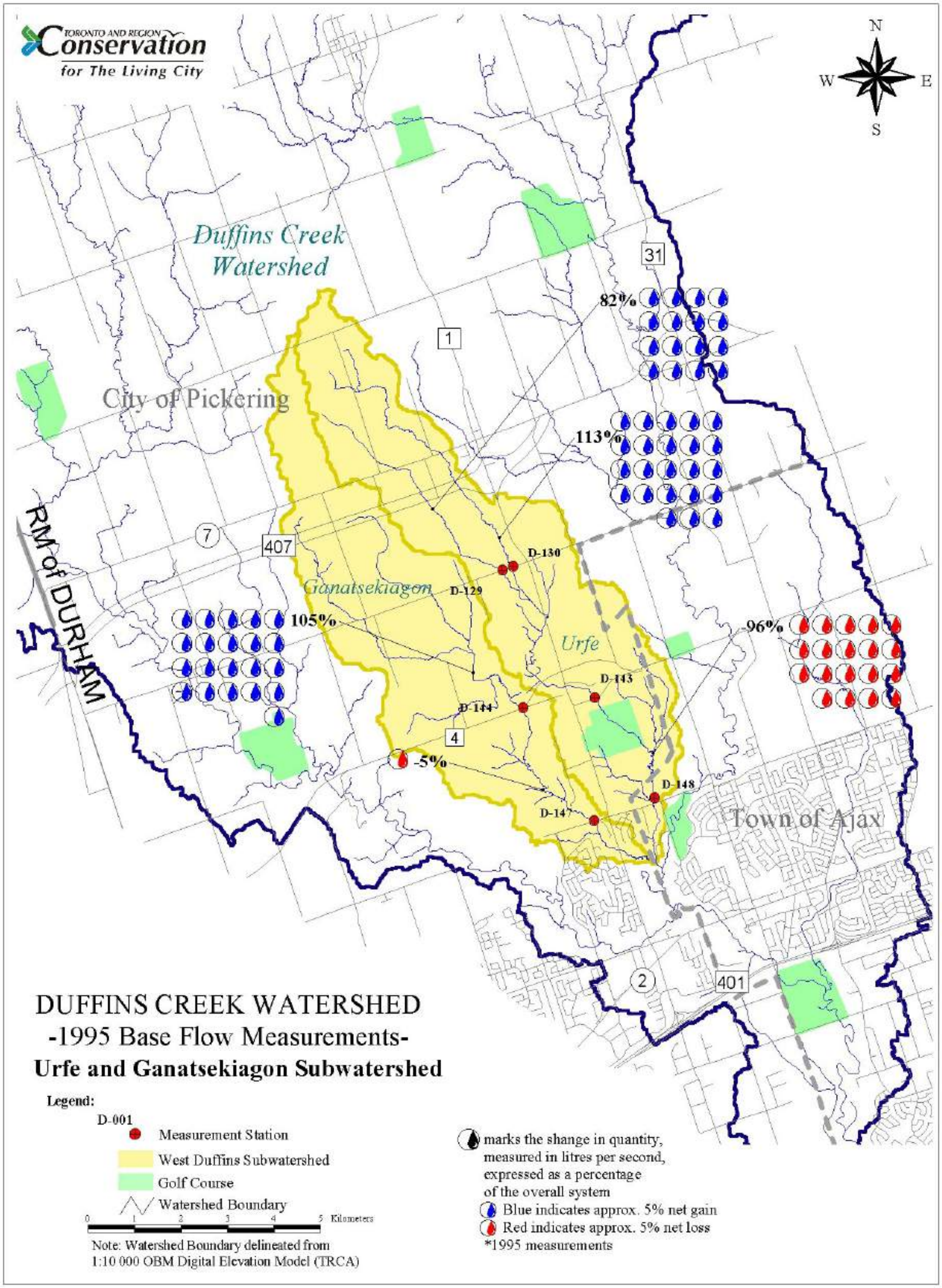
While the flow data collected and the mapping products prepared through the Low Flow Plan provide valuable information and direction on their own, some of the key uses of the information will come from identifying and integrating the information into the development of other water management strategies.

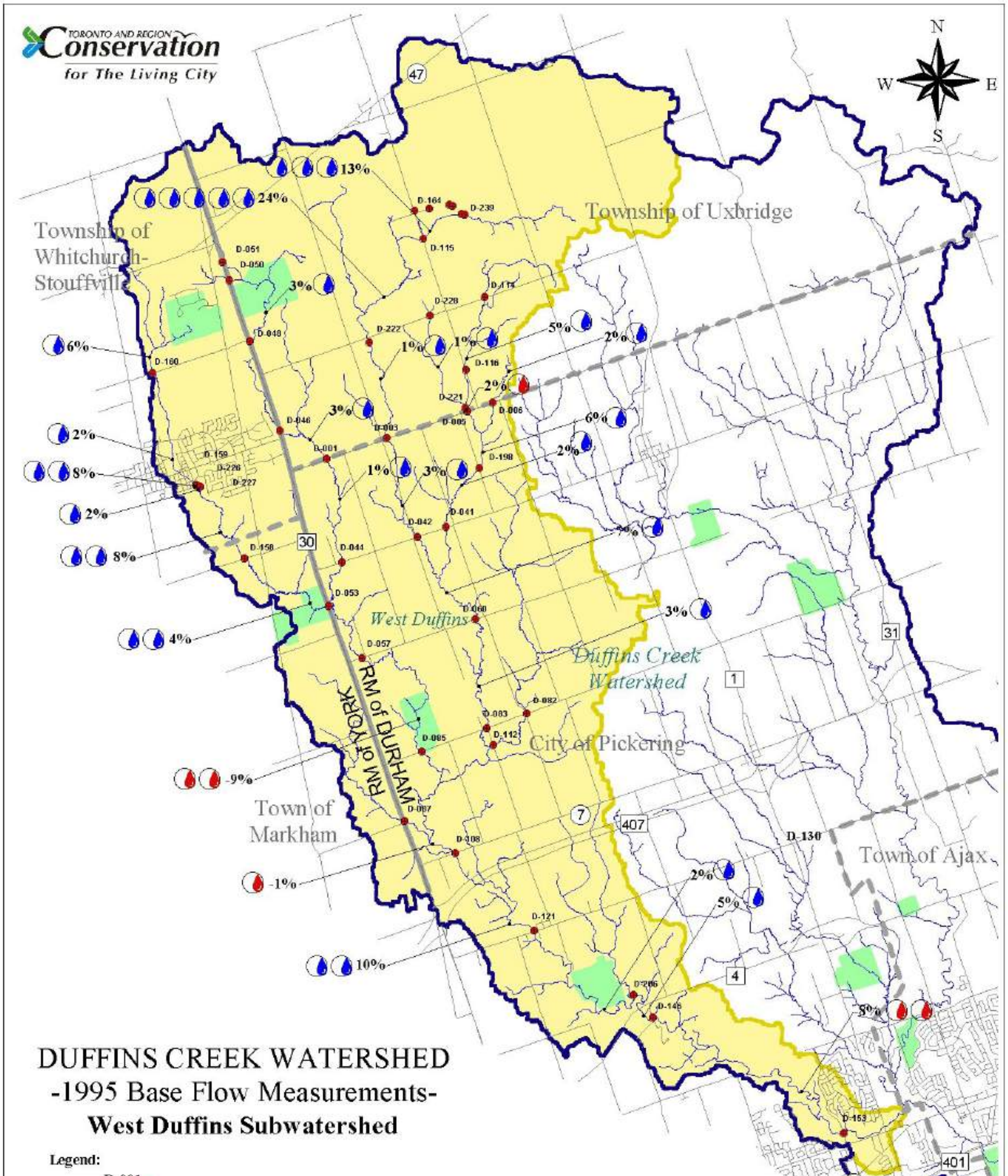
To ensure that the data is effectively integrated into other management planning activities, individual program assessments need to be undertaken with regard to these programs to define how the low flow data or low flow mapping products can be of use.

Some uses where the low flow information can readily be integrated related to developing a better understanding of how low flows fit within the hydrologic cycle, such as in the development of a ground water model. The low flow or base flow information reflects the location and amounts of ground water discharge to the surface systems and as such the data is instrumental in the calibration or verification of a ground water model. Additional areas of integration exist with respect to the aquatic ecosystem. A direct relationship exists between the amount of baseflow, whether the reach is a discharge zone and the quality and productivity of a stream reach in terms of its fishery. As such, understanding the distribution of baseflow within a watershed integrated with known fishery data can be used in the development and monitoring of the Fish Management Plan, both in terms of the planning, and also in the monitoring process. Integrating baseflow monitoring sites and aquatic monitoring sites will provide a basis for long term planning and assessment work as well as allowing impact assessments based upon watershed and sub-watershed land use change analysis from ground water modelling. The above are examples of integration between different activities and data sources within the watershed. Other opportunities at integration will be explored.

APPENDIX A


TORONTO AND REGION Conservation
for The Living City
Township of Uxbridge
Duffins Creek Watershed
East Duffins
RM of YORK
RM of DURHAM
City of Pickering
Town of Ajax
N
W
E
S
33%
9%
7%
8%
11%
12%
-10%
DUFFINS CREEK WATERSHED
-1995 Base Flow Measurements-
East Duffins Subwatershed
Legend:
D-001
Measurement Station
East Duffins Subwatershed
Golf Course
Watershed Boundary
Kilometers
Note: Watershed Boundary delineated from
1:10 000 OBM Digital Elevation Model (TRCA)
marks the shange in quantity,
measured in litres per second,
expressed as a percentage
of the overall system
Blue indicates approx. 5% net gain
Red indicates approx. 5% net loss
*1995 measurements


TORONTO AND REGION Conservation
for The Living City
N
S
W
E
Duffins Creek
Watershed
31
1
City of Pickering
7
407
RM of DURHAM
82%
113%
105%
96%
-5%
D-130
D-129
Ganatsekiagon
Urfe
D-143
D-144
4
D-148
D-147
Town of Ajax
2
401
DUFFINS CREEK WATERSHED
-1995 Base Flow Measurements-
Urfe and Ganatsekiagon Subwatershed
Legend:
D-001
Measurement Station
West Duffins Subwatershed
Golf Course
Watershed Boundary
0 1 2 3 4 5 Kilometers
Note: Watershed Boundary delineated from
1:10 000 OBM Digital Elevation Model (TRCA)
marks the shange in quantity,
measured in litres per second,
expressed as a percentage
of the overall system
Blue indicates approx. 5% net gain
Red indicates approx. 5% net loss
*1995 measurements


TORONTO AND REGION Conservation
for The Living City
N
W
E
S
DUFFINS CREEK WATERSHED
-1995 Base Flow Measurements-
West Duffins Subwatershed
Township of Whitchurch-Stouffville
Township of Uxbridge
Town of Markham
City of Pickering
Town of Ajax
RM of YORK
RM of DURHAM
West Duffins
Duffins Creek Watershed
47
30
7
407
1
31
4
2
401
13%
24%
3%
6%
2%
8%
2%
8%
4%
-9%
-1%
10%
1%
1%
5%
2%
2%
3%
1%
3%
6%
2%
3%
2%
5%
D-164
D-239
D-115
D-051
D-050
D-114
D-228
D-222
D-048
D-116
D-160
D-221
D-006
D-005
D-046
D-003
D-001
D-159
D-226
D-227
D-198
D-041
D-042
D-158
D-044
D-053
D-060
D-057
D-082
D-083
D-112
D-085
D-087
D-108
D-130
D-121
D-206
D-146
D-153
Legend:
D-001
Measurement Station
West Duffins Subwatershed
Golf Course
Watershed Boundary
0
1
2
3
4
5 Kilometers
Note: Watershed Boundary delineated from 1:10 000 OBM Digital Elevation Model (TRCA)
marks the shange in quantity, measured in litres per second, expressed as a percentage of the overall system
Blue indicates approx. 5% net gain
Red indicates approx. 5% net loss
*1995 measurements

Duffins Creek - 1995 Sampling Locations M.Hinton G.S.C

Date	Site	Q (l/s)	Error	Northing	Easting	Map Sheet	MOEE Station #	Site description
17-Aug-95	D-001	16.7	1.5	4870429	643487	30 M/14	65	Reesor @ Ux-Pkg Twnln
18-Aug-95	D-003	113	8	4870845	644691	30 M/14	20	West Duffins Ck. @ Ux-Pkg twnln
18-Aug-95	D-005	12.6	2.5	4871385	646308	30 M/14	21	Wixon Ck. @ Ux-Pkg twnln
18-Aug-95	D-006	6.1	1.1	4871556	646806	30 M/14		E. trib to Wixon Ck. @ Ux-Pkg twnln
21-Aug-95	D-007	6.1	0.3	4871767	647416	30 M/14		Trib to Michell Ck. @ Ux-Pkg twnln, 450m E of s/l 24
21-Aug-95	D-011	6	0.7	4872318	649004	30 M/14		Trib to Michell Ck. @ Ux-Pkg twnln, 600m E of s/l 20
21-Aug-95	D-012	4.4	0.7	4872560	649692	30 M/14		Trib to Michell Ck. @ Ux-Pkg Twnln 200m W of Old Brock Rd
21-Aug-95	D-014	2.6	0.2	4872845	650502	30 M/14		Trib to Duffins Ck. @ Ux-Pkg Twnln 550m E of Brock Rd. (Dur 1)
21-Aug-95	D-015	0.14	0.02	4873022	651010	30 M/14		seep to Trib to Duffins Ck. @ Ux-Pkg Twnln 1100m E of Brock Rd. (Dur 1)
20-Aug-95	D-019	57.1	5.8	4875251	654411	31 D/3		Duffins Ck., Conc.7 500m N of Glen Major
20-Aug-95	D-020	1	0.2	4874830	654641	31 D/3		trib to Duffins Ck.Conc.7 @ Glen Major
16-Aug-95	D-021	139	13	4873647	655004	30 M/14		Duffins Ck.,Conc.7 300m N of CP tracks
20-Aug-95	D-021	139	10	4873647	655004	" "		" "
16-Aug-95	D-025	177	16	4871924	654106	30 M/14	32	Duffins Ck. @ Durham 5
20-Aug-95	D-025	211	19	4871924	654106	" "		
16-Aug-95	D-026	14.9	2.3	4871880	653973	30 M/14		Trib to Duffins Ck.@ Durham 5, 950m E of Westney Rd.
20-Aug-95	D-026	18.9	3	4871880	653973	" "		" "
16-Aug-95	D-027	24.1	1.6	4871709	653482	30 M/14		Trib to Duffins Ck.@ Durham 5, 400m E of Westney Rd.
20-Aug-95	D-027	23.8	2.4	4871709	653482	" "		" "
16-Aug-95	D-028	9.5	1	4871623	653222	30 M/14		Trib to Duffins Ck.@ Durham 5, 150m E of Westney Rd.
20-Aug-95	D-028	12.7	1.6	4871623	653222	" "		" "
16-Aug-95	D-029	6.2	0.8	4871589	653114	30 M/14		Trib to Duffins Ck.@ Durham 5, 25m E of Westney Rd.
20-Aug-95	D-029	5.9	0.2	4871589	653114	" "		" "
21-Aug-95	D-034	22.1	2.6	4870296	649469	30 M/14	66	Michell Ck. @ Durham 5, 300m E of s/l 20
21-Aug-95	D-035	0.65		4870080	648877	30 M/14		Trib to Michell Ck.@ Durham 5, 300m W of s/l 20
21-Aug-95	D-037	1.11		4869843	648197	N/A		No Description Available
16-Aug-95	D-041	56.2	4.8	4869070	645884	30 M/14	18	Wixon Ck. @ Durham 5

18-Aug-95	D-041	41.6	6.2	4869070	645884	" "		" "
31-Aug-95	D-041	45.2	6.1	4869070	645884	" "		" "
17Aug95	D-042	114	9	4868877	645299	30 M/14	17	West Duffins Ck. @ Durham 5
18-Aug-95	D-042	122	9	4868877	645299	" "		" "
8-Sep-95	D-042	202	16	4868877	645299	" "		" "
17-Aug-95	D-044	19.2	1.6	4868374	643801	30 M/14	16	Reesor @ Durham 5
17-Aug-95	D-046	9.4	1.4	4870995	642560	30 M/14	64	Reesor @ Durham 5, 200m N of rd. to Stouffville
17-Aug-95	D-048	8.1	1.6	4872780	641957	30 M/14		Reesor @ Durham 5 & Bethesda Sdrd.
18-Aug-95	D-048	12.9	1.8	4872780	641957	" "		" "
17-Aug-95	D-050	0.7	0.1	4874001	641543	N/A		No Description Available
17-Aug-95	D-051	0.4	0.1	4874362	641415	N/A		No Description Available
16-Aug-95	D-053	82.6	7.1	4867494	643533	30 M/14	59	Stouffville Ck @ Durham 30
17-Aug-95	D-053	84	9.2	4867494	643533	" "		" "
17Aug95	D-057	102	8	4866463	644194	30 M/14	37	Reesor @ Conc 8
17-Aug-95	D-060	185	15	4867228	646464	30 M/14	38	West Duffins Ck. @ Conc 8
21-Aug-95	D-062	1.7	0.3	4869123	649552	30 M/14		Trib to Michell Ck. @ s/l 20, 1150m S of Durham 5
21-Aug-95	D-063	18.6	1.7	4869569	649400	30 M/14		Michell Ck. @ s/l 20, 650m S of Durham 5
21-Aug-95	D-065	20.1	1.5	4869303	650373	30 M/14	8	Michell Ck. @ Brock Rd
22-Aug-95	D-066	1.3	0.2	4868131	652779	30 M/14		Trib. to Brougham Ck. @ s/l 14, 1.7 km N of Conc 7.
21-Aug-95	D-067	45.1	3.6	4868541	652638	30 M/14		Michell Ck. @ s/l 14 (old trail, wooden bridge)
16-Aug-95	D-068	40.6	4.3	4868165	653644	30 M/14	29	Michell Ck. @ s/l 12, 1km N of Conc 7
21-Aug-95	D-068	33.3	3.4	4868165	653644	" "		" "
21-Aug-95	D-071	266	18	4869782	653928	30 M/14	31	Duffins Ck. @ Conc 8.
21-Aug-95	D-076	330	24	4867670	653977	30 M/14		Duffins Ck. @ Durham 31
21-Aug-95	D-076	328	25	4867670	653977	" "		" "
22-Aug-95	D-077	0.35		4867460	653409	N/A		No Description Available
22-Aug-95	D-078	0.5	0.1	4866519	650662	N/A		No Description Available
18-Aug-95	D-082	1	0.2	4865347	647492	N/A		No Description Available
17-Aug-95	D-083	195.1	15.3	4865064	646691	30 M/14	40	West Duffins Ck. @ Durham 31
16-Aug-95	D-085	86.3	8.1	4864595	645400	30 M/14	42	Reesor @ Durham 31
17-Aug-95	D-085	76	8.2	4864595	645400	" "		" "
16-Aug-95	D-087	0.45		4863210	645050	30 M/14		Major Ck. @ Durham 30

22-Aug-95	D-092	377	39	4865574	654697	30 M/14	7	Duffins Ck @ 6th Conc, W of Greenwood Rd.
22-Aug-95	D-094	3.99		4865355	654076	30 M/14		Trib. to Brougham Ck. @ Hwy 7, 450m E of s/l 14
22-Aug-95	D-096	10.5	1.1	4865011	653137	30 M/14		Trib. to Brougham Ck. @ Hwy 7, 250m E of s/l 16
16-Aug-95	D-108	284	20	4862571	646066	30 M/14	10	West Duffins Ck. @ Hwy 7 (Greeen River)
17-Aug-95	D-108	270	18	4862571	646066	" "		" "
16-Aug-95	D-112	0.41	0.07	4864722	646829	30 M/14	41	Trib. to West Duffins Ck @ s/l 30, 700m S of Dur 31
18-Aug-95	D-112	0.99		4864722	646829	" "		" "
18-Aug-95	D-114	0.73		4873657	646651	31 D/3		Wixon Ck @ Webb Rd.
18-Aug-95	D-115	83.3	7.6	4874819	645431	31 D/3		West Duffins Ck. @ Conc. 3
31-Aug-95	D-115	39.5	3.1	4874819	645431	" "		" "
16-Aug-95	D-116	14.2	1.6	4872214	646283	30 M/14		Wixon Ck @ Conc. 3
18-Aug-95	D-116	15.3	1.1	4872214	646283	" "		" "
17-Aug-95	D-121	300	24	4861011	647635	30 M/14	43	West Duffins Ck. @ Whitevale
23-Aug-95	D-129	1.8	0.3	4862626	652410	30 M/14		Urfe Ck @ Whitevale Rd., 400m W of Brock Rd.
23-Aug-95	D-130	2.5	0.2	4862687	652575	30 M/14	57	Urfe Ck @ Whitevale Rd., 250m W of Brock Rd.
16-Aug-95	D-133	41	3.5	4863438	654736	30 M/14	28	Brougham Ck @ Whitevale Rd.
22-Aug-95	D-133	30.5	2.9	4863438	654736	" "		" "
16-Aug-95	D-134	427	35	4863553	655073	30 M/14	2	Duffins Ck @ Whitevale Rd.
22-Aug-95	D-134	336	30	4863553	655073	" "		" "
22-Aug-95	D-139	468	43	4861650	655895	30 M/14	55	Duffins Ck. @ Taunton Rd.
23-Aug-95	D-143	4.3	0.7	4860716	653826	N/A		No Description Available
24-Aug-95	D-144	13.8	1.7	4860557	652730	30 M/14	22	Ganatsekiagon Ck. @ Taunton Rd, 850m W of Brock Rd.
17-Aug-95	D-146	319	21	4859280	650016	30 M/14	9	West Duffins Ck. @ Clarke's Hollow
16-Aug-95	D-147	16.8	3.6	4858869	653808	30 M/14	23	Ganatsekiagon Ck. @ Rossland Rd, 250m W of Brock Rd.
24-Aug-95	D-147	13.2	1.8	4858869	653808	" "		" "
16-Aug-95	D-148	11.1	1.1	4859204	654736	30 M/14	26	Urfe Ck @ Rossland Rd.
23-Aug-95	D-148	2.2	0.4	4859204	654736	" "		" "
23-Aug-95	D-149	424	30	4859425	655460	30 M/14	27	Duffins Ck @ Rossland Rd.
24-Aug-95	D-149	441	34	4859425	655460	" "		" "
23-Aug-95	D-151	8.8		4858085	657839	30 M/14		Miller's Ck @ Highway 2
16-Aug-95	D-152	867	49	4857368	655769	30 M/14	5	Duffins Ck @ Highway 2
17-Aug-95	D-152	767	57	4857368	655769	" "		" "

24-Aug-95	D-152	613	47	4857368	655769	" "		" "
31-Aug-95	D-152	598	37	4857368	655769	" "		" "
16-Aug-95	D-153	288	18	4856976	653828	30 M/14	13	West Duffins Ck. @ Valley Farm Rd.
17-Aug-95	D-153	295	20	4856976	653828	" "		" "
24-Aug-95	D-153	229	17	4856976	653828	" "		" "
17-Aug-95	D-158	72	6.2	4868446	641854	30 M/14	61	Stouffville Ck. @ 19th ave.
17-Aug-95	D-159	20.9	1.9	4869919	640872	30 M/14	62	Stouffville Ck. Upstream of WPCP @ Burkholder St.
17-Aug-95	D-160	16.1	1.9	4872149	640013	30 M/14	12	Stouffville Ck. @ Bethesda srd.
18-Aug-95	D-164	0.2	0.09	4875388	645248	N/A		No Description Available
18Aug95	D-168	0.26	0.04	4875421	645546	31 D/3		Trib to West Duffins @ Secord Rd., 300m E of Conc.3
20-Aug-95	D-173	5.4	0.7	4872519	652774	30 M/14		Trib to Duffins Ck.@ Westney Rd. 1km N of Durham 5
20-Aug-95	D-174	0.7	0.03	4873022	652605	30 M/14		Trib to Duffins Ck.@ Westney Rd. 550m S of Ux-Pkg twnln
21-Aug-95	D-177	10.8	1.1	4871978	651207	30 M/14		Trib to Duffins Ck. @ s/l 14, 1km N of Durham 5
16-Aug-95	D-178	22.6	2	4870845	653332	30 M/14	68	Trib to Duffins Ck. @ Westney Rd.
21-Aug-95	D-178	22.4	2	4870845	653332	" "		" "
21-Aug-95	D-179	0.13	0.003	4869426	652896	N/A		No Description Available
22-Aug-95	D-180	0.51	0.04	4866751	653152	30 M/14		Trib. to Brougham Ck. @ s/l 14, 600m S of Durham 31
22-Aug-95	D-183	0.17	0.01	4864230	653045	N/A		No Description Available
18-Aug-95	D-198	35.7	3.2	4870253	646547	N/A		No Description Available
21-Aug-95	D-200	21.7	2.1	4871224	652321	N/A		No Description Available
20-Aug-95	D-202	0.77		4870615	654281	30 M/14		trib to Duffins Ck. @ s/l 8, 675m N of Conc. 8
22-Aug-95	D-203	0.7	0.2	4864295	655137	30 M/14		trib to Duffins Ck. @ Greenwood Rd, 675m N of Whitevale Rd.
16-Aug-95	D-206	4.5	0.7	4859731	649620	30 M/14		Trib to West Duffins Ck. E of golf course, upstream of Taunton Rd.
23-Aug-95	D-209	18.1	2.6	4856984	657128	30 M/14		Miller's, Ck.@ Jackwin Dr., W of Jallan Dr. (just N of 401)
20-Aug-95	D-211	15.4	2.1	4874017	653914	31 D/3		Trib to Duffins Ck.,1.6km W of Conc.6, on Ux-Pkg twnln (footpath)
20-Aug-95	D-212	0.11		4874018	653917	31 D/3		small trib to Duffins Ck.,1.61km W of Conc.6, on Ux-Pkg twnln (footpath)
20-Aug-95	D-213	6.3	0.9	4874060	654037	31 D/3		Trib to Duffins Ck.,1.7km W of Conc.6, on Ux-Pkg twnln (footpath)
21-Aug-95	D-215	7.6	0.9	4871732	649615	30 M/14		Michell Ck. @ Hoxton St. 225m W of Old Brock Rd.

22-Aug-95	D-218	25.6	2	4863865	654091	30 M/14		Brougham Ck., West branch confl. N.W. of Greenwood CA (1km upstream of Whitevale Rd.)
22-Aug-95	D-219	5.3	0.7	4863861	654118	30 M/14		Brougham Ck. East branch confl. N.W. of Greenwood CA (1km upstream of Whitevale Rd.)
18-Aug-95	D-221	3.7	0.7	4871450	646271	30 M/14		Wixon Ck. W. Branch 100m N. of Pick-Ux twnln
16Aug95	D-222	106	9	4872754	644347	30 M/14	36	West Duffins Ck. @ Webb Rd. Downstream of beaver pond (actually D-222)
18-Aug-95	D-222	111	9	4872754	644347	" "		" "
17-Aug-95	D-226	44.8	7.4	4869904	640904	30 M/14	11	Stouffville WPCP outflow
17-Aug-95	D-227	4.3	0.7	4869876	640963	N/A		No Description Available
18-Aug-95	D-228	0.015	0.004	4873292	645553	N/A		No Description Available
30-Aug-95	D-239	33.2	3	4875306	646253	31 D/3		SE tributary to Secord's Pond, 100m upstream of pond
30-Aug-95	D-240	45.4	3.8	4875507	645949	31 D/3		NW tributary to Secord's pond
30-Aug-95	D-241	0.6	0.2	4875323	646184	31 D/3		small trib to Secord's Pond, near SE tributary
30-Aug-95	D-242	0.42		4875483	646014	N/A		No Description Available

APPENDIX B

SITE ID	Q L/s	Northing	Easting
1	4.9	4868415	656531
2	1.3	4868150	655790
3	0	4866212	657131
4	2.5	4866424	657731
5	12.9	4866023	656592
6	1.4	4864392	658130
7	13.8	4864513	658532
8	4.6	4863118	657964
9	0	4863474	658398
10	12.8	4862569	659134
11	21.2	4860546	659503
12	27.1	4858680	660254
13	29.8	4856749	660835
14	33.5	4855218	661093
15	7.5	4856612	660423
16	0	4855551	661267
17	32.5	4857980	660341
18	6.9	4864150	657285
19	0	4856600	660427

Carruthers Creek 2000
TRCA Baseflow Sampling Locations

APPENDIX C

PROTOCOL FOR DEFINING WATER TAKING REQUIREMENTS WITHIN THE TRCA

With the growing number of new golf courses being built within the Watersheds of the TRCA and the existing courses undergoing renewal of their Water Taking Permits, it is imperative that the Authority identify and develop a protocol for dealing with these water taking issues.

The Ministry of Environment, the Provincial Agency responsible for The Permit to Take Water Program has revised its historical practices in an attempt to deal with a number of management issues including that of ensuring that the Aquatic ecosystem is maintained in a sustainable way when issuing permits. The intent of this initiative is to ensure that for new or renewal permits, that the flow rate required to sustain the Aquatic system is left untouched by any water taking. At present, MOE applies a measured flow based approach in determining this flow quantity. In this approach, the average base flow quantity determined from sufficiently long term data is considered to be necessary to sustain the aquatic ecosystem. Where long term daily flow data are available, the average base flow quantity is determined by first constructing the flow duration table or flow duration curve. The base flow is then defined as the flow rate that is equalled or exceeded 60% of the time (the 60% duration flow).

-A joint Federal/Provincial study is underway to look at the feasibility and issues around developing a biologically definable protocol to define the flow necessary to sustain the aquatic ecosystem . In the interim, MOE continues to define this rate using the aforementioned flow rate.

One of the challenges in implementing the present protocol set by MOE relates to the relative number of locations where detailed flow data exists to allow for the accurate determination of the 60 % duration flow . Within our area, only 17 sites exist where current flow data is available. The use of gauging sites well down or up- stream of the point of interest for a water taking leads to the use of an assumptive technique to try and develop a representative flow. Traditionally an areal reduction formulae was used which assumes that changes in flow rate are based upon a direct relationship with the surficial watershed drainage area. Unfortunately when dealing with low flows or base flows, the flow rate is predominantly made up of ground water flow inputs to the watercourse which may and often do not reflect a drainage area input in such a linear fashion. A recent application for water taking used the areal reduction factor and defined a 67 % reduction in the 60 % stream gauge flow to the point of the proposed water taking. Use of measures base flows reflected a reduction rate closer to 45 %, which confirmed the need to utilize measurements to accurately define the base flows at any specific point of interest along the watercourse.

The Authority is currently developing a data base of point base flow measurements throughout our watersheds at a multiple of sites in addition to existing stream gauge locations. This data will allow for a better understanding of ground water inputs and will be useful in defining more accurately the reduction values to be applied to these 60 % flow rates as well as an understanding of base flows closer to water taking points to confirm the applicability of using the current flow indicator.

Staff of the Authority in discussions with MOE Central Region staff have developed a protocol to ensure that future water taking applications correctly define the flow conditions which need to be protected at the point of water taking. The following represents this protocol.

1) Define the 60 % duration flow (i.e. base flow) at the closest active stream gauge. Evaluate the data and its representativeness of present conditions, based upon an applicable length of data (ie: series of the last 20 years, so that the data range includes dry or drought years)

2) Use TRCA Low Flow Data if applicable. If not, the proponent will;

   - Following a minimum of 72 hours of no precipitation measure the flow rate using a procedure approved by the TRCA. (Water Survey of Canada Protocol) at both the site and at the applicable Stream Gauge station.

   -Compare the measured flow at the Gauge site to the flow rate defined by the site's stage discharge relationship.

   - If the measured flow and the gauged flow at the gauge site are within 10 %, use the ratio of measured low flows to define the reduction factor and compute the 60 % duration flow at the water taking. If the flow rates are not within 10 %, additional measurements will be required.

3) Once the 60 % duration flow has been defined, the proponent will undertake additional low flow measurements on site, along with a surveyed cross sections at the water taking location or at the hydraulic control being used to measure the flow. The proponent will use these flow measurements to develop a defensible stage discharge relationship, to define the actual elevation / depth of the approved 60 % duration flow at the proposed water taking intake location.

4) This elevation will be used to set the invert of the designed water taking intake mechanism. A permit from the TRCA for the intake structure which will be designed to have the intake along the side of the watercourse and operate as a side drop weir, and the intake is to constructed in a manner to be non adjustable.

T.R.C.A. Stream Discharge Measurement Methodology

Over the last three years the TRCA's baseflow monitoring methodology has been refined to accommodate greater accuracy and ground coverage in the data collection process. Watersheds are divided into drainage basins and then broken down to reaches within that basin. This division ensures that an entire basin can be sampled within a single dry period, and any precipitation events will not skew the collected data. Should a precipitation event occur, a period of 72 hours is allowed for surface runoff and groundwater infiltration to occur. If all the sites in a drainage basin are not completed within the same dry period, the entire basin may require re-measuring.

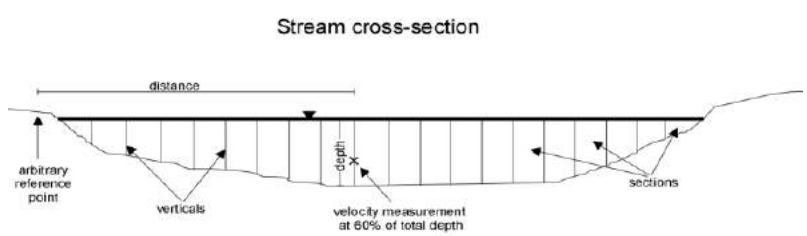


Figure 1. Velocity-Area method of stream flow measurement. Stream velocity, depth and distance are recorded for each vertical. The stream discharge is calculated for each section and summed across the stream.

Sampling sites are chosen starting from the headwaters down to the mouth from topographic maps prior to any field recognisance, exact transects are then chosen in the field to find the best suited segment for baseflow measurements. The sampling locations are chosen at major and minor road crossings for two main reasons, easier access for field staff, and road crossings provide an opportunity to form a Stage/Discharge relationship.

Upon arrival at the mapped sampling location, a suitable transect must be found. For accuracy of measurements the stream segment should have a uniform bed, free of debris such as logs and rocks. The transect should be well up or downstream from any bends or meanders, and the riverbanks should not be undercut. Transects must be at a 90° angle to the streamflow.

Once a suitable transect has been located the channel is broken into 20 panels (or 5% of river per panel). Panels do not have to be uniform width along the transect, if an area of the river is moving significantly faster than the rest, the panels could be narrowed, if there is a slow pocket the opposite is true. In certain situations it is not possible to fit 20 panels, it may be possible to dam up a small uniform channel and take a measurement within. If damming is not possible, less than 20 panels must be used. In this situation, as many panels that will fit should be used, while panel widths should not be less than 40mm. These panels are measured for depth, width and water velocity (See figure 1). This is the velocity-area method of stream gauging. Depth and velocity are measured using a Marsh Mcbirney portable flow meter and depth rod, velocity measurements must be taken at 60% of the depth from the waters surface. If the water is greater than .75 meters, velocity measurements shall be taken at 20% and 80% of the depth from the surface. The width is acquired from a graduated tape spanning the transect. The collected measurements are recorded into an Excel spreadsheet where the panels are calculated and the total discharge of that stream segment is given. This final discharge figure is referenced with the closest upstream discharge and compared for accuracy and continuity. Should the figures show a discrepancy the site is re-assessed, and another sampling may be required. Field crews are also required to record any comments regarding that segment of the river. Permitted and non-permitted water takers are noted, as well as any land use that may be surface water dependant.

T.R.C.A Baseflow Measurement Protocol

The Basis of a sound Low Flow Management Plan is the knowledge and understanding of a watershed's baseflow distribution. A complete mapping of baseflow discharge requires streamflow measurements on all tributaries, throughout the watershed. However, there are many factors that influence baseflow and may skew the results of the measurements. These inaccuracies may incorrectly influence management decisions regarding low water and aquatic issues. Therefore, to obtain a reading of baseflow that is as unaffected by outside influences as possible, the following is a list of procedures to follow when measuring baseflow.

1. Streamflow discharge measurements will be carried out according to TRCA accepted "General Metering Criteria". Refer to Guide provided by JDE Ventures, and Environment Canada's "Hydrometric Field Manual - Measurement of Streamflow".

2. Flow Meters will be calibrated at least once per year, as close to the beginning of the summer lowflow period as possible. Calibrations are done by National Calibration Service of Environment Canada.

3. For consistency of results, the same meter should be used throughout the measurement of a watershed. Each meter has different correction factors, and each too, have differing degrees of error. Therefore, meters are assigned to a watershed, as opposed to a crew.

4. Site locations and general knowledge of the watershed will be obtained before field work commences. Site locations are chosen at major and minor road/river crossings, additional sites are to be added as need be, in order to integrate with other departments or related studies. These sites are labeled from headwaters to mouth (North to South), as shall be sampled as such. General knowledge of the watershed should be attained from such sources as the Permit To Take Water database, surficial geology and land use maps.

5. Sampling sites will be separated into sub-watersheds, and then into drainage basins. Each drainage basin should be sampled in the same dry period, or if possible the same day. If a precipitation event should occur to disrupt this time line, the drainage basin shall be re-measured. To achieve true baseflow measurements, sampling must take place at least 72 hours after a precipitation event. Upon the re-start of sampling, water clarity shall be used to judge if runoff is affecting the flow.

6. Upon the commencement of a new day of sampling, the closest site upstream shall be re-measured to ensure continuity and consistency. If the new site falls below a confluence, both contributing reaches shall be re-measured. If compared results show a significant difference (>10%), then the entire reach may have to be re-measured.

7. With the addition of iPAQ hand held computers to our equipment, on-the-spot calculations can be made, and a final "total discharge" can be attained from the iPAQ software. As well as calculations, the iPAQ unit is used to geo-reference each site, and record various data regarding river conditions, site observations, and measurements as requested (See Appendix 1). Once a final discharge number is calculated and added to the database, it should also be written on your field maps. With accessability to on-site results, quality control is attained by comparing visual observations, and upstream records with the calculated result.

If a discrepancy is found, the site shall be re-measured fully. If a discrepancy persists, site location may be a factor, and a new site should be located. When protocol is followed, and proper methodology is used for the velocity-area method of stream gauging, it should be necessary to measure flow only once per site visit.

8. Once finished sampling, the site (if altered) will be restored to it's previous condition, and all equipment, garbage, etc. shall be removed.

9. All crews are issued a cellular telephone which must remain charged and be kept on during all field work.

Specific Issues

The following are specific issues that have come up in past projects by previous baseflow monitoring crews. These issues must be dealt with in a consistent manner to ensure data integrity and accuracy.

1. Site Location: Accuracy can be greatly reduced if an improper sampling site is chosen. To ensure accuracy of your site look for the following parameters;
   A. Flat uniform riverbed
   B. Free from obstructions (weed masses, log jams, large rocks...)
   C. Sloped riverbanks, no undercutting.
   D. Moving water (no pooling or back eddies)
   E. Marshes adversely affect flow, do not sample in a marsh.

When choosing your sampling site, remember, a little time spent looking around the site location can save you a lot of time sampling.

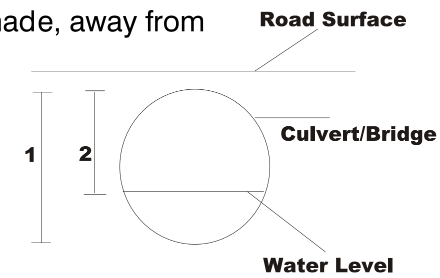
2. Confluences: A confluence shall be treated as a trio of sites, all recorded in a single dry period. The two reaches above the confluence, and the post-union site downstream should be sampled as close to the confluence as possible.

3. Trespassing: You do not have the right to enter any privately owned property. If the site location falls on private property you must get landowner contact before proceeding. If the landowner refuses, a new site location shall be determined.

4. Data Backup: The "Compaq iPAQ" should have battery life for 2-3 days without charging. If

the battery dies, all information on the iPAQ is lost. So as not to lose any data, the iPAQ should be brought into the office to be charged and backed up every 2-3 days.

Recording Additional Data from Baseflow Sites.



Temperature - Air temperatures should be taken first, in the shade, away from your body. Water temperatures shall be measured mid-depth in the river thalwag. The thermometer shall not be in direct sunlight, and should be kept submerged for at least 60 seconds.

Stage/Discharge - A stage/discharge relationship shall be attained through 3 measurements over a given time. Measurement 1 is the height of culvert/bridge, from top to riverbed or culvert bottom. Measurement 2 is the water height. This shall be measured top down, from culvert/bridge top, down to top of water surface. Measurement 3 is the total flow for that site. An important note is to comment on where these measurement were taken. eg: South side of road, East culvert.

Photographs - Two photographs should be taken at each site; photo 1- upstream of location, photo 2 - site location and downstream.

Comments - The comment field is one of the most important recordings. Comments should include suspected baseflow altering land uses, landowner issues, site problems, in stream barriers, and any other observations made by the crew. Crews should get used to filling in comments for every site, a seemingly unimportant observation may be quite pertinent during baseflow analysis.

APPENDIX D

Water Budget in Urbanizing Watersheds

Duffins Creek Watershed

For: **Toronto and Region Conservation**

By: **Clarifica Inc.**
Water Resources Engineering and Science Consulting

May 21, 2002

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1 Introduction

Understanding and quantifying water balance components is of particular interest when planning watershed management strategies. Land use changes during urbanization are known to shift the water balance in a watershed: increasing surface runoff and decreasing the amount of water retained on-site. After urbanization, water will be distributed differently temporarily and spatially, more available in some places and times and less in others. There are also changes in the amount of water entering the ground with impacts to the water table levels. This can be significant in shallow, unconfined groundwater aquifer systems where ground water supplies water to vegetation root zones and is a source of base flow in streams through seepage along stream valleys when there is a hydraulic gradient from water-bearing soil layers.

1.1 Definitions

Water balance analysis is the accounting (quantification) of the main components of the water cycle. This includes ‘Precipitation’ inputs from the atmosphere (‘Rainfall’ or ‘Snowfall’), flow over land surfaces (‘runoff’), along drainage channels and rivers (‘Streamflow’), groundwater systems (‘Groundwater Infiltration’), or moisture returned back to the atmosphere (‘Evaporation’). Water reaching land surfaces can also be temporarily stored on land or vegetated surfaces (‘Interception’).

‘Excess’ water, known as surface runoff, can occur as uniform ‘sheet’ flow or as concentrated flow within rivulets, swales, ditches, streams and rivers. The ‘excess’ term refers to the precipitation or snowmelt not retained in the soil or intercepted and held in surface depressions, leafs, etc. Runoff can occur during rainfall and/or snowmelt events. Runoff, groundwater discharge, and direct precipitation replenishes streams, surface reservoirs and lakes.

Snow accumulates in ‘snowpacks’ during snowfalls when the temperature is below freezing. Above freezing, the snowpack first ‘absorbs’ the liquid until it reaches the ‘liquid water holding capacity’ and then releases it back to the surface (‘Snowmelt Runoff’) or to the underlying soil.

Groundwater infiltration is the process by which water first enters the surficial soils, moves downward and then replenishes groundwater reservoirs. Soilwater can travel downward, laterally, or upward under artesian and ‘tension’ (negative) pressures. Artesian pressures push water upwards toward the surface and under higher conductivity soils, create groundwater ‘discharge’ areas.

Water is also transferred back to the atmosphere as water vapor through evaporation (liquid water to gas) and sublimation (solid ice or snow to gas). Evapotranspiration is a special case of evaporation by which evaporation occurs at the surface of moist cells within plant tissues, moves into intercellular leaf spaces and diffuses through stomates to the atmosphere (ASCE, 1996).

Cumulative effects of urbanization on infiltration and baseflows are generally difficult to quantify with certainty due to the difficulties associated with hydrogeologic characterization as well as the concurrent influences from human activities. Examples include municipal discharges, water taking, contributions from foundation drain collectors, man-made reservoirs, etc. However, good estimates have been obtained in the past through the application of physically-based and calibrated empirical models.

1.2 Objectives

The objective of this study is to characterize the surface water balance of the Duffins Creek watershed for existing and future land use conditions. Results from the study will assist watershed managers deal with potential changes associated with future urbanization.

Three land use conditions are considered as per current TRCA planning approach:

1. Existing Conditions (2000).
2. Future Official Plan - includes future urban development as committed on Municipal Official Plans.
3. Future Official Plan with Natural Heritage Strategy - includes future urban development committed in Municipal Official Plans, together with headwaters and creek valley reforestation as expected under the TRCA's Natural Heritage Strategy.

1.3 Report Contents

This report summarizes of the work completed to assess the water budget of the Duffins Creek watershed. The report describes the:

1. Definitions: this section.
2. Methodology: describes the overall analysis approach and hydrologic equations.

3. Input Data: describes the climate and physical watershed parameters.

4. Calibration: describes the stream flow data and data processing including baseflow separation and adjustment of parameter that were necessary to match the observed wet-weather flow as measured at several stream gauging stations.

5. Long-term simulation: presents the long-term average water budget results.

6. Conclusions and Recommendations

Detailed input and output information as well as other supporting documentation is provided in the appendices.

2 Methodology

2.1 General Approach

The water balance analysis methodology calculates the water balance component of each basin using the '**WABAS**' system. **WABAS** (**WA**ter **B**alance **A**nalysis **S**ystem) was developed by Clarifica Inc. to analyze the hydrologic water balance of rural and urbanizing watersheds. **WABAS** was designed to use the data from other surface hydrology analysis techniques (SCS CN runoff method), snowmelt methodology (GAWSER), an unsaturated groundwater infiltration and evaporation techniques. The model operates from an Excel worksheet platform. It requires climate time series input of daily precipitation, average or maximum-minimum daily temperature, and measured pan evaporation. Outputs are time series of runoff, infiltration, evaporation, and storage conditions within each water balance reservoir (pervious and impervious interception storage, surficial soil storage, snowpack storage).

Input data also includes hydrometric (measured flows), and physical basin parameters. Local climate data and measured flows are used for surface runoff calibration. Physical basin parameters define the surface and surficial properties of each basin affecting the storage and movement of water from one stage to another including imperviousness, interception abstractions, vegetation, and surficial soil characteristics. These parameters are collected directly or indirectly based typical land-use or surrogate soil and vegetation parameters. Because the model outputs daily time step volumetric results, it does not require routing coefficients. However, for the Duffins watershed, a three-day unit hydrograph lag was found suitable for calibrating observed daily average in-stream flows following rainfall events and this was incorporated as part of the surface runoff response.

The water balance calculates average annual depths for each of the following components:

1. Precipitation (rain and snow).
2. Runoff.
3. Groundwater infiltration.
4. Evaporation.

Additional hydrologic component results can be provided if necessary. The general modeling methodology is illustrated in **Figure 1**. WABAS keeps track of stored water in multiple 'reservoirs' representing different physical locations and states (illustrated with circles in **Figure 1**). Water moves from one reservoir to another or out of the system based on specific physical and climate condition. The next sections present the modeling approach.

The study methodology includes the following steps. These are explained in more detail later in this report.

1. Collect physical, climate and hydrometric information from the nearest gauges to the study area.

2. Analyze the climate information to create time series of continuous measured precipitation, temperature and evaporation data. The climate data period must correspond to the stream flow data period to allow for model calibration. Apply data infill techniques to complete the time series using the next favorable gauge location and or regression.

3. Analyze hydrometric information for selected gauges for calibration. Separate the baseflow from the total measured stream flow to isolate the wet-weather component of the total hydrograph. The baseflow approach is described under the calibration section.

4. Collect watershed physical data from previous hydrologic studies and remotely sensed data. Physical data includes: basin boundaries and areas, soil information (soil types and properties: hydraulic conductivity, porosity, etc.), existing and future land uses and related imperviousness, vegetation types and area coverage.

5. Process the physical data to obtain basin-averaged water balance input parameters. This stage, completed by TRCA staff, includes the overlay of land use, soil, and vegetation information over basin boundaries using GIS. Additional analysis is required to establish area-averaged parameters upstream of each stream flow gauge.

6. Model calibration. This stage required the systematic evaluation of empirical and non-measured modeling parameters to match observed flows at the stream gauge locations. Adjustments for individual basin parameters upstream of the gauged location using proportional method.

7. Long-term modeling using complete climate series.

8. Summary of results and documentation. Results are presented as average annual values for each of the main water budget components.

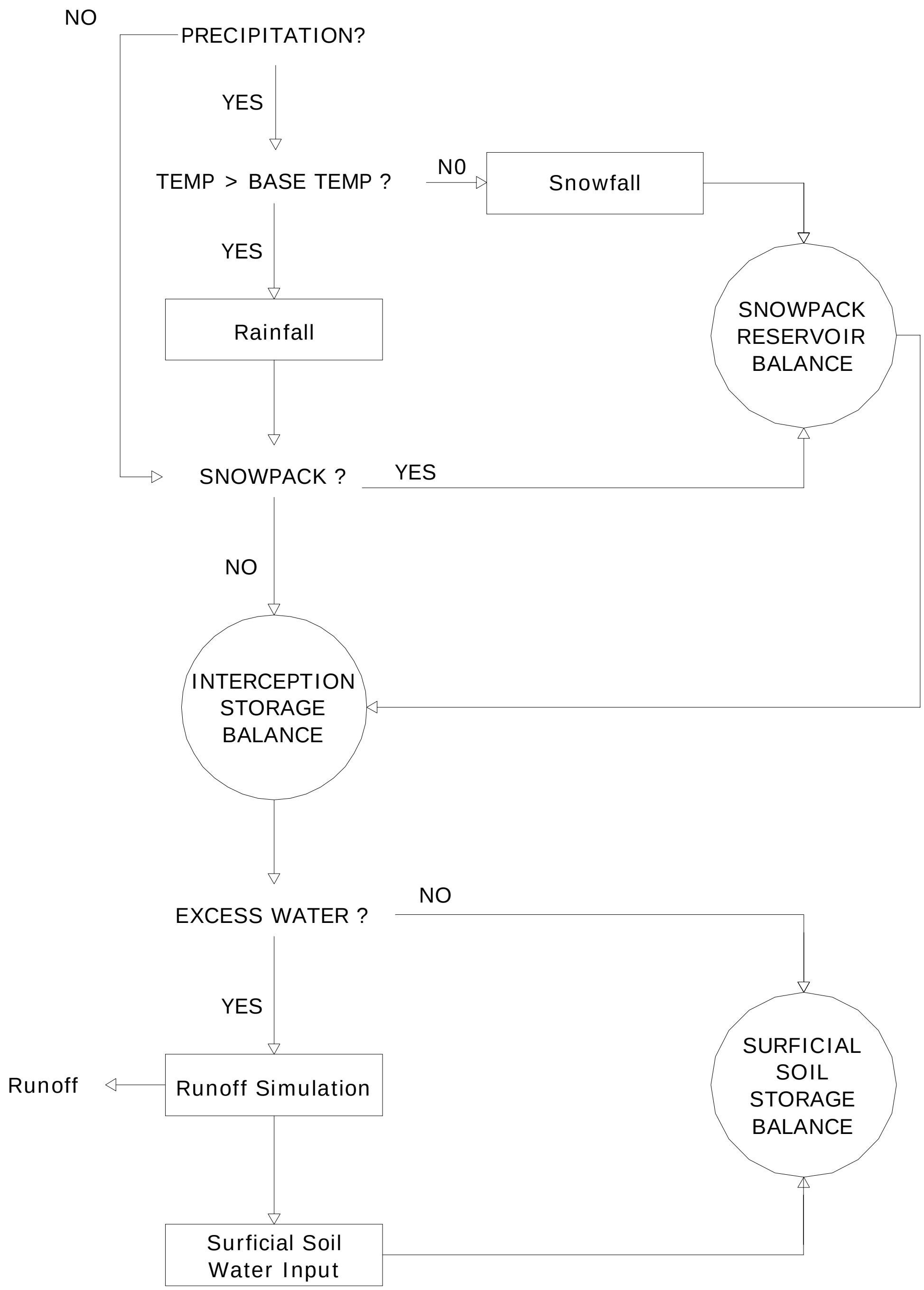


Figure 1: Snowpack, Interception, Surficial Soil Storage Schematics

2.2 Computation Methods

2.2.1 Snowpack Reservoir Balance

Two options area available in WABAS to simulate snow accumulation and melt: Environment Canada's average temperature index method and the GAWSER model maximum-minimum temperature method. The 'max-min' temperature method was used for the Duffins Creek watershed water balance.

The max-min reservoir balance routines in WABAS accumulate, consolidate, and release water from the snowpack in response to the passing of time, inputs of snowfall and rainfall, and due to temperature changes. During periods with snow on the ground, WABAS keeps track of the snowpack conditions by updating its density and liquid water holding capacity. As rainfall or snowmelt occurs, water is absorbed by the snowpack and the liquid water holding capacity decreases to a pre-determined limit after which excess water is released as runoff. Refreeze occurs during days when the temperature falls below the base value, typically 0 degrees Celsius. WABAS calculates both snowmelt and re-freeze during days when the maximum and minimum temperatures fluctuate across the base temperature.

Specifically, the model simulates one of three conditions during the day, as illustrated in **Figure 2**. As shown, melts occurs during period when the temperature exceeds the base value during part or the entire day. Conversely, refreeze occurs when the temperature falls below the base temperature. The area between the temperature line to the base temperature (hatched in figure) is a measure of the intensity of melt or freeze and is expressed as cumulative 'degree-hours'. The greater the degree-hours the more melt occurs. The lesser (negative) degree-hours the more refreeze occurs.

The model applies degree-day equations to calculate snowmelt and refreeze. Snowmelt is calculated as follows:

$$MELT = KM \cdot (T_{AIR} - T_{BAS})$$

Where: KM = melt factor, in mm/day/^{o}C.
T_{AIR} = air temperature, in degrees Celsius.
T_{BAS} = base temperature at which snow melts, in degrees Celsius

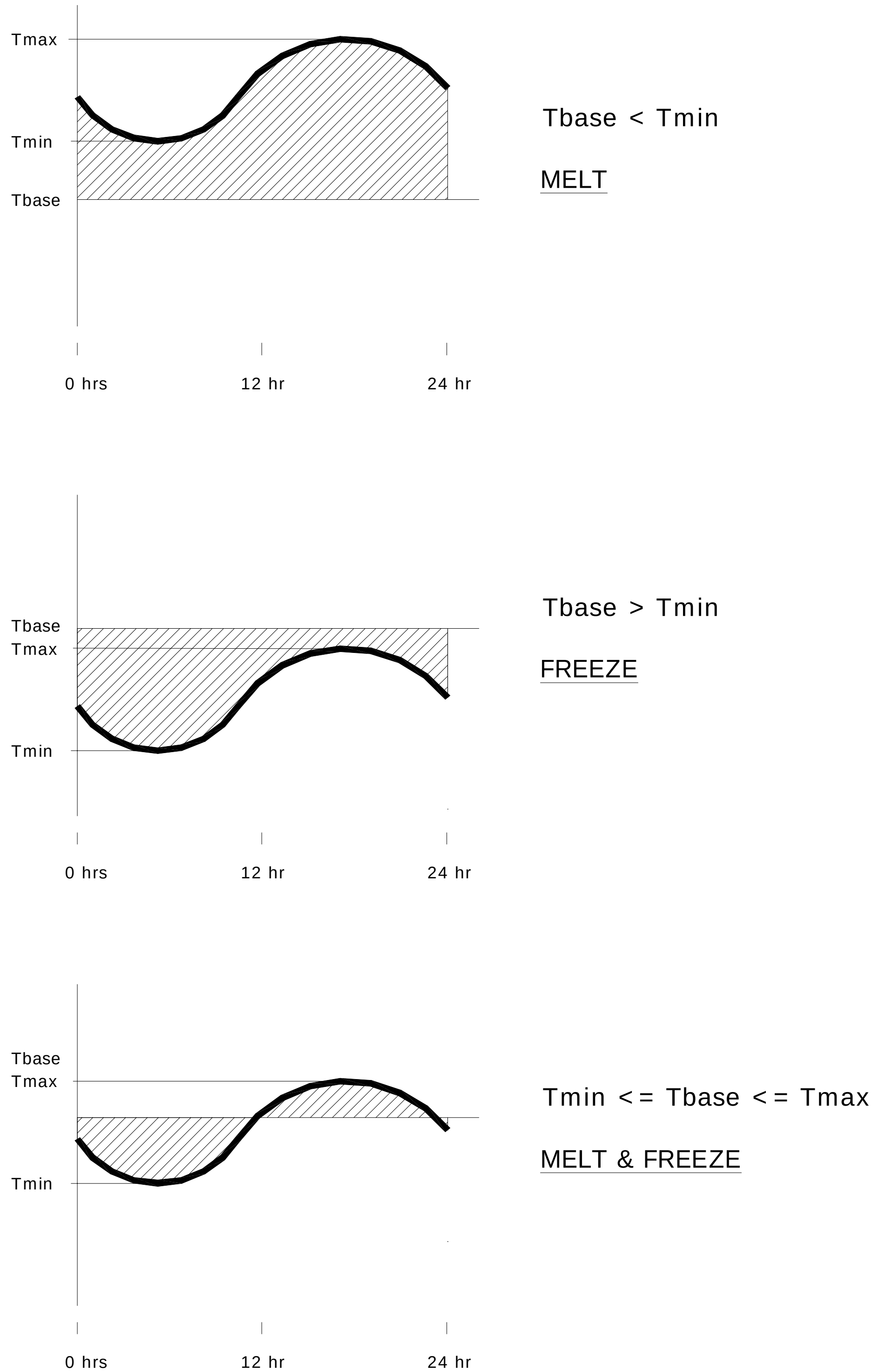


Figure 2: Snowmelt Cases in WABAS

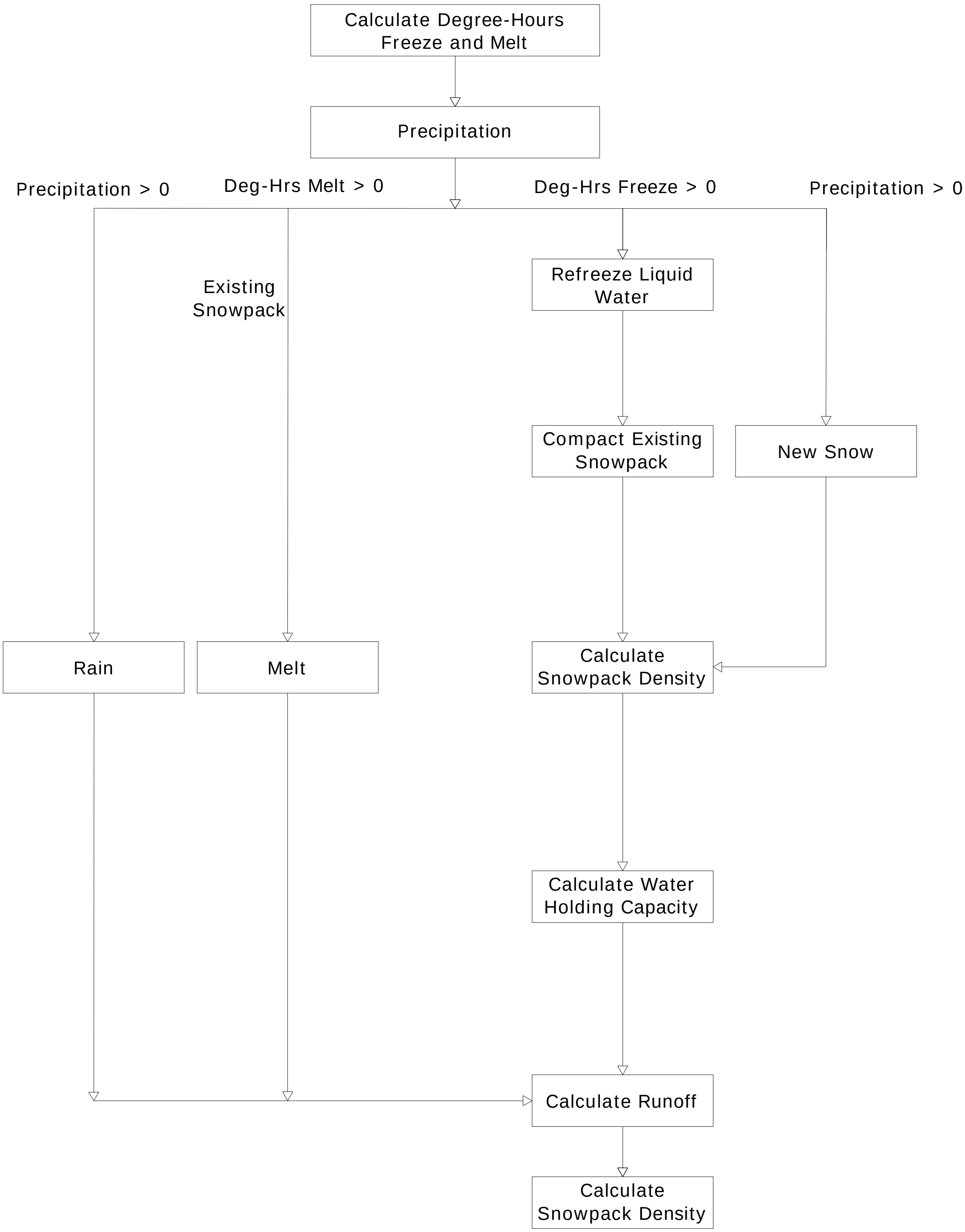


Figure 3: Snowpack Reservoir Balance Computation

The melt factor, KM, is time-varying and depends on location, type of cover, exposure to solar radiation, time of year, and meteorological conditions. There is no melt when the air temperature stays below the base temperature.

Refreeze is calculated as:

$$REFREEZE = KF \cdot (T_{BAS} - T_{AIR})$$

Where: KF = refreeze factor, in mm/day/ ^{o}C.
T_{AIR} = air temperature, in degrees Celsius.
T_{BAS} = base temperature at which snow melts, in degrees Celsius

The refreeze factor, KF, has units of mm/day/^{o}C and is also time-varying. It is set equal to KM.

The analysis implements a sinusoidal time-varying function to represent daily and seasonal parameter variations. For example, daily temperature variations are represented as follows:

$$T = \left(\frac{T_{MAX} - T_{MIN}}{2}\right) \cdot SIN\left[\left(\frac{t - t_{T\min}}{12} - \frac{1}{2}\right) \cdot \pi\right] + \left(\frac{T_{MAX} + T_{MIN}}{2}\right)$$

Where: T_{MAX} = refreeze factor, in mm/day/ ^{o}C.
T_{MIN} = air temperature, in degrees Celsius.
t = current time, in hours.
t_{Tmin} = time when minimum temperature occurs, in hours.

Cumulative degree-melt or degree-freeze hours are calculated by integrating for the areas between the daily temperature curve and the base temperature. As indicated previously, this can be positive (melt), negative (freeze), or both (melt and freeze) during one day. Similarly, precipitation is distributed as rain and snow based on the relative magnitudes of degree-days.

The snowpack reservoir balance tracks the solid and liquid water content and the relative dry-density of the snowpack. Snowmelt runoff occurs when the liquid water content exceeds the liquid water holding capacity of the pack. The runoff volume, in mm, is calculated as follows:

$$RUNOFF = LWC - LWCAP$$

Where, RUNOFF = snowmelt runoff, in millimetres
LWC = liquid water content, in millimetres
LWCAP = liquid water holding capacity, in millimetres

The liquid water content of the snowpack at the end of the snowmelt event is equal to the liquid water holding capacity, LWCAP. The LWCAP is a function of the density of the snowpack, where density is expressed as:

$$RHO = \frac{SWC}{SDEP}$$

Where, RHO = relative dry density of the snowpack, vol/vol.
SWC = solid water content, in millimetres
SDEP = snowpack depth, in millimetres

The greater the density of the snowpack, the less water it can hold. New snow has the lowest density and highest water holding capacity. As per the GAWSER documentation, the relative dry density of new snow varies from 0.02 to 0.15, with a typical value of 0.1.

Snowpack density reductions occur due to melt and compaction. Compaction is calculated as follows:

$$RHO_F = \frac{(RHO_I \cdot RHO_{MAX})}{\left(RHO_I + (RHO_{MAX} - RHO_I) \cdot \exp\left(-\frac{DT}{KC}\right)\right)}$$

Where, RHO_F = final relative dry density of the snowpack, vol/vol.
RHO_I = initial relative dry density, vol/vol.
RHO_{MAX} = maximum specified relative dry density, vol/vol.
DT = time period, in hours.
KC = compaction time constant, in hours.

The compaction time constant, KC, is a function of the air temperature, T. In WABAS, the average daily temperature is used to calculated KC as:

$$KC = B \cdot \exp(-A \cdot \overline{T})$$

Where, A, B = coefficients, in 1/C^o and hours, respectively.
$\overline{T}$ = average daily temperature, in C^o.
RHO_{MAX} = maximum specified relative dry density, vol/vol.
DT = time period, in hours.
KC = compaction time constant, in hours.

2.2.2 Interception (Abstraction) Storage Balance

Abstraction losses account for rainfall on vegetation on depressed areas where there is no possibility for lateral or downward movement. WABAS accounts for abstraction losses over pervious and impervious surfaces separately. In both cases, rain or snowmelt first fills the depressed storage prior to generating runoff and/or replenishing the surficial soil storage reservoir. After filling the depressions, abstraction storage is restored through evaporation. The amount of water stored, ABSTOR, in depressions is:

$$ABSTOR_F = ABSTOR_I + INPUT_{R+SM} - OUTPUT_{EVAP}$$

Where, $ABSTOR_F$ = final water in abstraction storage, in millimetres
$ABSTOR_I$ = final water in abstraction storage, in millimetres
$INPUT_{R+SM}$ = rainfall and snowmelt input to abstraction storage, in millimetres
$OUTPUT_{EVAP}$ = rainfall input to abstraction storage, in millimetres

ABSTOR is defined as part of the basin physical data for pervious and impervious areas.

2.2.3 Active Hydrologic Soil Zone Balance

The available storage in the active hydrologic soil zone, S, is very important in the water budget analysis process. The active soil zone connects the surface and groundwater systems. The amount of water entering the active hydrologic zone is controlled by the surface runoff equation, which in turn depends on how much storage is available in the active zone. The more storage available the more water absorbed into the surficial soil resulting in lower surface runoff. The amount entering the active hydrologic zone during wet-weather events is thus:

$$SI = TOTAL\_EXCESS\_WATER_{PER} - RUNOFF_{PER}$$

Where SI refers to water input. Water entering the active zone can be retained in the soil matrix by surface tension forces or moves downward into groundwater system (groundwater infiltration) or is lost through evapotranspiration. Other processes that may occur within the active hydrologic zone such as interflow movement are very difficult to simulate due to the variable soil conditions and are often dealt through model calibration.

WABAS calculates the water balance of this active soil storage accounting for inflows from the surface (water that does not runoff), and losses to evaporation and infiltration.

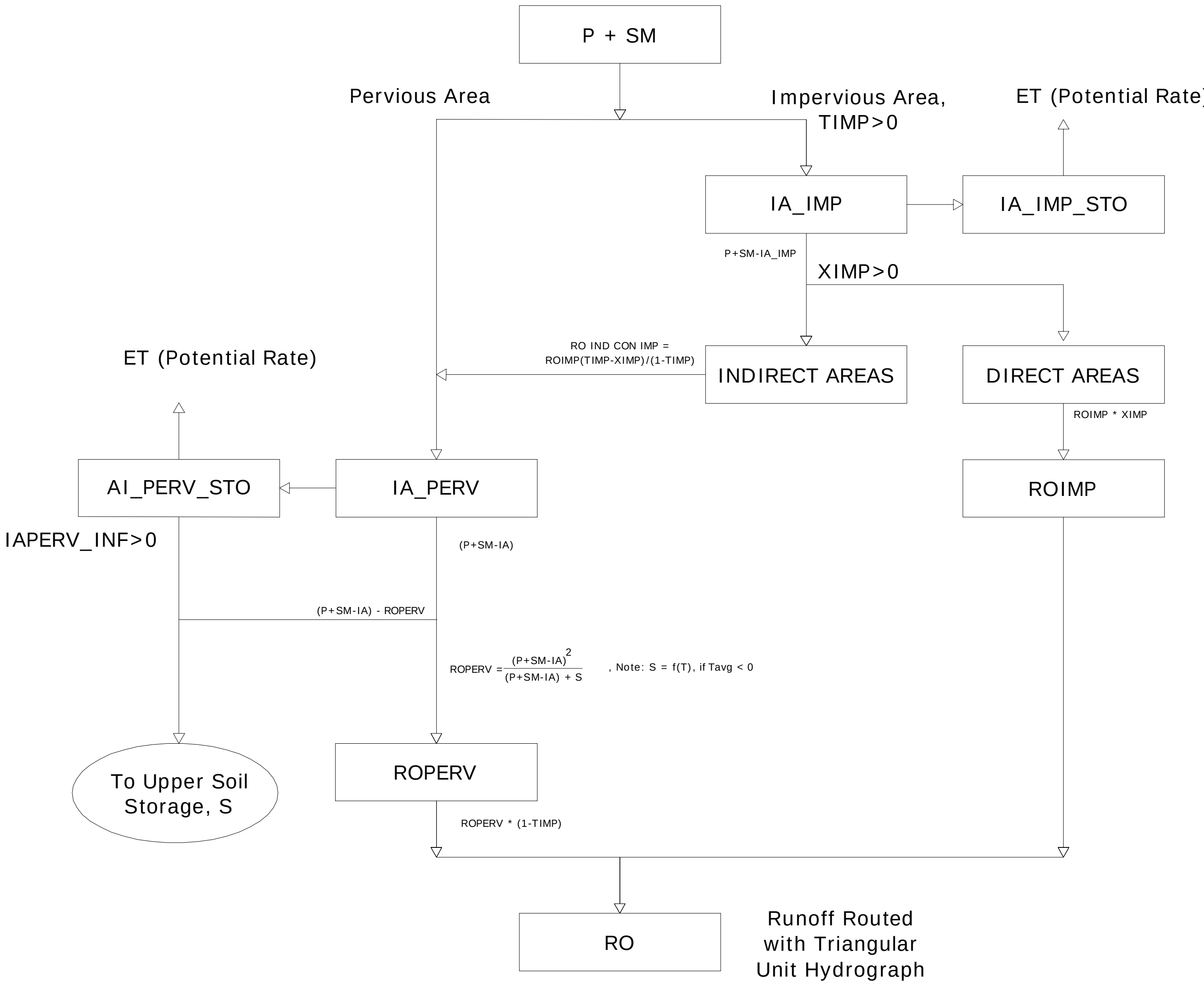


Figure 4: Active Hydrologic Soil Zone Balance

2.2.3.1 Runoff

Runoff is calculated independently from pervious and impervious surfaces. For impervious surfaces, runoff is simply the difference between the rainfall plus snowmelt and the abstraction losses.

$$RUNOFF_{IMP} = RAIN + SNOWMELT - ABSLOSS_{IMP}$$

Where, $RUNOFF_{IMP}$ = runoff from impervious land surfaces, in millimetres
RAIN = measured rainfall, in millimetres
SNOWMELT = melt water released from snowpack, in millimetres
$ABSLOSS_{IMP}$ = abstraction losses over impervious land surface, in millimetres

Rain plus snowmelt is determined from the snow reservoir routine, ensuring that precipitation as rain is not retained in the snowpack. Runoff from pervious surfaces is calculated using the modified form of the US Soil Conservation Service (SCS) Curve Number (CN) method. This method is consistent with other hydrologic analysis methods applied in several hydrologic models in southern Ontario. The form of the SCS runoff equation is:

$$RUNOFF_{PER} = \frac{(RAIN + SNOWMELT + ICRO - ABSLOSS_{PER})^2}{(RAIN + SNOWMELT + ICRO - ABSLOSS_{PER}) + S}$$

Where, RUNOFFPER = runoff from pervious land surfaces, in millimetres
RAIN = measured rainfall, in millimetres
ICRO = effective runoff from indirectly connected impervious land surfaces, in millimetres
SNOWMELT = melt water released from snowpack, in millimetres
ABSLOSSPER = abstraction losses over pervious land surface, in millimetres
S = available storage in active hydrologic soil zone, in millimetres

As per impervious land surfaces, rain plus snowmelt is determined from the snow reservoir routine, ensuring that precipitation as rain is not retained in the snowpack. The term ICRO is the net contribution of water from impervious surfaces onto pervious surfaces referred to as 'indirectly connected impervious areas'. This 'net' factor accounts for several physical conditions reduce the impacts of indirectly connected impervious areas on pervious areas:

- Unlike precipitation and snowmelt, which are generally uniformly distributed over the pervious areas, runoff contributions from impervious areas are often concentrated in flow channels.

- Indirectly connected impervious areas are not always uniformly distributed over the entire basin and only affect a fraction of the pervious surfaces.

The net effect is that water from indirectly connected areas is somewhat reduced and not available over the entire pervious surfaces. WABAS implements this condition through a reduction factor for the indirectly connected areas. Evaluation of typical lot layouts and grading suggest that a 0.20 multiplication factor (80% reduction) of the indirectly connected areas is a reasonable value.

The water balance analysis also incorporates an effective soil storage adjustment during winter conditions in the presence of a snowpack. This factor simulates soil freeze conditions with an apparent reduction in available soil storage. Literature on this topic indicates that the infiltration characteristics of frozen versus unfrozen ground is not well understood and depends upon the moisture content at the time of freezing (SWMM4, p. 437). The snow pack insulates the underlying soil and if the ground was frozen prior to snowfall it will remain frozen thereafter, even after the snow starts to melt. During snowmelt, WABAS assumes that the soil has very little storage available (approx. 90% reduction) for the purpose of calculating net runoff. Again, this approach accounts for uneven area-distribution of the snowpack or for different soil freeze condition during snowfall.

2.2.3.2 Evaporation

Evaporation is measured parameter. Evapotranspiration (ET) is calculated using a modified version of the U.S. Agricultural Research Service (ARS) equation. ET from soil water accounts for the vegetation characteristics and amount of soil water available in the active hydrologic zone.

The form of the ET equation is as follows (Viessman, 1977):

$$ET = GI \cdot k \cdot PE \cdot \left(\frac{S - SA}{AWC} \right)^n$$

Where, ET = actual evapotranspiration, in millimetres
GI = vegetation growth index as a proportion of maturity
k = ratio of ET to potential ET (PET) at full canopy with freely-available water
PE = lake evaporation taken as the potential, in millimetres
S= as identified in the following table, percentage.
SA= available porosity (unfilled by water).
AWC = porosity drainable only by evapotranspiration
n = an exponent that varies with soil type in the range of 0.1 to 0.25.

The growth index (GI) is modified seasonally by a sinusoidal distribution over the summer growing season. The model calculates actual ET from the vegetation growth index as a function of the of year, lake evaporation and the underlying soil conditions. The resulting ET is a measure of the water loss from surficial soil storage largely through diffusion of water vapour from plant leaves to the atmosphere (transpiration). The algorithm depletes surficial abstraction at the potential rate. The PET remaining and 'evapotranspiration opportunity' are used to quantify and extend the water loss from the upper soil storage to the root zone. Evapotranspiration opportunity is defined as the maximum amount of water available for evapotranspiration at a particular location during a prescribed time period.

2.2.3.3 Infiltration

Water moves from the active hydrologic soil zone downward according to Darcy's law. Darcy's law may be expressed

$$q = -K \frac{\partial h}{\partial z}$$

Where, q = Darcy flux in millimetres/day
K = saturated hydraulic conductivity, in millimetres per day
$\frac{\partial h}{\partial z}$ = is the hydraulic gradient in a downward direction

WABAS moves water downward within the hydrologically active zone based on the average relative permeability (calculated as function of water saturation) within the unsaturated zone. The movement from the active hydrologic zone downward is determined as a sharp wetting front.

3 Input Data

3.1 Climate Data

Climate data used in the water balance simulation includes precipitation, temperature, and pan evaporation measurements. Climate data is required for the entire period of simulation. For the Duffins Creek watershed this includes 15 years from 1986 to 2000. The last four years are also used for calibrating the model to measured runoff flows at 6 gauging stations. Calibration is discussed in section Error! Reference source not found..

Measured daily precipitation is the basic water input to the system. Precipitation includes rainfall and snowfall in millimeters of water (water equivalents). The system differentiates rainfall and snowfall from the difference between measured temperature (maximum and minimum daily temperatures or average daily temperature[1]) and the 'base' temperature. Typically, 0 degree Celsius is used as the base temperature. Pan evaporation is transformed to lake evaporation

The Duffins Creek water balance analysis considered measured precipitation from several stations in the region with data during the same period as the measured stream flow. The stations included are:

- Buttonville Airport
- Stouffville WPCP
- Toronto Lester B. Pearson Airport
- Cherrywood (Ontario Hydro)

The meteorological station locations are illustrated in **Figure 5**. The Stouffville WPCP station did not have data during the calibration period from 1997 to 2000.

Data screening revealed that precipitation data was not available for all stations during the period of available flows and data infill was required. Further review showed that Buttonville Airport rainfall records produced the most consistent response when compared with the measured stream flow. Cherrywood, although closer to the watershed, produced the least consistent results. Regression analysis of the measured daily precipitation between stations confirmed the results. Pairing of daily precipitation at Pearson Airport, Buttonville Airport and Cherrywood station resulted in a poor relation

[1] Two snowmelt routines available: GAWSER using maximum and minimum daily temperatures or AES index method using average daily temperature.

between Cherrywood and the two other gauges.

Table 1: Daily Precipitation Regressions

Relation	Regression
Cherrywood-Pearson	0.49
Pearson-Buttonville	0.81
Buttonville-Cherrywood	0.53

The Buttonville Airport gauge has been in operation for at least 15 years from 1986 to 2000 and it can be used for long-term simulation and characterization of average water budget components. The gauge is relatively close to the Duffins Creek watershed and there is little orographic variations which could lead in significantly-different precipitation patterns and volumes as observed by the relatively consistent precipitation-streamflow relations (shown in the calibration). Precipitation data infill showing actual values used are included in **Appendix H**.

Maximum and minimum temperature data was collected for:

- Buttonville Airport
- Stouffville WPCP
- Toronto Lester B. Pearson Airport

Similarly, review of temperature records revealed that the data was not available for all stations during the period of measured flows and data infill was required. In this case, the Stouffville WPCP data was given higher preference followed by Buttonville and the Pearson gauge. Precipitation data infill showing actual values used are included in **Appendix I**.

Historical Lake Evaporation data was available at three stations:

- Hamilton RGB station (in Burlington),
- Lindsay Frost, and
- Peterborough (Trent University).

The Hamilton station contains data from 1986 to 1996 and is the closest to the study area. Because operation of all three stations has ceased (1996 for the Hamilton RGB, Peterborough in 1995, and Lindsay Frost in 1984), an averaged seasonal evaporation function was derived and used for the period of calibration from 1997 to 2000 and for the winter periods when the pan evaporation stations were shut down. The seasonal lake evaporation function for the Hamilton RGB station is shown in **Figure 5**. Daily values are interpolated based on the day of the year from those shown in the figure. Evaporation data infill showing actual values used are included in **Appendix J**.

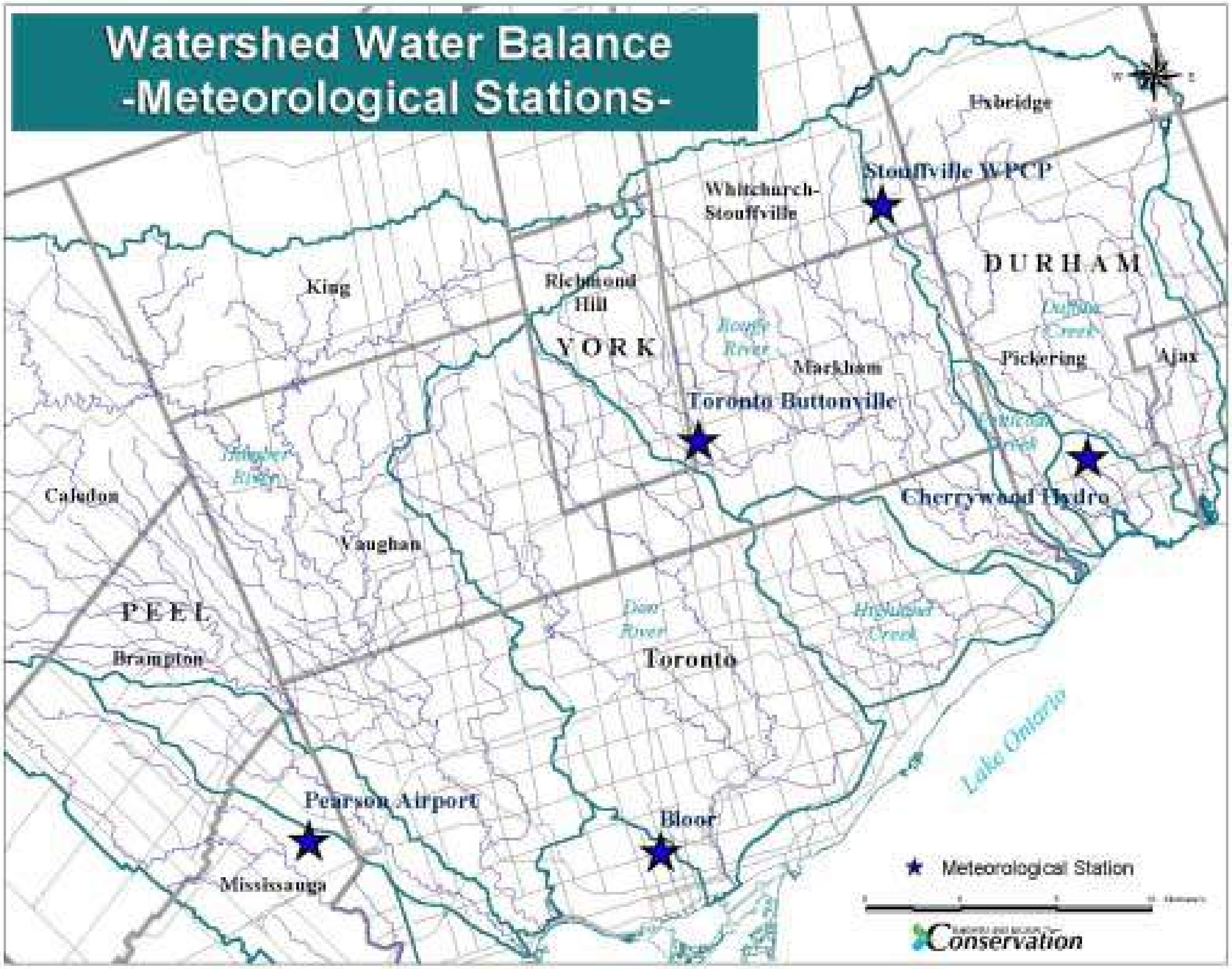


Figure 5: Precipitation Station locations

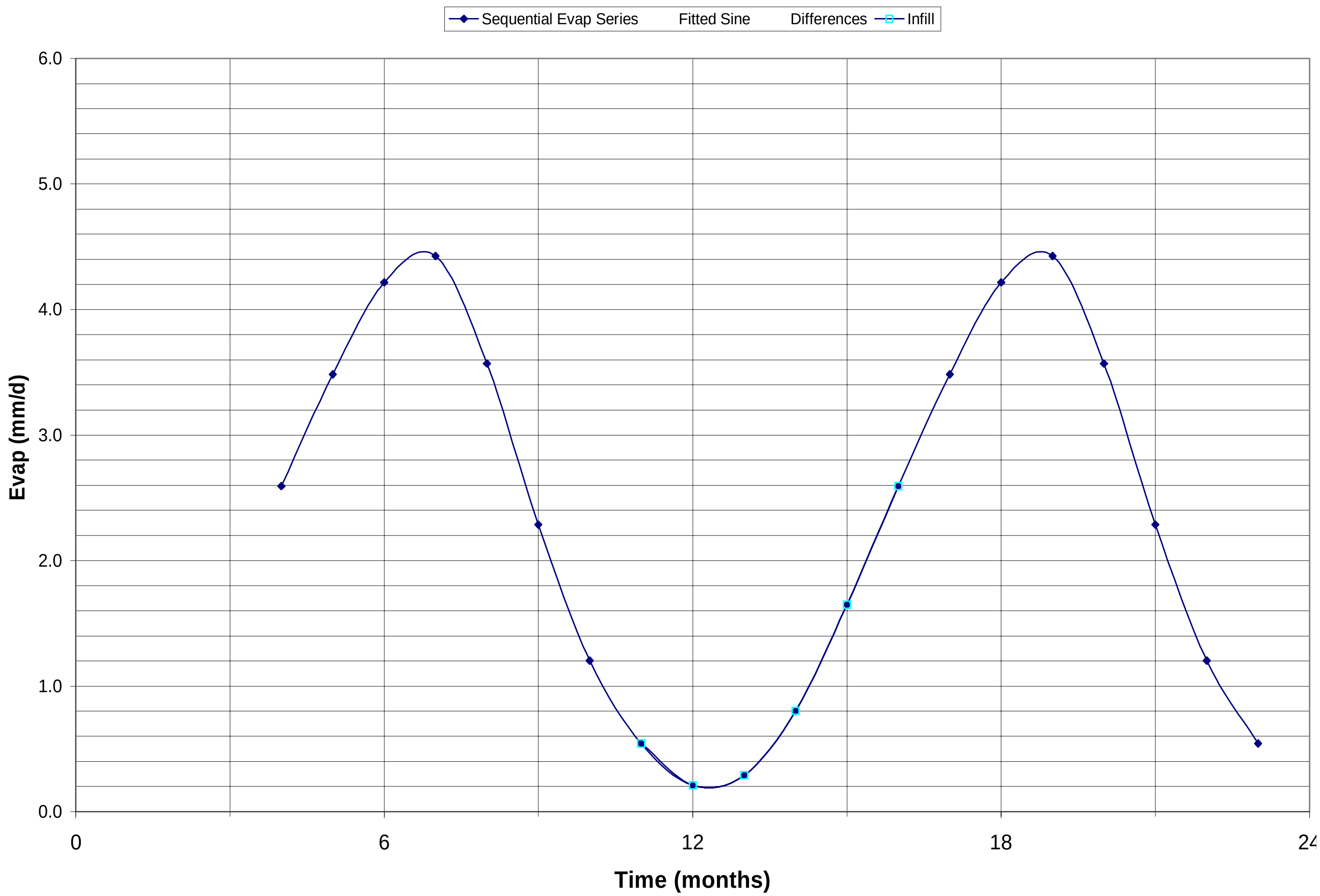


Figure 6 : Averaged Lake Evaporation – Hamilton RGB AES Station

The long-term annual precipitation values are summarized in **Table 2**.

Table 2: Annual Precipitation in Long-term Water Balance Analysis

Year	Days in Record	Precipitation [mm]
1986	223	833
1987	365	823
1988	366	676
1989	365	776
1990	365	921
1991	365	752
1992	366	1065
1993	365	799
1994	365	754
1995	365	925
1996	366	1034
1997	365	762
1998	365	734
1999	365	805
2000	366	984
Average		844

3.2 Physical Watershed Parameters

Physical watershed input used by the WABAS program consists of basin areas, land use, maximum abstraction storage, soil and vegetation information. Duffins Creek watershed data was collected from existing hydrologic models (OTTHYMO model of Duffins Creek watershed), surficial soil mapping, and air photography.

Table 3 lists the physical basin parameters. The information was entered into a GIS system and processed by the TRCA to produce basin-averaged parameters. The basin discretization is illustrated in **Figure 7.** Specific parameter values for each scenario are listed in **Appendix A**.

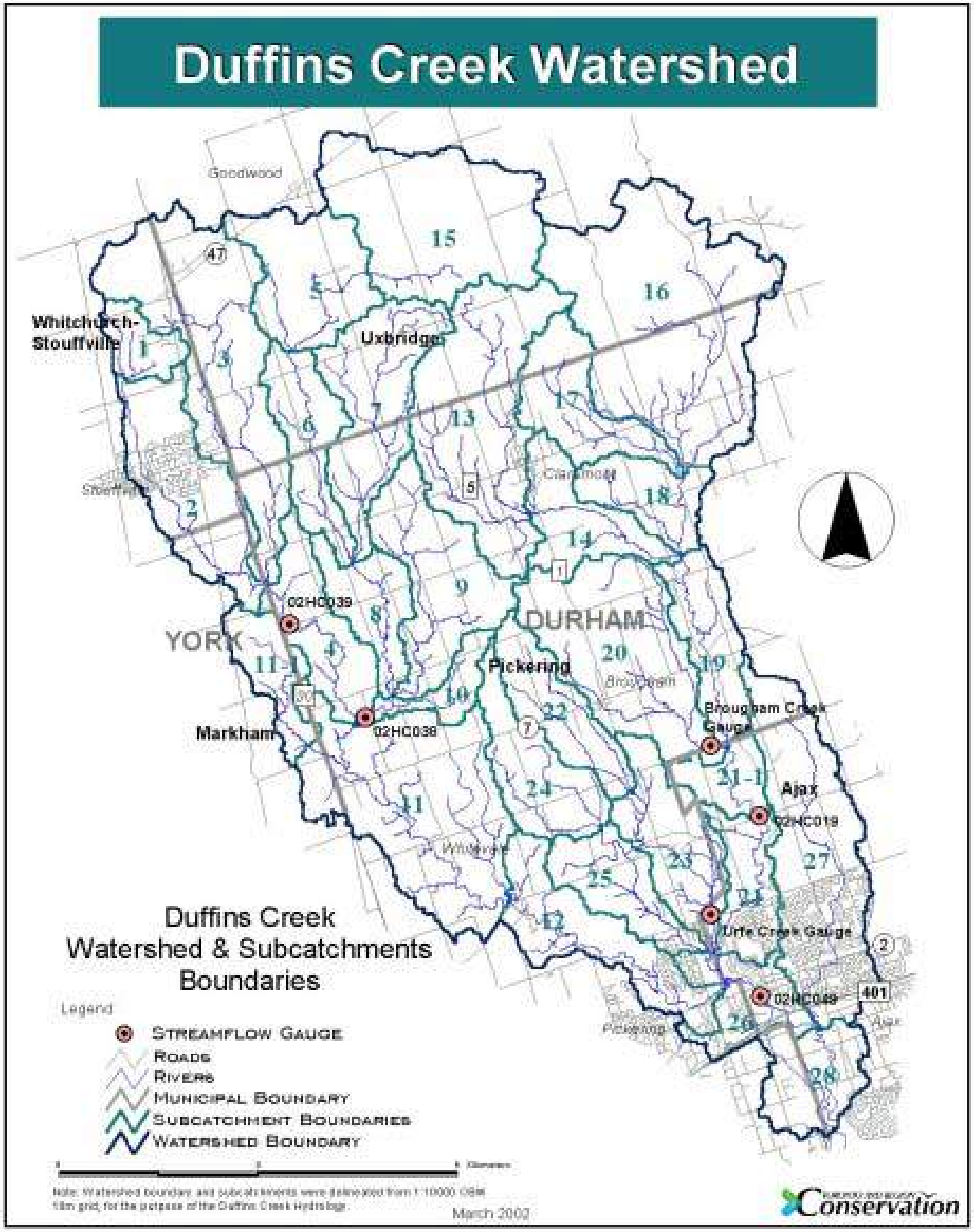


Figure 7: Duffins Creek Basins

Table 3: Physical Basin Parameters

Parameter	Description [Units]
AREA	Basin area [Hectares]
TIMP	Basin imperviousness [Fraction]
XIMP	Directly connected imperviousness [Fraction]
Z_IMP	Indirectly Connected Area Efficiency [%]
IA_imp	Depression storage/Interception Storage over impervious areas [millimetres]
IA_per	Depression storage/Interception Storage over pervious areas [millimetres]
CN*	Modified Soil Conservation Service (SCS) Curve Number [no units]
VEG_K3	Watershed vegetation cover function [mm]
PO	Porosity [%]
G	Soil water drained by gravity [%]
K	Saturated hydraulic conductivity [mm/day]

Most of these parameters have been described in **Section 2.2**. The following parameters warrant additional description.

3.2.1 TIMP and XIMP

TIMP and XIMP are typically not measured directly but rather inferred based on typical urban design practices. Values used in the Duffins analysis

Table 4: Land Use-Imperviousness Relation

Land Use*	Description	TIMP
1	Rural – Undisturbed	0%
2	Rural – Agricultural	0%
3	Urban - Very Low Impervious	15%
4	Urban - Average Impervious	40%
5	Urban - High Impervious	55%
6	Urban - Very High Impervious	75%

*Source: Aquafor Beech grouping of land use (percentages used in Duffins Hydrology update)

The directly connected area represents impervious areas draining into pervious areas. As discussed, previously, WABAS applies a user-defined modifier to reflect the concentrated inflow points and lack of uniform water distribution. The following table presents the relation between the TIMP and XIMP values.

Table 5: Land Use-Directly Connected Imperviousness Relation

Land Use*	Description	Percent of TIMP Directly Connected
1	Rural – Undisturbed	0
2	Rural – Agricultural	0
3	Urban - Very Low Impervious	0
4	Urban - Average Impervious	75%
5	Urban - High Impervious	75%
6	Urban - Very High Impervious	100%

3.2.2 Z_IMP

The Z_IMP parameter modifies the XIMP by effectively reducing the indirectly connected impervious area runoff to the pervious areas. As indicated previously, the conditions at the boundary between impervious and pervious areas result in poorly-distributed water inputs. First, unlike precipitation which uniformly distributes the water over the pervious areas, runoff contributions from impervious lands is often concentrated at specific inflow points and continues along concentrated channels. This includes roof runoff discharging into residential backyards. Lot grading concentrates the flow into swales and out to the road. Rear-lot catchbasins have the same effect: efficient removal of surface runoff. Second, indirectly connected impervious areas are not always uniformly distributed over the entire basin and only provide inputs to a fraction of the pervious surfaces. The Z_IMP value of 0.2 was used in the Duffins Creek watershed analysis. This value corresponds is a measure of the proportion of the area covered by concentrated flow streams in rear lot swales as compared to the total pervious lot area.

3.2.3 IA_IMP and IA_PER

These values represent the maximum abstraction storage volumes. In single event simulation models such as OTTHYMO, IA refers to ‘Initial Abstraction’, corresponding to the initial rainfall losses.

IA_IMP is the only source of losses from impervious areas. A standard value of 0.8 mm is used in the analysis.

IA_PER represents the interception and depression storage losses over pervious lands. This value is a calibration parameter. Typical values range from 1.5 mm for urban pervious areas (graded lands) to 1.5 to 8.0 mm over rural pervious areas.

The modified SCS CN method explicitly accounts for abstraction losses prior to estimating the soil absorption into the active hydrologic zone. Therefore, normally, water in IA_PER storage is not available for infiltration and leaves the surface through evaporation. However, WABAS provides the option of allowing some of the water in IA_PER to enter the surficial soil storage. This option has been provided for calibration to account for additional infiltration such as from internally-drained areas (areas without a surface outlet) and has not been used for the Duffins Creek watershed analysis.

3.2.4 Modified CN Number

Basin-weighted CN numbers are calibration parameters used by the WABAS model to determine the range of soil moisture storage within the active hydrologic soil zone. Initial CN numbers values have been obtained from OTTHYMO hydrologic models used for flood-flow estimation. These initial CN values were estimated from the hydrologic soil group coverage within each basin as determined by the GIS overlay process.

3.2.5 VEG_K3

The VEG_K3 is the ‘Evapotranspiration Parameter’ dependent on the vegetation coverage over the basin. The evapotranspiration parameter is a function of the watershed cover as shown below.

Table 6: Evapotranspiration Parameter - Vegetation Cover Factor

Land Cover	VEG_K3 (mm)
Open land	5.08
Grassland	5.84
Light forest	7.11
Heavy forest	7.62

The values in **Table 6** have been standardized for the Duffins Creek watershed coverage conditions as follows:

Table 7: Land Use – Land Cover Type Relation

Land Use	Land Cover Type	VEG_K3 (mm)
Agricultural	2	5.84
Meadow	2	5.84
Wetland	3	7.11
Forest	4	7.62
Fed. Airport Lands	2	5.84
Urban	1	5.08
Urban Open Space	1	5.08

The values in **Table 6** and **Table 7** are used in the GIS overlay analysis to produce basin-averaged VEG_K3 values for each basin input into the WABAS system.

3.2.6 PO, G and K

Soil characteristics are characterized using basin-averaged: porosity, PO; the gravity-drained porosity, G; and the saturated hydraulic conductivity, K. Values for the first two are derived from standard literature sources as follows:

Table 8: Hydrologic Capacities of Soil Texture Classes

Soil Class	**Porosity**	**G**
Clay	18.8	7.3
Clay Loam	25.7	13.0
Loam	30.0	14.4
Organic**	36.6	23.5
Sand	32.3	19.0
Sandy Loam	30.9	18.6
Silt Loam	31.3	11.4
Variable**	36.6	23.5

* - Source: Viessman, 1977.
** - Assigned values for Fine Sand Loam

Input values for each basins and scenarios are presented in **Appendix A**.

4 Calibration

4.1 Methodology

Model calibration is the process by which modelled and measured runoff flows are matched by varying 'calibration' parameters. The calibration process involves collection, screening and analysis of measured flows and climate data, as well as the systematic evaluation of the response of runoff to variations of calibration parameters. Specifically, the following steps were taken during calibration:

1. Collection and evaluation of measured flow data at several locations in the watershed.

2. Baseflow separation. The process requires the analysis and quantification of low flow patterns and separation from the total observed stream flow. The difference between total stream flow and baseflow is assumed to be the wet-weather response.

3. Isolate and quantify the physical watershed parameters upstream of each flow gauge.

4. Set-up basin model with the physical watershed information at each gauging station and with climate data corresponding to the measured flow period. Include additional years of climate data prior to calibration to provide a 'warm-up' period to estimate 'initial' conditions.

5. Execute model while varying calibration parameters within physical limits to best match wet-weather hydrograph obtained in Step 2.

6. Adjust individual basin calibration parameter to match gauge calibration results.

4.2 Analysis of Measured Stream Flow

The water balance analysis has been calibrated using measured flows from 1997 to 2000 at various locations in the watershed. The station locations are illustrated in **Figure 8**. The watershed characteristics upstream of the gauges are summarized in **Table 9**. The measured hydrographs are illustrated in **Appendix B**.

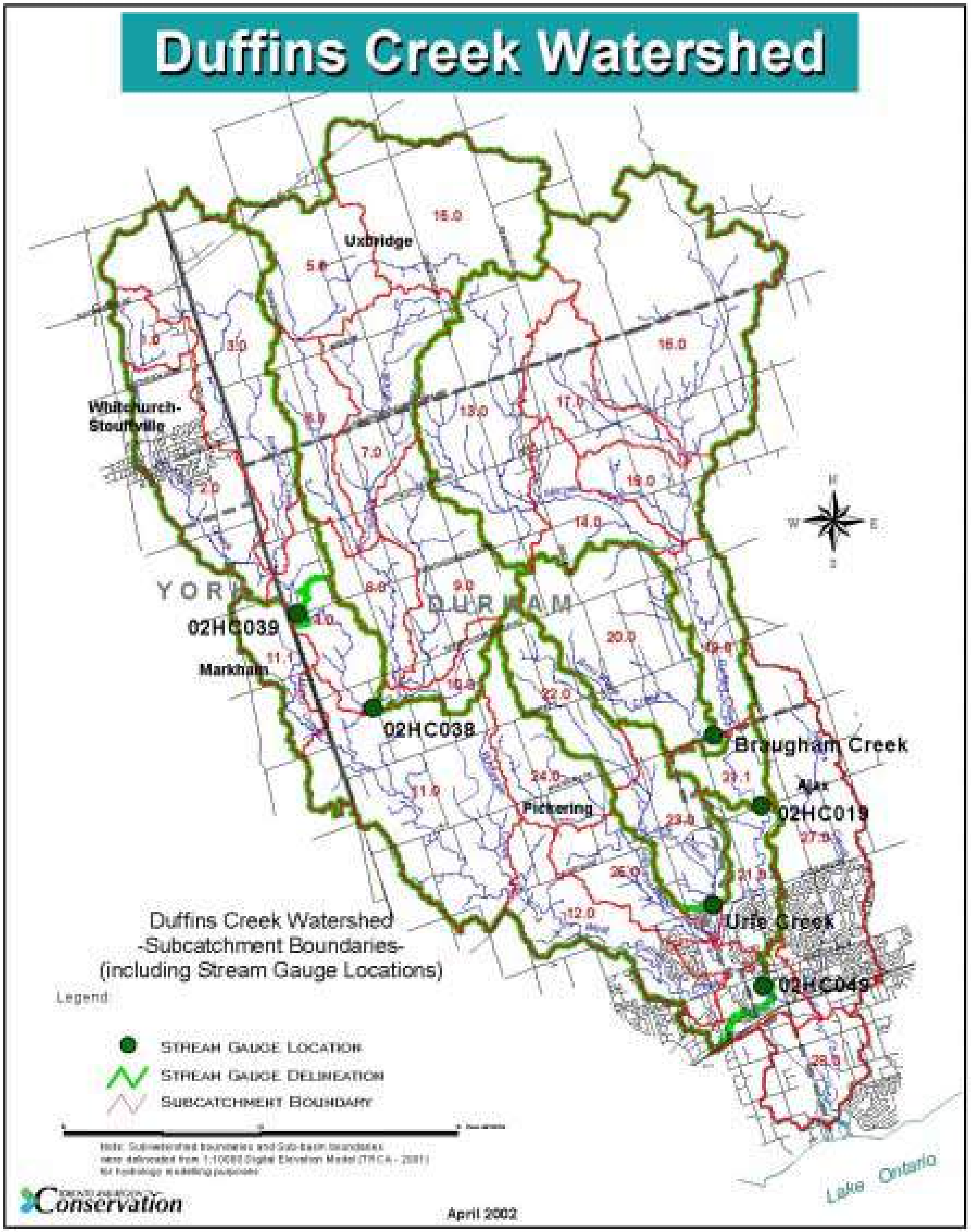


Figure 8: Duffins Creek Water Balance Calibration Locations

Table 9: Physical Basin Parameters Upstream of Gauges

Gauge	Location	Area (ha)	Imp. (fraction)**	Initial CN Estimate*
02HC019	East Duffins Creek	8,692	0.008	75
02HC036	Brougham Creek	1,536	0.007	78
02HC037	Urfe Creek	1,389	0.000	83
02HC038	Wixon Creek	6,197	0.000	70
02HC039	Reesor Creek	3,509	0.035	80
02HC049	West Duffins Creek	25,806	0.017	77

*-Initial CN estimate (rounded) based on OTTHYMO hydrologic model of watershed.
**- Imp. = Impervious fraction (existing conditions).

The following six tables summarize the data availability during the four years calibration period. As seen, the data coverage is not consistent throughout the period.

Table 10: East Duffins Creek Gauge Data Coverage

Gauge	Location	Start Date	End Data
02HC019	East Duffins Creek	01-Jan-97	31-Dec-97
Days with measured flow =		364	

Table 11: Brougham Creek Gauge Data Coverage

Gauge	Location	Start Date	End Data
02HC036	Brougham Creek	05-Jun-97	20-Dec-97
		09-Jan-98	08-Feb-98
		20-Feb-98	05-Sep-98
		07-Sep-98	17-Nov-98
		22-Nov-98	29-Jan-99
		17-Mar-99	09-Apr-99
		15-Apr-99	20-Jan-00
		07-Feb-00	30-Dec-00
Days with measured flow =		1194	

Table 12: Urfe Creek Gauge Data Coverage

Gauge	Location	Start Date	End Data
02HC037	Urfe Creek	05-Jun-97	31-Jul-97
		12-Aug-97	29-Dec-97
		09-Jan-98	01-Aug-98
		06-Aug-98	21-Aug-98
		23-Aug-98	26-Sep-98
		31-Oct-98	09-Jan-99
		23-Jan-99	27-Jul-99
		31-Jul-99	25-Aug-99
		27-Aug-99	27-Aug-99
		06-Sep-99	25-Jan-00
		16-Feb-00	06-Mar-00
		17-Mar-00	12-Aug-00
		15-Aug-00	05-Sep-00
		09-Sep-00	09-Dec-00
Days with measured flow =		1148	

Table 13: Wixon Creek Gauge Data Coverage

Gauge	Location	Start Date	End Data
02HC038	Wixon Creek	01-Oct-97	31-Oct-97
		01-Apr-98	31-Dec-98
		23-Jan-99	31-Dec-00
Days with measured flow =		1012	

Table 14: Reesor Creek Gauge Data Coverage

Gauge	Location	Start Date	End Data
02HC039	Reesor Creek	31-Jan-97	06-Jun-97
		12-Jun-97	16-Aug-99
		24-Aug-99	31-Dec-00
Days with measured flow =		1416	

Table 15: West Duffins Creek Gauge Data Coverage

Gauge	Location	Start Date	End Data
02HC049	West Duffins (South of Kingston Road)	01-Jan-97	31-Dec-97
Days with measured flow =		364	

4.3 Baseflow Separation

Separation of baseflow from the total measured hydrograph yields the wet-weather flow used for calibration. During extended dry-weather conditions, baseflow is equal to the measured flow. During wet-weather events, baseflow is established using an forward and backward-step averaging approach. Sample baseflow separation results are illustrated in **Figure 9**. The complete set of baseflow separation charts are presented in **Appendix B**.

4.4 Physical Watershed Parameters at Gauging Stations

The physical watershed parameters at the gauging stations are listed in **Appendix A**. Part of this data is shown in **Table 9**. The data collection approach at the gauges is similar to the data collection for each basin. The same GIS overlay approach was used to calculate Area, Imperviousness, CN and soil and vegetation parameters. Only Existing Conditions data are used for the analysis.

4.5 Parameter Adjustment for Calibration

Three parameters were used for calibration: the CN number; specified maximum abstraction over pervious areas, '$ABSLOSS_{per}$'; and the saturated hydraulic conductivity, 'K'. These parameter were first adjusted to match the measured wet-weather flow (i.e. 'Runoff' component of the total streamflow hydrograph). Subsequently, for the complete watershed water balance simulation, individual basin parameters upstream of the gauges were modified in the same proportion.

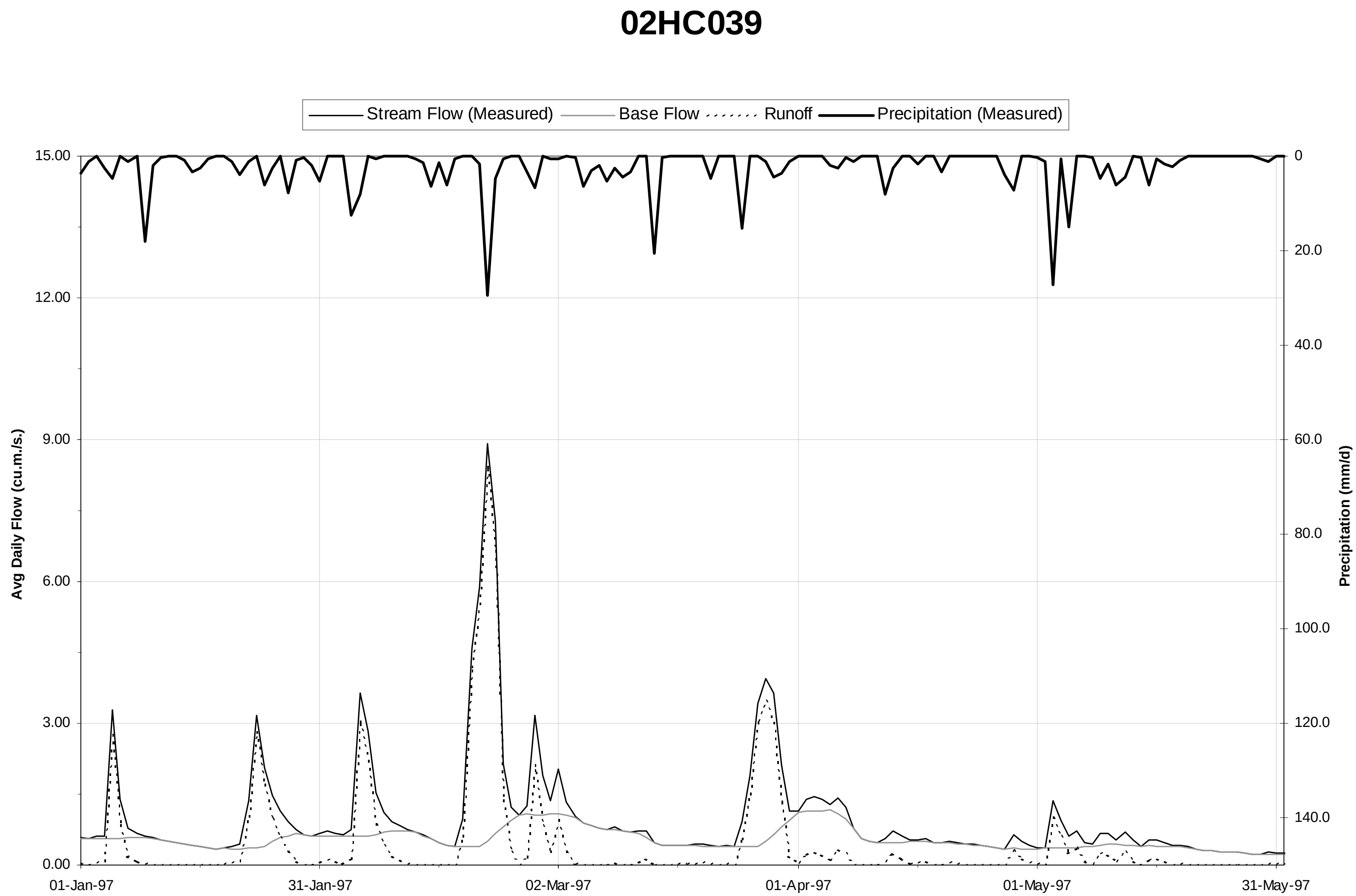


Figure 9: Sample Baseflow Separation - Reesor Creek Gauge

4.6 Calibration Results

Table 16 shows the calibration parameter adjustments at each of the gauges.

Table 16: Parameter Calibration Adjustment Factors

Gauge #	CN	IAPER	K
02HC019	1.10	0.75	0.75
02HC036	1.10	0.75	0.75
02HC037	1.20	0.75	0.75
02HC038	1.00	1.00	1.00
02HC039	1.10	0.75	0.75
02HC049	1.10	0.75	0.75

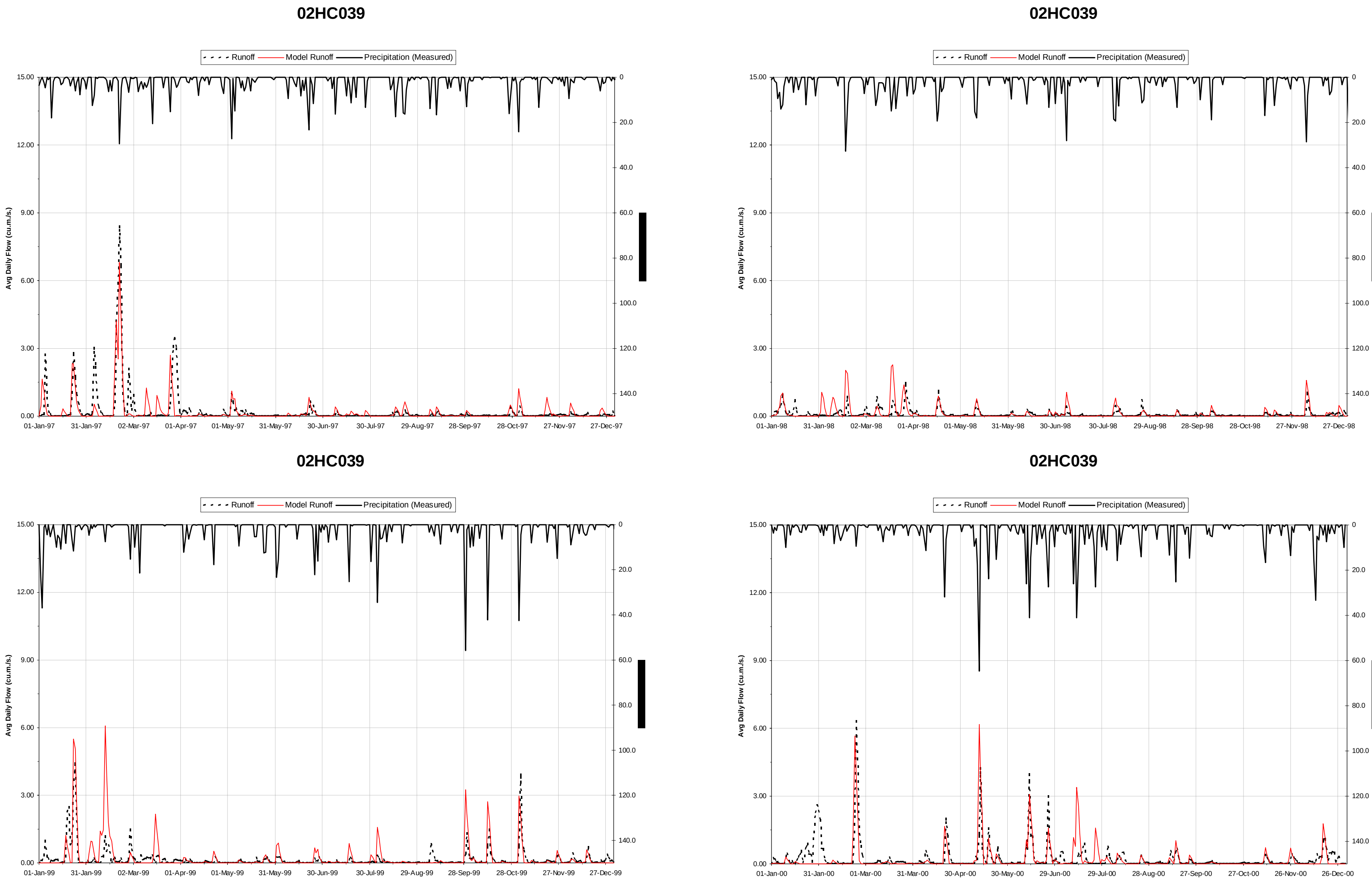
Table 17 summarizes the measured and modelled runoff coefficient during the four years of data at each of the Gauges. These runoff coefficients corresponds only to the periods with actual measured data.

Table 17: Measured and Simulated Runoff Coefficients

Gauge #	Measured	Model
02HC019	0.20	0.17
02HC036	0.19	0.16
02HC037	0.22	0.19
02HC038	0.13	0.12
02HC039	0.23	0.23
02HC049	0.20	0.22

Figure 10 illustrates the calibration results at Reesor Creek. The complete set of charts are included in **Appendix C**.

Figure 10: Reesor Creek (Station 02HC039) Sample Calibration Results



4.7 Sources of Error

The model yields consistent rainfall-runoff response and a good relation between measured and model runoff. Antecedent moisture also affects the generated runoff volumes as expected.

However, differences should be expected due to the numerous uncontrolled conditions associated with climate monitoring, stream flow monitoring, geographical differences, local and regional variability of storm events, and modelling simplifications. For example, obvious discrepancies between historical measurements and modelled flows can often be explained through the observed differences between measured stream flows at different locations. **Figure 11** illustrates the error associated with the precipitation and stream flow measurements can affect the simulation accuracy.

These gauge differences in measured flow patterns indicate:

1. Measurements errors.

2. Differences in local climatic conditions.

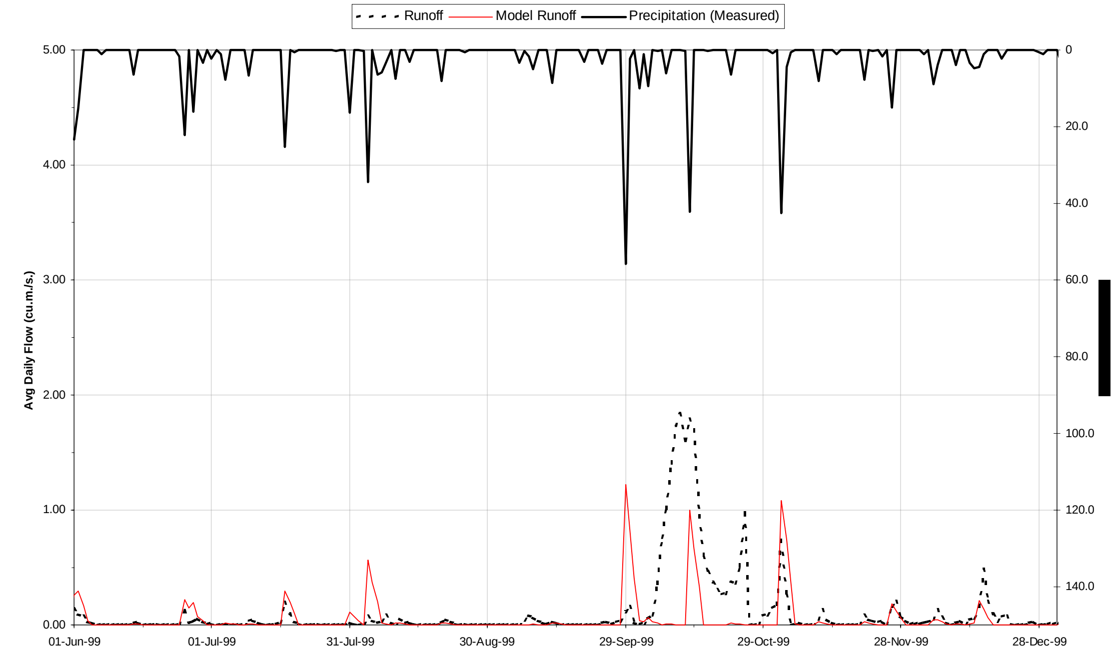
3. Other local differences not captured by the modelling approach, such as human activities (discharges, stormwater management facility operation, etc).

Another problems can be the stage-discharge relations used at the gauges, particularly during winter and ice conditions in the creeks. This information source can be questioned based on the occasional inconsistencies in precipitation and runoff volumes as observed in the measured data.

Another source of potential bias is the location and accuracy of precipitation data, particularly with the location of the Buttonville Airport gauge with respect to the study area. Although the rainfall-stream flow analysis showed that the Buttonville precipitation gauge was the best source for the study, it is still a compromise given that the Airport is about 15 km from the basin.

The WABAS computations approach was selected to achieve multiple objectives such as consistency with existing hydrologic models, availability of data, flexibility for adaptation, simplicity, etc. Future efforts can be directed towards enhancing all computational methods using site-specific monitored data. However, this should be done simultaneously with climate data collection.

Braugham Creek - 02HC036



Reesor Creek - 02HC039

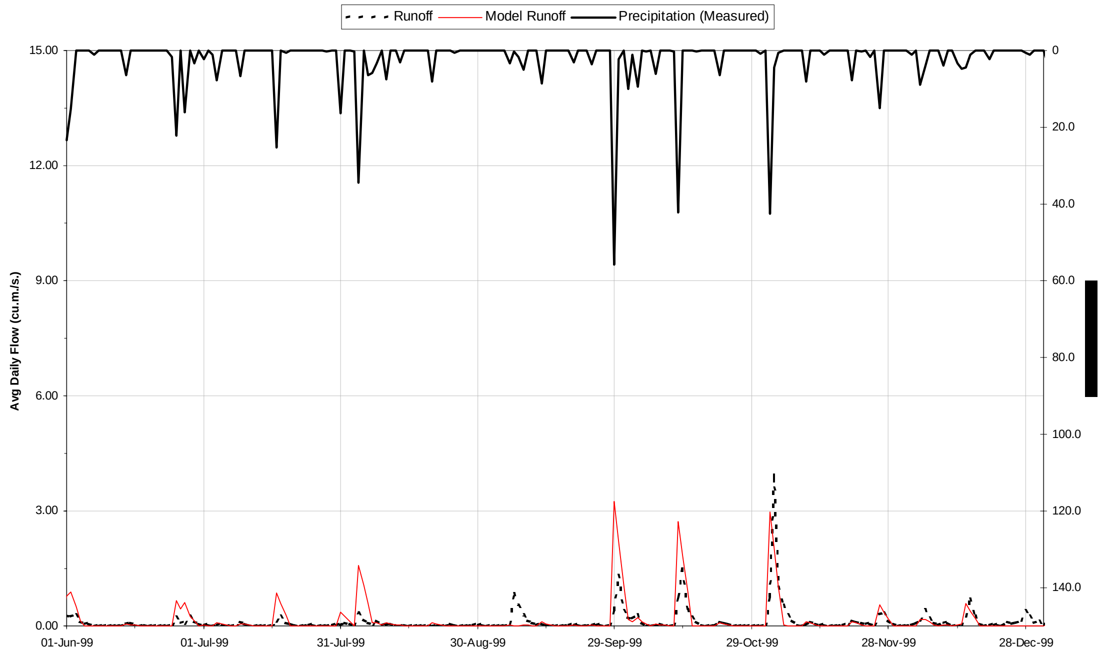


Figure 11: Analysis of Errors Illustration – Oct 1999 Event

5 Long-Term Water Balance

5.1 Annual Water Balance

The long-term water balance analysis was completed using 15 years of climate data and future land-use scenarios for each of the 30 basins in the Duffins Creek Watershed as described in Sections 2 and 3.

Long-term average precipitation input is presented in Table 18. Total precipitation is distributed into rainfall and snowfall according to the snowfall algorithm. The simulated data is compared with climate 'Normals' at the Toronto (Bloor Street), Pearson Airport, and the AES Richmond Hill gauges. Additional AES climate station 'Normals' in Ontario are presented in **Appendix D**.

Table 18: Climate Data Summary

Parameter	**Simulated**	**AES Stations**		
		Toronto Gauge	**Toronto Pearson Airport**	**Richmond Hill**
Rainfall	702 mm	689	665	689
Snowfall	142 mm	135	124	158
Precipitation	844 mm	819	781	847

These results show good agreement between the model and the historical Ontario Climate Normals and thus provide more confidence in the snowmelt-rainfall distribution. WABAS output tables are presented in **Appendix E** and detailed yearly results are included in **Appendix F**. The following summarizes the watershed-weighted water budget components for each scenario. Basin totals for each scenario are presented in Table 20 to Table 22.

Table 19: Water Balance Results Summary

Scenario	**Precipitation [mm]**	**Runoff [mm]**	**GWI [mm]**	**E [mm]**	**IN-OUT* [mm]**
Existing	844	145	206	489	4
Future (OP)	844	170	197	472	5
Future with Natural Heritage	844	162	195	481	6

* - The "IN-OUT" refers to the overall numerical continuity (Water Input– Water Output = Storage Change).

Table 20: Existing-Conditions Average Yearly Water Balance by Basin

Basin	Area, A	Total Imp, TIMP	Dir Con Imp, XIMP	RO	C	GWI	E
	[ha]	[Frac]	[Frac]	[mm]	[Frac]	[mm]	[mm]
1	281.55	0.022	0.000	156	0.18	200	483
2	1085.19	0.091	0.071	219	0.26	177	443
3	1897.99	0.023	0.017	145	0.17	208	485
4	681.59	0.000	0.000	150	0.18	197	492
5	920.64	0.000	0.000	60	0.07	231	549
6	643.98	0.000	0.000	139	0.16	185	515
7	1082.14	0.000	0.000	95	0.11	215	530
8	516.51	0.000	0.000	108	0.13	210	521
9	1073.12	0.000	0.000	140	0.16	184	514
10	262.69	0.000	0.000	109	0.13	208	522
11	2068.58	0.004	0.003	149	0.18	200	489
11.1	425.03	0.000	0.000	177	0.21	180	482
12	895.05	0.053	0.043	145	0.17	214	480
13	1736.50	0.016	0.012	142	0.17	210	488
14	622.51	0.023	0.018	143	0.17	209	487
15	1702.66	0.000	0.000	62	0.07	237	540
16	2625.02	0.000	0.000	94	0.11	232	513
17	707.88	0.002	0.001	102	0.12	228	509
18	506.83	0.000	0.000	120	0.14	217	502
19	618.84	0.021	0.016	125	0.15	217	497
20	1547.47	0.007	0.005	132	0.15	217	490
21	509.20	0.134	0.101	247	0.29	175	418
21.1	327.44	0.000	0.000	90	0.11	236	513
22	632.59	0.000	0.000	175	0.21	185	478
23	803.91	0.008	0.006	135	0.16	216	488
24	713.77	0.000	0.000	140	0.16	206	494
25	590.88	0.022	0.017	119	0.14	226	494
26	522.68	0.337	0.298	392	0.46	120	328
27	1698.16	0.230	0.172	257	0.30	171	412
28	600.84	0.230	0.229	258	0.30	161	420
Total	**28301**	**0.038**	**0.030**	**145**	**0.17**	**206**	**489**

Notes: Total Imp = Imperviousness over entire basin
Dir Con Imp = Directly-connected imperviousness
RO = Average yearly runoff depth over basin
C = Average runoff coefficient
GWI = Groundwater infiltration
E = Evaporation (and evapotranspiration)

Table 21: Future-Conditions Average Yearly Water Balance by Basin

Basin	Area, A	Total Imp, TIMP	Dir Con Imp, XIMP	RO	C	GWI	E
	[ha]	[Frac]	[Frac]	[mm]	[Frac]	[mm]	[mm]
1	281.55	0.022	0.000	156	0.18	200	483
2	1085.19	0.182	0.139	290	0.34	151	398
3	1897.99	0.034	0.027	155	0.18	205	479
4	681.59	0.000	0.000	150	0.18	197	492
5	920.64	0.000	0.000	60	0.07	231	549
6	643.98	0.000	0.000	139	0.16	185	515
7	1082.14	0.000	0.000	95	0.11	215	530
8	516.51	0.000	0.000	108	0.13	210	521
9	1073.12	0.000	0.000	140	0.16	184	514
10	262.69	0.000	0.000	109	0.13	208	522
11	2068.58	0.025	0.019	163	0.19	198	479
11.1	425.03	0.000	0.000	177	0.21	180	482
12	895.05	0.192	0.145	250	0.30	180	410
13	1736.50	0.016	0.012	142	0.17	210	488
14	622.51	0.023	0.018	143	0.17	209	487
15	1702.66	0.000	0.000	62	0.07	237	540
16	2625.02	0.000	0.000	94	0.11	232	513
17	707.88	0.002	0.001	102	0.12	228	509
18	506.83	0.000	0.000	120	0.14	217	502
19	618.84	0.021	0.016	125	0.15	217	497
20	1547.47	0.007	0.005	132	0.15	217	490
21	509.20	0.231	0.174	316	0.37	151	373
21.1	327.44	0.007	0.005	95	0.11	235	509
22	632.59	0.028	0.021	196	0.23	179	465
23	803.91	0.222	0.167	320	0.38	150	371
24	713.77	0.119	0.090	225	0.27	179	435
25	590.88	0.255	0.191	300	0.35	165	375
26	522.68	0.337	0.283	388	0.46	124	329
27	1698.16	0.271	0.212	287	0.34	163	390
28	600.84	0.416	0.389	393	0.46	115	331
Total	**28301**	**0.071**	**0.056**	**170**	**0.20**	**197**	**472**

Notes: Total Imp = Imperviousness over entire basin
Dir Con Imp = Directly-connected imperviousness
RO = Average yearly runoff depth over basin
C = Average runoff coefficient
GWI = Groundwater infiltration
E = Evaporation (and evapotranspiration)

Table 22: Future-Conditions plus Natural Heritage Strategy Average Yearly Water Balance by Basin

Basin	Area, A	Total Imp, TIMP	Dir Con Imp, XIMP	RO	C	GWI	E
	[ha]	[Frac]	[Frac]	[mm]	[Frac]	[mm]	[mm]
1	281.55	0.022	0.000	141	0.17	201	498
2	1085.19	0.182	0.139	277	0.33	157	406
3	1897.99	0.034	0.027	145	0.17	204	489
4	681.59	0.000	0.000	149	0.17	197	493
5	920.64	0.000	0.000	51	0.06	218	571
6	643.98	0.000	0.000	125	0.15	181	533
7	1082.14	0.000	0.000	84	0.10	210	545
8	516.51	0.000	0.000	107	0.13	209	522
9	1073.12	0.000	0.000	137	0.16	183	518
10	262.69	0.000	0.000	109	0.13	208	522
11	2068.58	0.025	0.019	160	0.19	197	482
11.1	425.03	0.000	0.000	172	0.20	181	487
12	895.05	0.192	0.145	250	0.30	180	409
13	1736.50	0.016	0.012	119	0.14	212	508
14	622.51	0.023	0.018	133	0.16	209	497
15	1702.66	0.000	0.000	46	0.05	222	572
16	2625.02	0.000	0.000	83	0.10	228	528
17	707.88	0.002	0.001	87	0.10	225	528
18	506.83	0.000	0.000	95	0.11	215	529
19	618.84	0.021	0.016	118	0.14	216	505
20	1547.47	0.007	0.005	129	0.15	215	495
21	509.20	0.231	0.174	316	0.37	151	373
21.1	327.44	0.007	0.005	95	0.11	229	514
22	632.59	0.028	0.021	193	0.23	179	466
23	803.91	0.222	0.167	320	0.38	150	370
24	713.77	0.119	0.090	224	0.26	180	436
25	590.88	0.255	0.191	300	0.35	166	375
26	522.68	0.337	0.283	388	0.46	124	329
27	1698.16	0.271	0.212	287	0.34	163	390
28	600.84	0.416	0.389	393	0.46	114	332
Total	**28301**	**0.071**	**0.056**	**162**	**0.19**	**195**	**481**

Notes: Total Imp = Imperviousness over entire basin
Dir Con Imp = Directly-connected imperviousness
RO = Average yearly runoff depth over basin
C = Average runoff coefficient
GWI = Groundwater infiltration
E = Evaporation (and evapotranspiration)

The long-term average runoff coefficients are summarized in the following table. The runoff volume versus imperviousness relation for all the basins and all scenarios is illustrated in **Figure 12**. The figure illustrates not only the linear function but also the effects of other controlling variables (with constant imperviousness), such as soils and vegetation cover. For example, runoff with 0.0% imperviousness varies from 46 mm/yr to 177 mm/yr. An approximate functional relation between groundwater infiltration (GWI) and saturated hydraulic conductivity (Ksat) is illustrated in **Figure 13**. This relation was generated using data from basins without any impervious area (TIMP = 0). A similar relation has been generated for the SCS curve number (CN) and is illustrated in **Figure 14**.

Table 23: Long-Term Average Runoff Coefficients, C

Scenario	C
Existing	0.17
Future (Official Plans)	0.20
Future with Natural Heritage Strategy	0.19

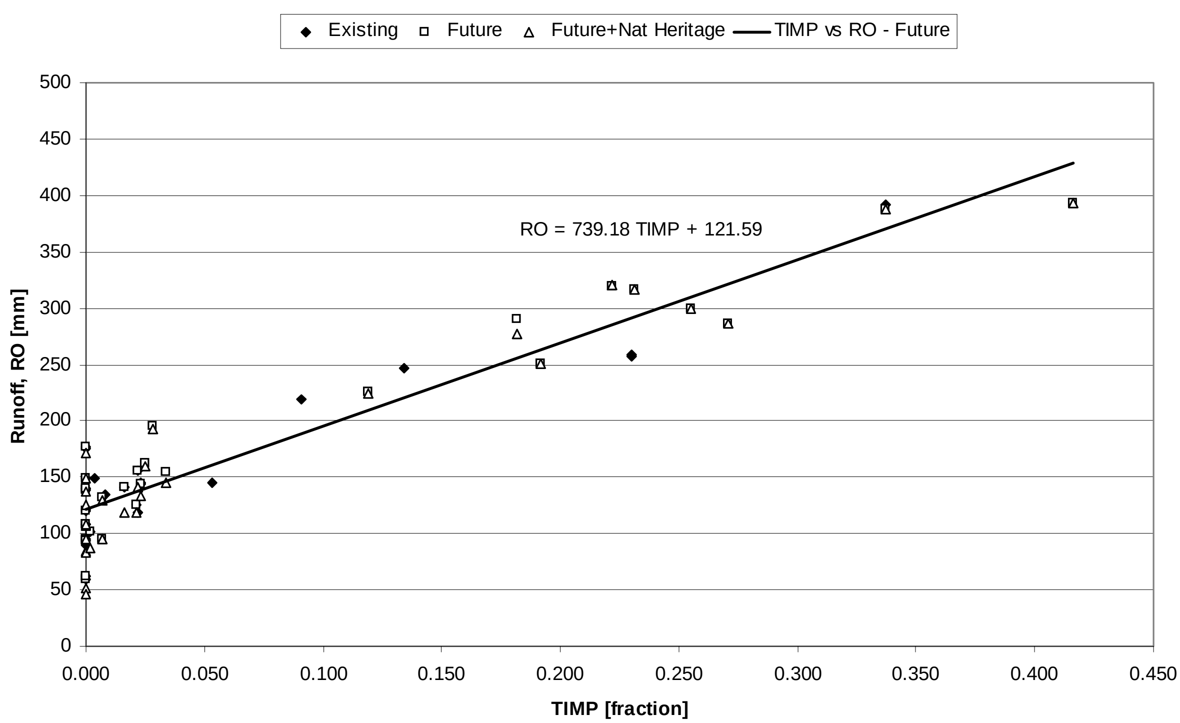


Figure 12: Runoff versus Imperviousness Relation

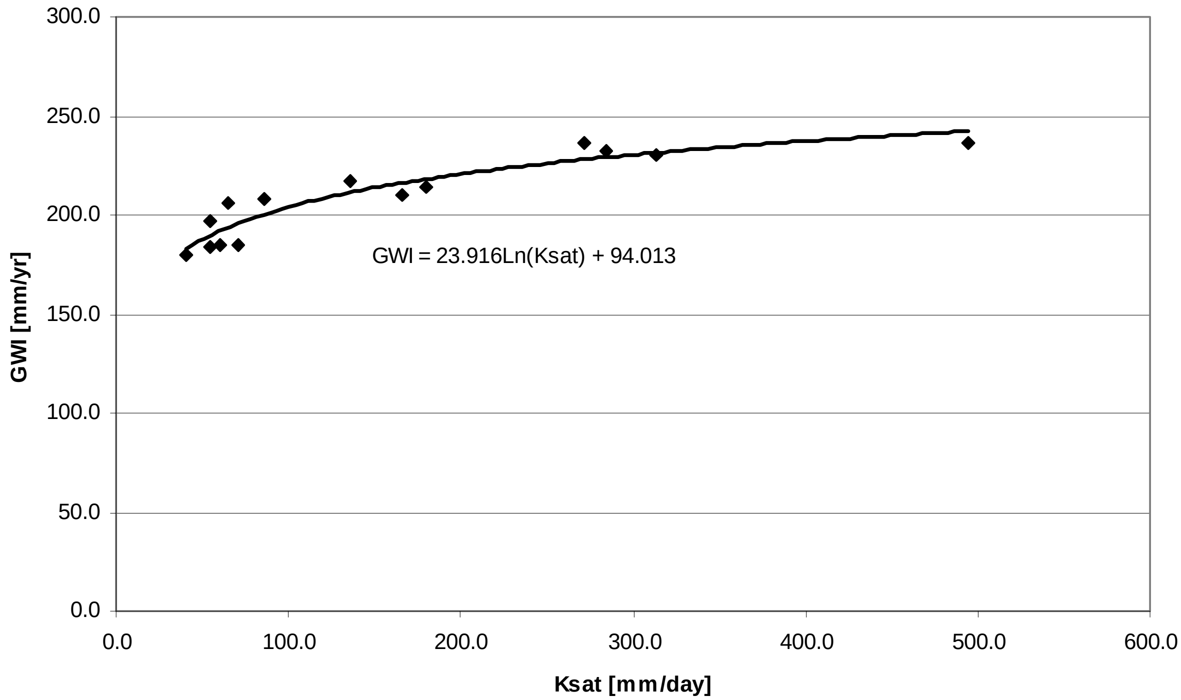


Figure 13: GWI versus Ksat

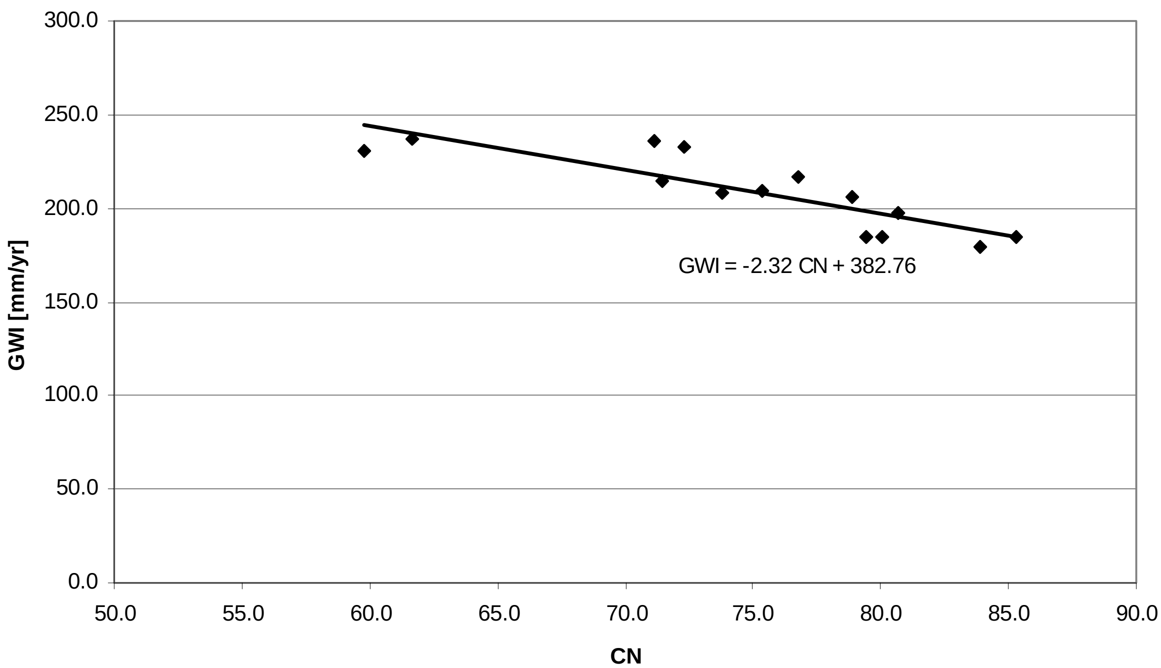


Figure 14: GWI versus CN

As expected, runoff increases with uncontrolled future urban development (Official Plan) as a direct result of higher imperviousness. The increase appears small due to the relatively small fraction of area that is considered for future development (i.e. small change in overall imperviousness). The reduction in groundwater infiltration with higher imperviousness is also expected. Again, these changes must be interpreted in the context of the 'relatively' small land-use changes at the sub-basin scale. More significant changes would be expected at a site-specific scale.

The Natural Heritage strategy yields a small reduction in runoff volume due to increased soil abstraction and evaporation associated with reforestation. However, this should be interpreted carefully due to the complex interactions between surface and groundwater systems typical of larger watershed areas. For example, as cited from UNESCO (1982): "A significant change in basin land use is often followed by an alteration of the regime and discharge of the stream draining the basin. Johnston and Meginnis (1960) point out that low flows in North Carolina (USA) increased as a result of timber felling in the mountains. On the other hand, in a small basin in Ohio, due to increased transpiration, low flows diminished after the planting of pine trees. Other authors (for example Riggs, 1965) have bound that in basins planted with pines the period of river flow decreased as the forest cover increased. But in the Tennessee River Valley (USA) it has been observed that a change in the amount of vegetation has not given rise to any important changes in minimum flow (Johnson, 1967). Perera (1975), working in Cuba on small experimental plots of 8 m high pines and native pasture, recorded a considerable reduction in overland flow from the pine plots compared with native pasture plots even for rain of more than 25 mm. This demonstrates the influence that increased transpiration can have on the low flow of a basin through increasing the consumption of soil water".

On the other hand, "in various tropical regions deforestation has led to a reduction of low flows and in some cases to the cessation of flow altogether. With replanting, low flows have been re-established. This phenomenon is due to changes in infiltration capacity that resulted from land cover modifications. Escobar and Rossi (1970) state that in wet sub-basins of the river Quiros in Peru, the basin yield reduced when natural cover (trees, bushes and perennial herbaceous plants) was replaced by commercial crops. This effect was observed up to an altitude of nearly 3000 metres.

This shows that flow depends on a balance between infiltration, which is affected by plant cover, and losses through transpiration. "When agricultural and land improvement measures are practiced extensively in a watershed, streamflow becomes more regular and, consequently, the flow during the low water period is increased. Lvovich (1973) asserts that in some regions. Autumn ploughing can modify the water balance of arable land by creating favourable conditions for replenishing groundwater, which supplies river flow during low water periods".

5.2 Monthly Water Balance

Average monthly water balance has also been calculated and detailed result tables are presented in **Appendix G**.

6 Conclusions and Recommendations

6.1 Conclusions

The water balance analysis of the Duffins Creek watershed has been completed using the Water Balance Analysis System (WABAS). The WABAS approach achieves multiple objectives such as consistency with existing hydrologic models, availability of data, flexibility for adaptation, simplicity, etc.

The surface runoff response has been calibrated at six historical stream flow gauging locations. The calibration shows good agreement between the model's runoff coefficient (C=0.18) and the measured flows (C=0.19). One of the main sources of error during calibration is the averaging of climate conditions over the entire watershed.

The water balance results include the following 15-year average over the entire Duffins watershed:

Table 24: Water Balance Results Conclusions

Scenario	**Precipitation [mm]**	**Runoff [mm]**	**GWI [mm]**	**E [mm]**
Existing	844	145	206	489
Future (OP)	844	170	197	472
Future with Natural Heritage	844	162	195	481

As expected, runoff volume increases with uncontrolled development. The increase is a direct result of higher imperviousness. The maximum runoff increase of 184 mm/year occurs in basin 23. Imperviousness in this basin increases from less than 1% to about 22%. The reduction in GWI infiltration over this basin will be about 65 mm/year.

Overall, the reductions in groundwater infiltration under future conditions appear small due to the relatively small change in land use over each basin (i.e. small change in overall imperviousness). More significant changes are expected within each development site.

The Natural Heritage strategy will reduce surface runoff volumes by about 5% per year as compared with Future Conditions alone. The Natural Heritage strategy also appears to reduce groundwater infiltration by 2 mm/year as a result higher evapotranspiration rates. However, this should be interpreted with care because findings by others suggest that reforestation can also be a source of increased infiltration due to root-channelling effects caused by deeper root zones. Ultimately, the net effects can be established through accurate and consistent monitoring of climate and hydrometric conditions within the watershed.

Evaluation of precipitation patterns occurring from year to year (data presented in appendices) shows that years with lower than average precipitation are critical in terms of groundwater infiltration (GWI) (i.e. significantly reduced infiltration). The reason is that lower rainfall years are also associated with higher evaporation rates. Conversely, years with higher precipitation yield significantly higher GWI.

6.2 Recommendations

The analysis results under different land-use scenarios provide specific targets for managing urban development. Since the changes in water balance components under different land uses are at a 'basin' scale, additional site-specific analysis will be required to establish site-specific targets under future proposed urban development conditions. These targets could then be met through the implementation of site-level stormwater management controls.

Water balance management analysis on a site-level can be simplified through generic relationships between land-use (imperviousness) and surface cover/soil characteristics. These relationships can be generated using multiple long-term simulations with the same years or records as in this study while varying typical site conditions. The results can be presented graphically or in tabular form for estimating groundwater infiltration rates and/or runoff volumes such as in **Figures 12, 13** and **14**.

Future efforts can be directed towards further enhancing the computational methods by calibrating the model using site-specific groundwater infiltration and evaporation data. For example, a field lysimeter study could be designed and instrumented with soil moisture sensors and other weather measurement devices to establish accurate water budgets under different soil and vegetation cover conditions. At the least, the installation of a weather/climate station should be considered to collect long-term site-specific weather data including precipitation, temperature, pan evaporation, solar radiation, wind speed, leaf moisture levels, etc. This data would be useful for calibrating and validating watershed-specific models.

Additional water balance analysis can be conducted to assess impacts of climate change in terms of reductions or increases in groundwater infiltration. Preliminary results show that GWI is very sensitive to changes in yearly precipitation volumes.

7 References

ASCE, 1996. “Hydrology Handbook”. American Society of Civil Engineers. 1996.

EWRG, 2000. “Flood Forecasting (FFOR) Program”. Manual. June 2000. Environmental Water Resources Group Ltd.

Graham, E.I.; H.R. Whiteley, and N.R. Thomson, 1997. “Development and Initial Refinement of a Water Balance Model as a Planning Tool, for Stormwater Management Application”. Advances in Modeling the Management of Stormwater Impacts – Vol. 5. W. James, Ed. Pub. By CHI, Guelph, Canada, 1997.

Huber, W.C.; R.E. Dickinson. “Storm Water Management Model, Version 4: User’s Manual”. Department of Environmental Engineering Sciences, University of Florida, Gainesville, Florida. For: Environmental Research Laboratory, Office of Research and Development. U.S. Environmental Protection Agency, Athens, Georgia.

Johnstone, K. and Louie, P.Y.T. “Water Balance Tabulations for Canadian Climate Stations”. Canadian Climate Centre, Atmospheric Environment Service. Undated.

UNESCO, 1982. “Methods Of Computation Of Low Streamflow”. Edited by T.A. McMahon and A. Diaz Arenas. UNESCO, Paris, 1982.

Viessman, W.; J.W. Kanpp; G.L. Lewis; and T.E. Harbaugh, 1977. “Introduction to Hydrology”. Second Edition, Harper and Row. 1977.

Appendix A: Watershed Parameters

Watershed Physical Input Parameters

Parameter	Description [Units]
AREA	Basin area [Hectares]
TIMP	Basin imperviousness [Fraction]
XIMP	Directly connected imperviousness [Fraction]
Z_IMP	Indirectly Connected Area Efficiency [%]
IA_imp	Depression storage/Interception Storage over impervious areas [millimetres]
IA_per	Depression storage/Interception Storage over pervious areas [millimetres]
CN*	Modified Soil Conservation Service (SCS) Curve Number [no units]
VEG_K3	Watershed vegetation cover function [mm]
PO	Porosity [%]
G	Soil water drained by gravity [%]
K	Saturated hydraulic conductivity [mm/day]

Notes: Z_IMP = 0.2
CN* = Starting value prior to calibration.
K = Starting value prior to calibration.

Impervious Area Parameters

Scenario	Basin	Area A [ha]	Impervious TIMP [Frac]	Dir Con Imp, XIMP [Frac]	Dep Sto IAIMP [mm]
Existing	1	281.55	0.022	0.000	0.8
Existing	2	1085.19	0.091	0.071	0.8
Existing	3	1897.99	0.023	0.017	0.8
Existing	4	681.59	0.000	0.000	0.8
Existing	5	920.64	0.000	0.000	0.8
Existing	6	643.98	0.000	0.000	0.8
Existing	7	1082.14	0.000	0.000	0.8
Existing	8	516.51	0.000	0.000	0.8
Existing	9	1073.12	0.000	0.000	0.8
Existing	10	262.69	0.000	0.000	0.8
Existing	11	2068.58	0.004	0.003	0.8
Existing	11.1	425.03	0.000	0.000	0.8
Existing	12	895.05	0.053	0.043	0.8
Existing	13	1736.50	0.016	0.012	0.8
Existing	14	622.51	0.023	0.018	0.8
Existing	15	1702.66	0.000	0.000	0.8
Existing	16	2625.02	0.000	0.000	0.8
Existing	17	707.88	0.002	0.001	0.8
Existing	18	506.83	0.000	0.000	0.8
Existing	19	618.84	0.021	0.016	0.8
Existing	20	1547.47	0.007	0.005	0.8
Existing	21	509.20	0.134	0.101	0.8
Existing	21.1	327.44	0.000	0.000	0.8
Existing	22	632.59	0.000	0.000	0.8
Existing	23	803.91	0.008	0.006	0.8
Existing	24	713.77	0.000	0.000	0.8
Existing	25	590.88	0.022	0.017	0.8
Existing	26	522.68	0.337	0.298	0.8
Existing	27	1698.16	0.230	0.172	0.8
Existing	28	600.84	0.230	0.229	0.8
Future	1	281.55	0.022	0.000	0.8
Future	2	1085.19	0.182	0.139	0.8
Future	3	1897.99	0.034	0.027	0.8
Future	4	681.59	0.000	0.000	0.8
Future	5	920.64	0.000	0.000	0.8
Future	6	643.98	0.000	0.000	0.8
Future	7	1082.14	0.000	0.000	0.8
Future	8	516.51	0.000	0.000	0.8
Future	9	1073.12	0.000	0.000	0.8
Future	10	262.69	0.000	0.000	0.8
Future	11	2068.58	0.025	0.019	0.8
Future	11.1	425.03	0.000	0.000	0.8
Future	12	895.05	0.192	0.145	0.8
Future	13	1736.50	0.016	0.012	0.8
Future	14	622.51	0.023	0.018	0.8
Future	15	1702.66	0.000	0.000	0.8
Future	16	2625.02	0.000	0.000	0.8
Future	17	707.88	0.002	0.001	0.8
Future	18	506.83	0.000	0.000	0.8
Future	19	618.84	0.021	0.016	0.8
Future	20	1547.47	0.007	0.005	0.8

Impervious Area Parameters

Scenario	Basin	Area A [ha]	Impervious TIMP [Frac]	Dir Con Imp, XIMP [Frac]	Dep Sto IAIMP [mm]
Future	21	509.20	0.231	0.174	0.8
Future	21.1	327.44	0.007	0.005	0.8
Future	22	632.59	0.028	0.021	0.8
Future	23	803.91	0.222	0.167	0.8
Future	24	713.77	0.119	0.090	0.8
Future	25	590.88	0.255	0.191	0.8
Future	26	522.68	0.337	0.283	0.8
Future	27	1698.16	0.271	0.212	0.8
Future	28	600.84	0.416	0.389	0.8
Future + Nat Heritage	1	281.55	0.022	0.000	0.8
Future + Nat Heritage	2	1085.19	0.182	0.139	0.8
Future + Nat Heritage	3	1897.99	0.034	0.027	0.8
Future + Nat Heritage	4	681.59	0.000	0.000	0.8
Future + Nat Heritage	5	920.64	0.000	0.000	0.8
Future + Nat Heritage	6	643.98	0.000	0.000	0.8
Future + Nat Heritage	7	1082.14	0.000	0.000	0.8
Future + Nat Heritage	8	516.51	0.000	0.000	0.8
Future + Nat Heritage	9	1073.12	0.000	0.000	0.8
Future + Nat Heritage	10	262.69	0.000	0.000	0.8
Future + Nat Heritage	11	2068.58	0.025	0.019	0.8
Future + Nat Heritage	11.1	425.03	0.000	0.000	0.8
Future + Nat Heritage	12	895.05	0.192	0.145	0.8
Future + Nat Heritage	13	1736.50	0.016	0.012	0.8
Future + Nat Heritage	14	622.51	0.023	0.018	0.8
Future + Nat Heritage	15	1702.66	0.000	0.000	0.8
Future + Nat Heritage	16	2625.02	0.000	0.000	0.8
Future + Nat Heritage	17	707.88	0.002	0.001	0.8
Future + Nat Heritage	18	506.83	0.000	0.000	0.8
Future + Nat Heritage	19	618.84	0.021	0.016	0.8
Future + Nat Heritage	20	1547.47	0.007	0.005	0.8
Future + Nat Heritage	21	509.20	0.231	0.174	0.8
Future + Nat Heritage	21.1	327.44	0.007	0.005	0.8
Future + Nat Heritage	22	632.59	0.028	0.021	0.8
Future + Nat Heritage	23	803.91	0.222	0.167	0.8
Future + Nat Heritage	24	713.77	0.119	0.090	0.8
Future + Nat Heritage	25	590.88	0.255	0.191	0.8
Future + Nat Heritage	26	522.68	0.337	0.283	0.8
Future + Nat Heritage	27	1698.16	0.271	0.212	0.8
Future + Nat Heritage	28	600.84	0.416	0.389	0.8

Pervious Area Parameters

Scenario	Basin	CN	IAPER [mm]	POROSITY [%]	G [%]	K [mm/d]	VEG_K3 [mm]	Z_IMP [Frac]
Existing	1	79.50	3.00	30.31	14.82	64.79	6.09	0.20
Existing	2	83.75	3.00	29.85	14.81	59.95	5.86	0.20
Existing	3	78.07	3.00	30.15	15.27	97.55	6.14	0.20
Existing	4	80.67	3.00	29.07	14.39	54.99	6.24	0.20
Existing	5	59.75	4.00	31.85	18.90	313.26	6.66	0.20
Existing	6	80.03	4.00	23.76	11.43	60.48	6.22	0.20
Existing	7	71.42	4.00	27.08	14.38	180.38	6.33	0.20
Existing	8	75.35	4.00	28.20	14.97	166.26	6.21	0.20
Existing	9	79.46	4.00	24.13	11.14	54.73	6.05	0.20
Existing	10	73.78	4.00	30.99	15.76	86.40	6.04	0.20
Existing	11	80.42	3.00	29.71	14.79	64.10	6.15	0.20
Existing	11.1	83.93	3.00	28.44	13.13	40.31	6.05	0.20
Existing	12	75.27	3.00	31.11	16.98	156.66	6.39	0.20
Existing	13	78.62	3.00	28.37	14.67	108.97	6.20	0.20
Existing	14	78.12	3.00	30.85	16.02	103.95	6.27	0.20
Existing	15	61.65	4.00	31.25	18.67	493.98	6.42	0.20
Existing	16	72.35	3.00	31.33	18.74	284.89	6.90	0.20
Existing	17	72.47	3.00	31.15	17.22	173.38	6.57	0.20
Existing	18	76.78	3.00	31.02	16.62	135.35	6.51	0.20
Existing	19	75.03	3.00	30.93	16.71	154.22	6.54	0.20
Existing	20	78.07	3.00	30.79	16.31	123.56	6.13	0.20
Existing	21	86.36	3.00	29.93	16.71	140.40	5.88	0.20
Existing	21.1	71.15	3.00	31.67	19.07	271.75	6.80	0.20
Existing	22	85.33	3.00	30.72	15.46	70.84	6.21	0.20
Existing	23	80.91	3.00	31.68	18.52	223.21	6.57	0.20
Existing	24	78.87	3.00	30.55	15.15	64.80	6.13	0.20
Existing	25	74.54	3.00	31.37	17.97	212.43	6.47	0.20
Existing	26	90.56	3.00	28.98	15.95	120.32	5.55	0.20
Existing	27	79.23	4.00	30.00	17.11	256.03	5.84	0.20
Existing	28	74.76	4.00	29.47	15.43	56.02	5.82	0.20
Future	1	79.50	3.00	30.31	14.82	64.79	6.09	0.20
Future	2	86.88	3.00	29.85	14.81	59.95	5.64	0.20
Future	3	78.69	3.00	30.15	15.27	97.55	6.10	0.20
Future	4	80.67	3.00	29.07	14.39	54.99	6.24	0.20
Future	5	59.75	4.00	31.85	18.90	313.26	6.66	0.20
Future	6	80.03	4.00	23.76	11.43	60.48	6.22	0.20
Future	7	71.42	4.00	27.08	14.38	180.38	6.33	0.20
Future	8	75.35	4.00	28.20	14.97	166.26	6.21	0.20
Future	9	79.46	4.00	24.13	11.14	54.73	6.05	0.20
Future	10	73.78	4.00	30.99	15.76	86.40	6.04	0.20
Future	11	80.56	3.00	29.71	14.79	64.10	6.04	0.20
Future	11.1	83.93	3.00	28.44	13.13	40.31	6.05	0.20
Future	12	80.72	3.00	31.11	16.98	156.66	5.95	0.20
Future	13	78.62	3.00	28.37	14.67	108.97	6.20	0.20
Future	14	78.12	3.00	30.85	16.02	103.95	6.27	0.20
Future	15	61.65	4.00	31.25	18.67	493.98	6.42	0.20
Future	16	72.35	3.00	31.33	18.74	284.89	6.90	0.20
Future	17	72.47	3.00	31.15	17.22	173.38	6.57	0.20
Future	18	76.78	3.00	31.02	16.62	135.35	6.51	0.20

Pervious Area Parameters

Scenario	Basin	CN	IAPER [mm]	POROSITY [%]	G [%]	K [mm/d]	VEG_K3 [mm]	Z_IMP [Frac]
Future	19	75.03	3.00	30.93	16.71	154.22	6.54	0.20
Future	20	78.06	3.00	30.79	16.31	123.56	6.13	0.20
Future	21	88.48	3.00	29.93	16.71	140.40	5.58	0.20
Future	21.1	71.36	3.00	31.67	19.07	271.75	6.78	0.20
Future	22	85.98	3.00	30.72	15.46	70.84	6.13	0.20
Future	23	90.11	3.00	31.68	18.52	223.21	5.78	0.20
Future	24	82.02	3.00	30.55	15.15	64.80	5.77	0.20
Future	25	84.25	3.00	31.37	17.97	212.43	5.74	0.20
Future	26	90.04	3.00	28.98	15.95	120.32	5.43	0.20
Future	27	80.29	4.00	30.00	17.11	256.03	5.57	0.20
Future	28	82.15	4.00	29.47	15.43	56.02	5.61	0.20
Future + Nat Heritage	1	76.45	3.00	30.31	14.82	64.79	6.55	0.20
Future + Nat Heritage	2	84.93	3.00	29.85	14.81	59.95	5.83	0.20
Future + Nat Heritage	3	76.60	3.00	30.15	15.27	97.55	6.47	0.20
Future + Nat Heritage	4	80.51	3.00	29.07	14.39	54.99	6.27	0.20
Future + Nat Heritage	5	54.97	4.00	31.85	18.90	313.26	7.40	0.20
Future + Nat Heritage	6	77.40	4.00	23.76	11.43	60.48	6.95	0.20
Future + Nat Heritage	7	67.94	4.00	27.08	14.38	180.38	6.83	0.20
Future + Nat Heritage	8	75.19	4.00	28.20	14.97	166.26	6.25	0.20
Future + Nat Heritage	9	78.97	4.00	24.13	11.14	54.73	6.20	0.20
Future + Nat Heritage	10	73.81	4.00	30.99	15.76	86.40	6.04	0.20
Future + Nat Heritage	11	80.09	3.00	29.71	14.79	64.10	6.15	0.20
Future + Nat Heritage	11.1	83.19	3.00	28.44	13.13	40.31	6.20	0.20
Future + Nat Heritage	12	80.72	3.00	31.11	16.98	156.66	5.91	0.20
Future + Nat Heritage	13	73.09	3.00	28.37	14.67	108.97	6.78	0.20
Future + Nat Heritage	14	75.74	3.00	30.85	16.02	103.95	6.60	0.20
Future + Nat Heritage	15	52.09	4.00	31.25	18.67	493.98	7.35	0.20
Future + Nat Heritage	16	68.76	3.00	31.33	18.74	284.89	7.43	0.20
Future + Nat Heritage	17	67.52	3.00	31.15	17.22	173.38	7.17	0.20
Future + Nat Heritage	18	69.93	3.00	31.02	16.62	135.35	7.35	0.20
Future + Nat Heritage	19	73.36	3.00	30.93	16.71	154.22	6.85	0.20
Future + Nat Heritage	20	77.64	3.00	30.79	16.31	123.56	6.35	0.20
Future + Nat Heritage	21	88.49	3.00	29.93	16.71	140.40	5.57	0.20
Future + Nat Heritage	21.1	71.60	3.00	31.67	19.07	271.75	7.10	0.20
Future + Nat Heritage	22	85.68	3.00	30.72	15.46	70.84	6.19	0.20
Future + Nat Heritage	23	90.11	3.00	31.68	18.52	223.21	5.76	0.20
Future + Nat Heritage	24	81.77	3.00	30.55	15.15	64.80	5.81	0.20
Future + Nat Heritage	25	84.25	3.00	31.37	17.97	212.43	5.69	0.20
Future + Nat Heritage	26	90.04	3.00	28.98	15.95	120.32	5.47	0.20
Future + Nat Heritage	27	80.23	4.00	30.00	17.11	256.03	5.61	0.20
Future + Nat Heritage	28	82.15	4.00	29.47	15.43	56.02	5.65	0.20

Impervious Area Parameters – At Gauge Locations

Scenario	Basin	Area A [ha]	Impervious TIMP [Frac]	Dir Con Imp, XIMP [Frac]	Dep Sto IAIMP [mm]
Existing	02HC019	8692.49	0.008	0.006	0.8
Existing	02HC036	1535.95	0.007	0.005	0.8
Existing	02HC037	1389.35	0.000	0.000	0.8
Existing	02HC038	6196.53	0.000	0.000	0.8
Existing	02HC039	3509.00	0.035	0.025	0.8
Existing	02HC049	25806.23	0.017	0.013	0.8

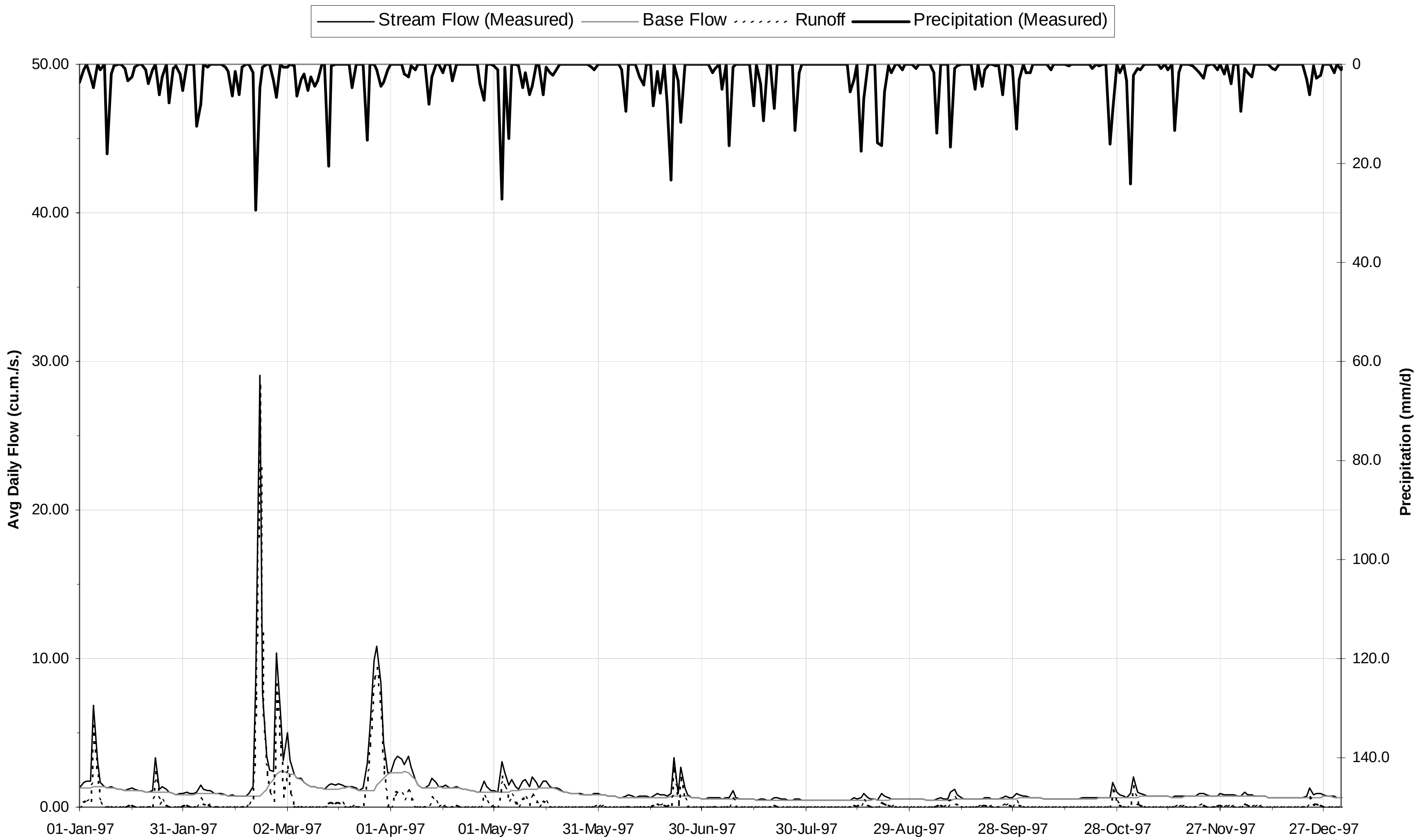
Pervious Area Parameters

Scenario	Basin	CN	IAPER [mm]	POROSITY [%]	G [%]	K [mm/d]	VEG_K3 [mm]	Z_IMP [Frac]
Existing	02HC019	75.44	3.0	30.56	16.92	180.7	6.50	0.20
Existing	02HC036	78.09	3.0	30.78	16.28	122.7	6.12	0.20
Existing	02HC037	82.62	3.0	31.22	17.11	155.1	6.42	0.20
Existing	02HC038	69.75	4.0	28.32	15.45	248.1	6.32	0.20
Existing	02HC039	80.04	3.0	29.83	14.92	79.8	6.06	0.20
Existing	02HC049	77.46	3.0	29.87	16.02	149.1	6.31	0.20

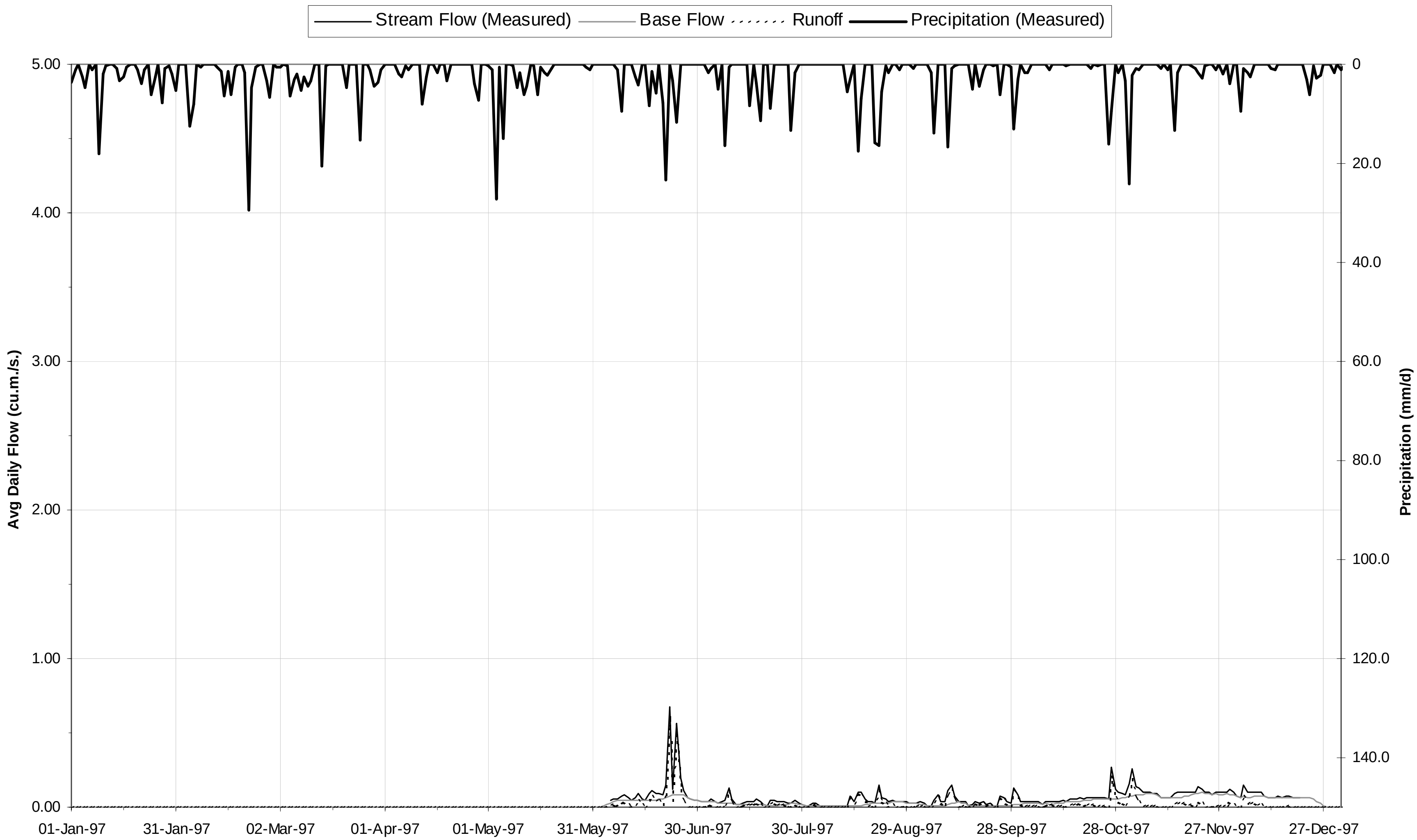
Appendix B: Baseflow Separation

Gauge	Location
02HC019	East Duffins Creek
02HC036	Braughan Creek
02HC037	Urfe Creek
02HC038	Wixon Creek
02HC039	Reesor Creek
02HC049	West Duffins Creek

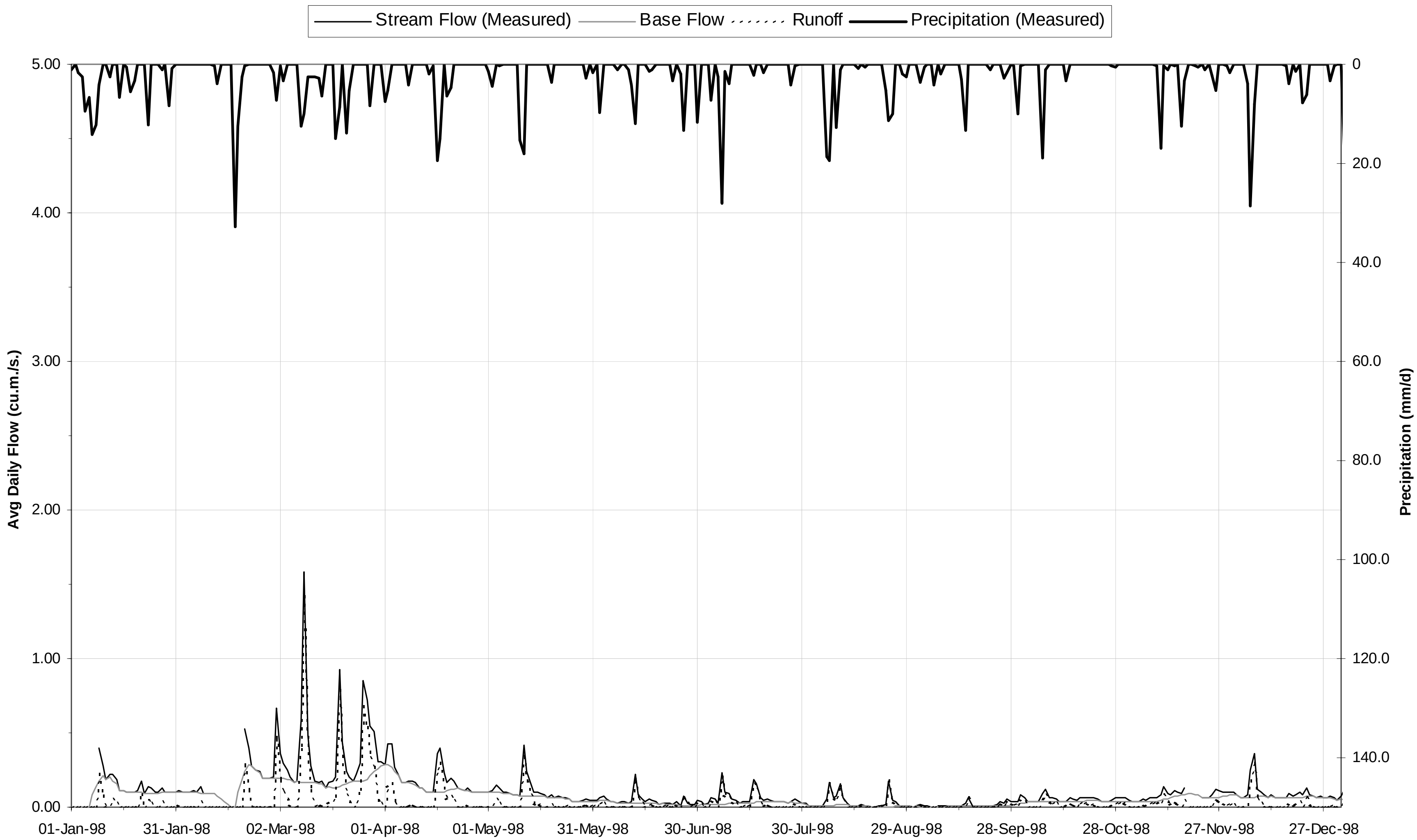
02HC019


Stream Flow (Measured)
Base Flow
Runoff
Precipitation (Measured)
Avg Daily Flow (cu.m./s.)
Precipitation (mm/d)
50.00
40.00
30.00
20.00
10.00
0.00
0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
01-Jan-97
31-Jan-97
02-Mar-97
01-Apr-97
01-May-97
31-May-97
30-Jun-97
30-Jul-97
29-Aug-97
28-Sep-97
28-Oct-97
27-Nov-97
27-Dec-97

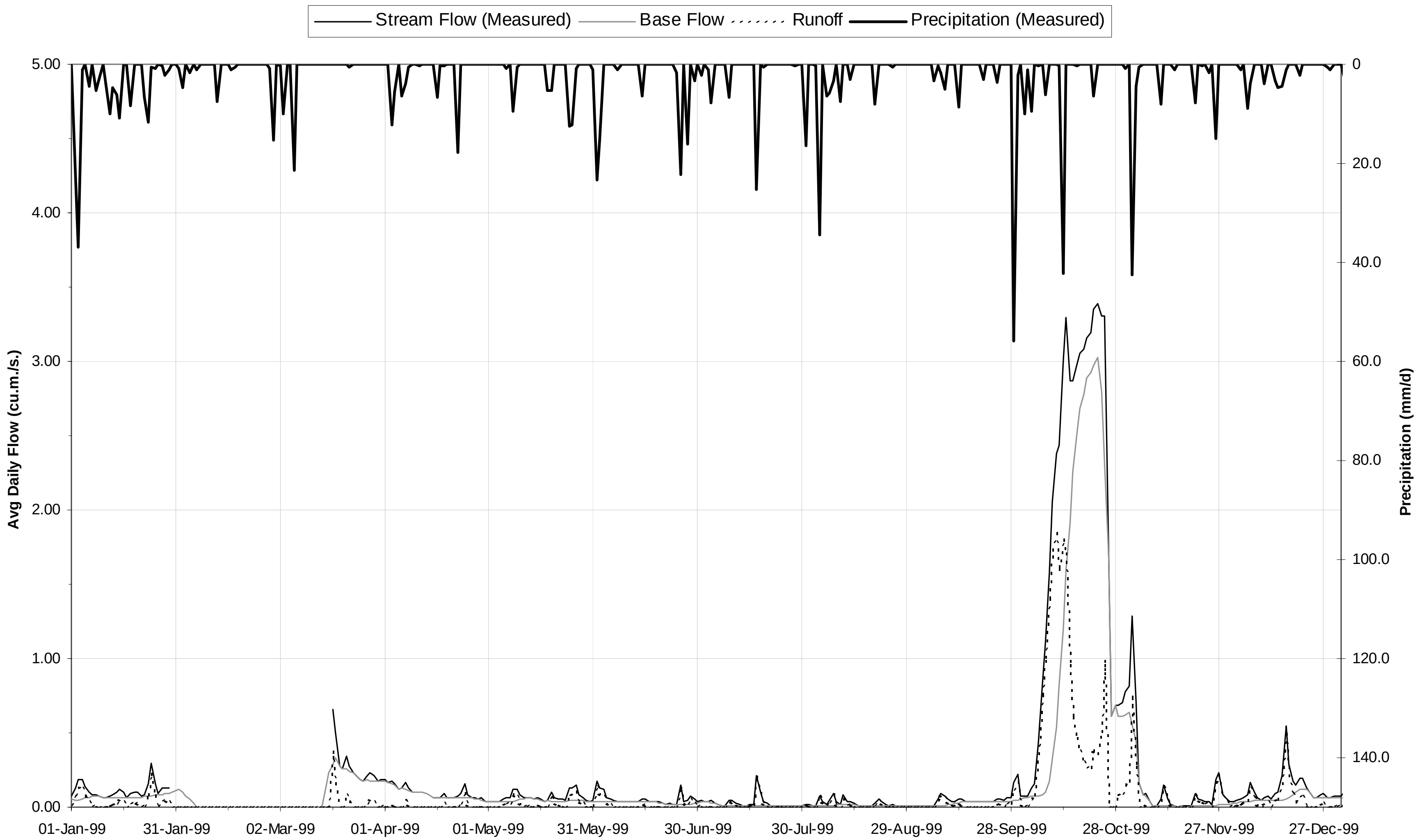
02HC036


Stream Flow (Measured)
Base Flow
Runoff
Precipitation (Measured)
Avg Daily Flow (cu.m./s.)
5.00
4.00
3.00
2.00
1.00
0.00
Precipitation (mm/d)
0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
01-Jan-97
31-Jan-97
02-Mar-97
01-Apr-97
01-May-97
31-May-97
30-Jun-97
30-Jul-97
29-Aug-97
28-Sep-97
28-Oct-97
27-Nov-97
27-Dec-97

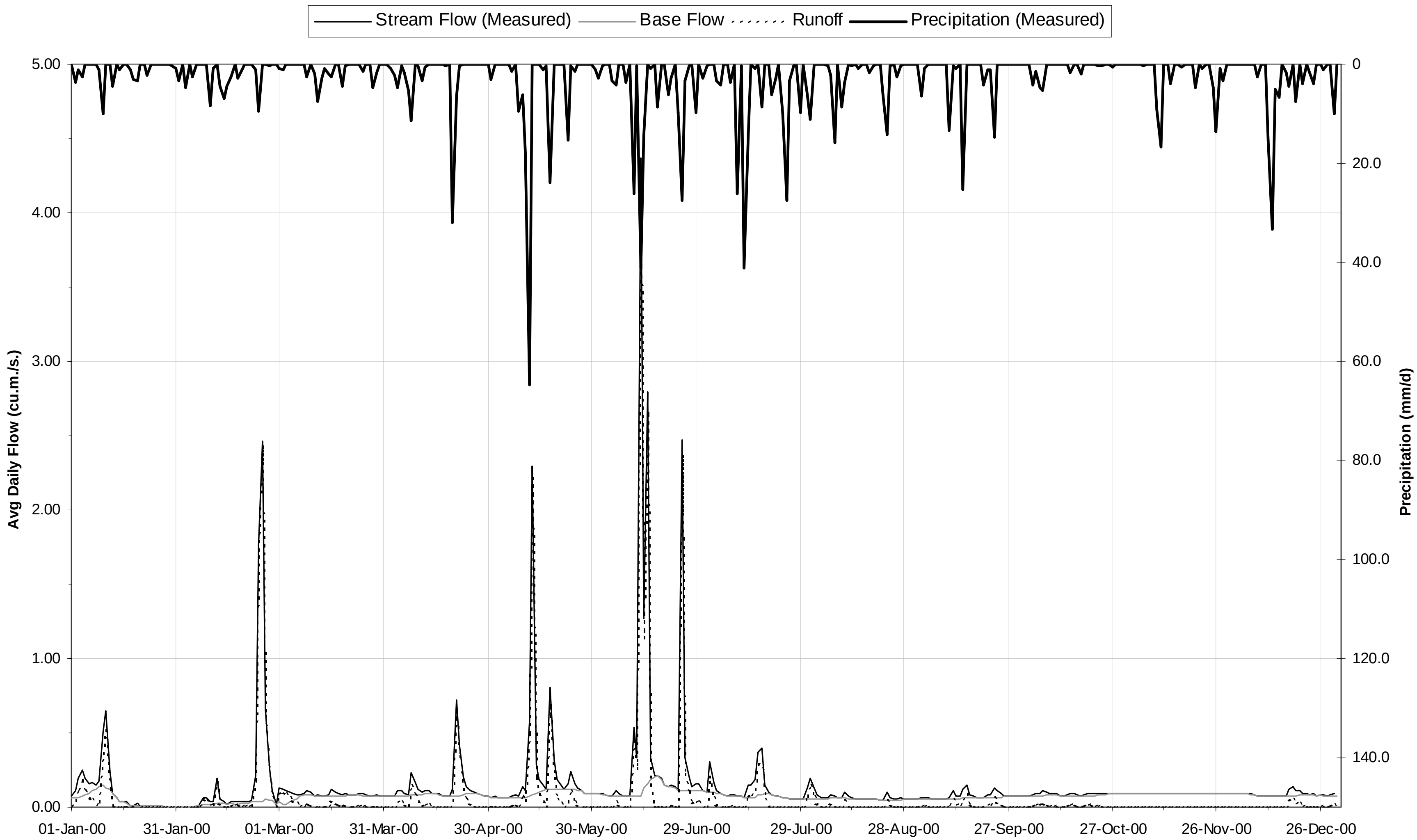
02HC036


Stream Flow (Measured)
Base Flow
Runoff
Precipitation (Measured)
Avg Daily Flow (cu.m./s.)
Precipitation (mm/d)
5.00
4.00
3.00
2.00
1.00
0.00
0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
01-Jan-98
31-Jan-98
02-Mar-98
01-Apr-98
01-May-98
31-May-98
30-Jun-98
30-Jul-98
29-Aug-98
28-Sep-98
28-Oct-98
27-Nov-98
27-Dec-98

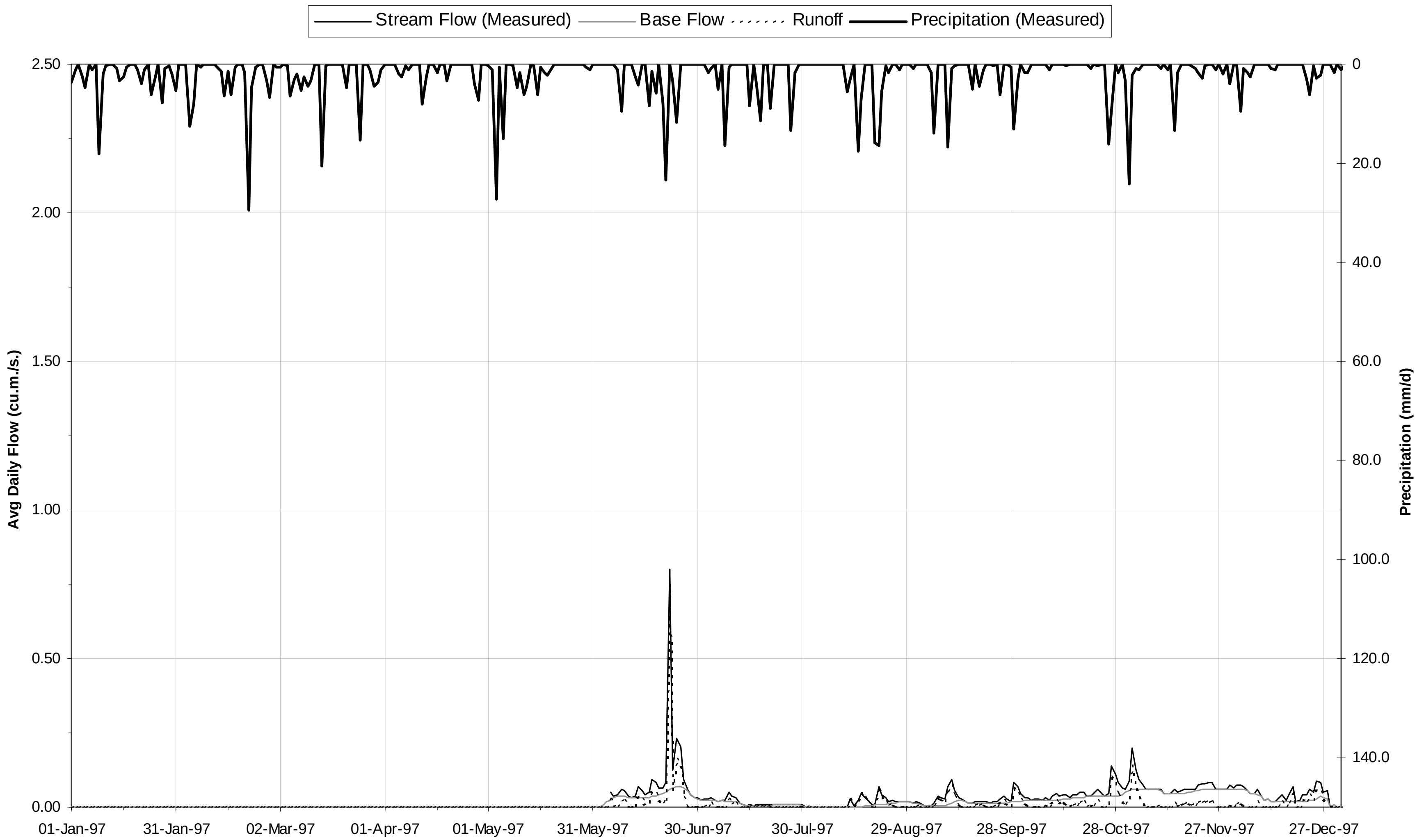
02HC036


Stream Flow (Measured)
Base Flow
Runoff
Precipitation (Measured)
Avg Daily Flow (cu.m./s.)
Precipitation (mm/d)
5.00
4.00
3.00
2.00
1.00
0.00
0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
01-Jan-99
31-Jan-99
02-Mar-99
01-Apr-99
01-May-99
31-May-99
30-Jun-99
30-Jul-99
29-Aug-99
28-Sep-99
28-Oct-99
27-Nov-99
27-Dec-99

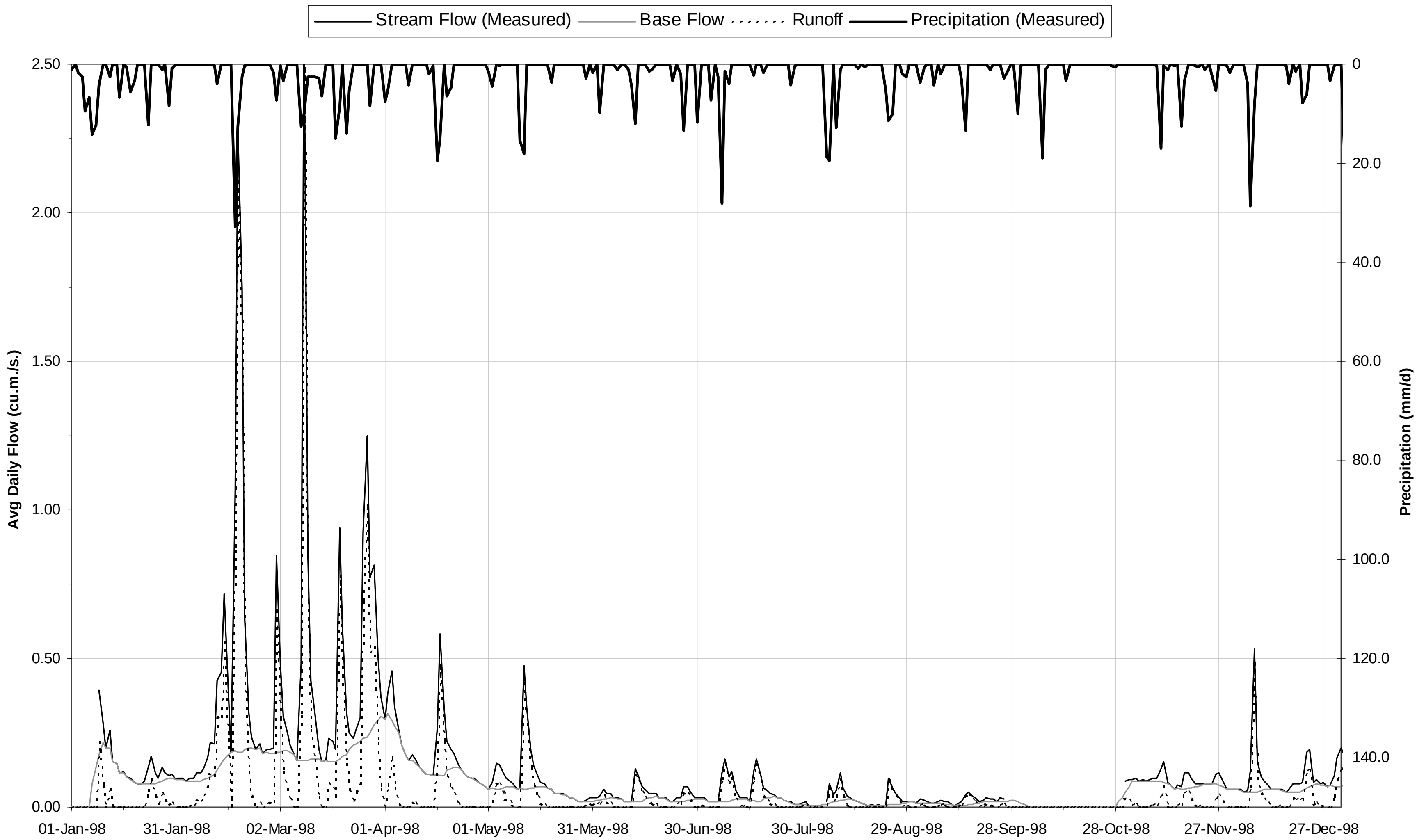
02HC036


Stream Flow (Measured)
Base Flow
Runoff
Precipitation (Measured)
Avg Daily Flow (cu.m./s.)
Precipitation (mm/d)
5.00
4.00
3.00
2.00
1.00
0.00
0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
01-Jan-00
31-Jan-00
01-Mar-00
31-Mar-00
30-Apr-00
30-May-00
29-Jun-00
29-Jul-00
28-Aug-00
27-Sep-00
27-Oct-00
26-Nov-00
26-Dec-00

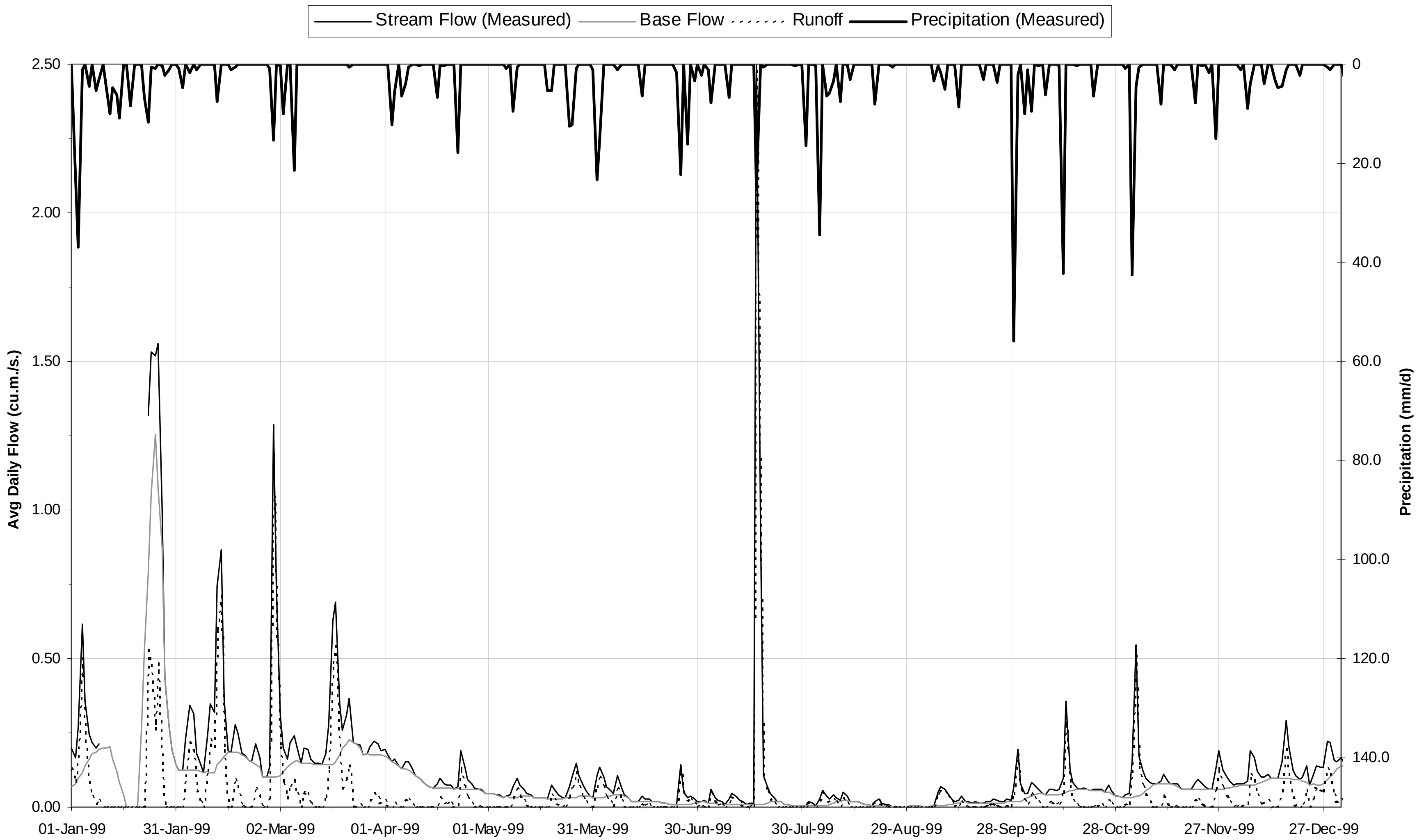
02HC037


Stream Flow (Measured)
Base Flow
Runoff
Precipitation (Measured)
Avg Daily Flow (cu.m./s.)
Precipitation (mm/d)
2.50
2.00
1.50
1.00
0.50
0.00
0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
01-Jan-97
31-Jan-97
02-Mar-97
01-Apr-97
01-May-97
31-May-97
30-Jun-97
30-Jul-97
29-Aug-97
28-Sep-97
28-Oct-97
27-Nov-97
27-Dec-97

02HC037


Stream Flow (Measured)
Base Flow
Runoff
Precipitation (Measured)
Avg Daily Flow (cu.m./s.)
Precipitation (mm/d)
2.50
2.00
1.50
1.00
0.50
0.00
0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
01-Jan-98
31-Jan-98
02-Mar-98
01-Apr-98
01-May-98
31-May-98
30-Jun-98
30-Jul-98
29-Aug-98
28-Sep-98
28-Oct-98
27-Nov-98
27-Dec-98

02HC037


Stream Flow (Measured)
Base Flow
Runoff
Precipitation (Measured)
Avg Daily Flow (cu.m./s.)
Precipitation (mm/d)
2.50
2.00
1.50
1.00
0.50
0.00
0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
01-Jan-99
31-Jan-99
02-Mar-99
01-Apr-99
01-May-99
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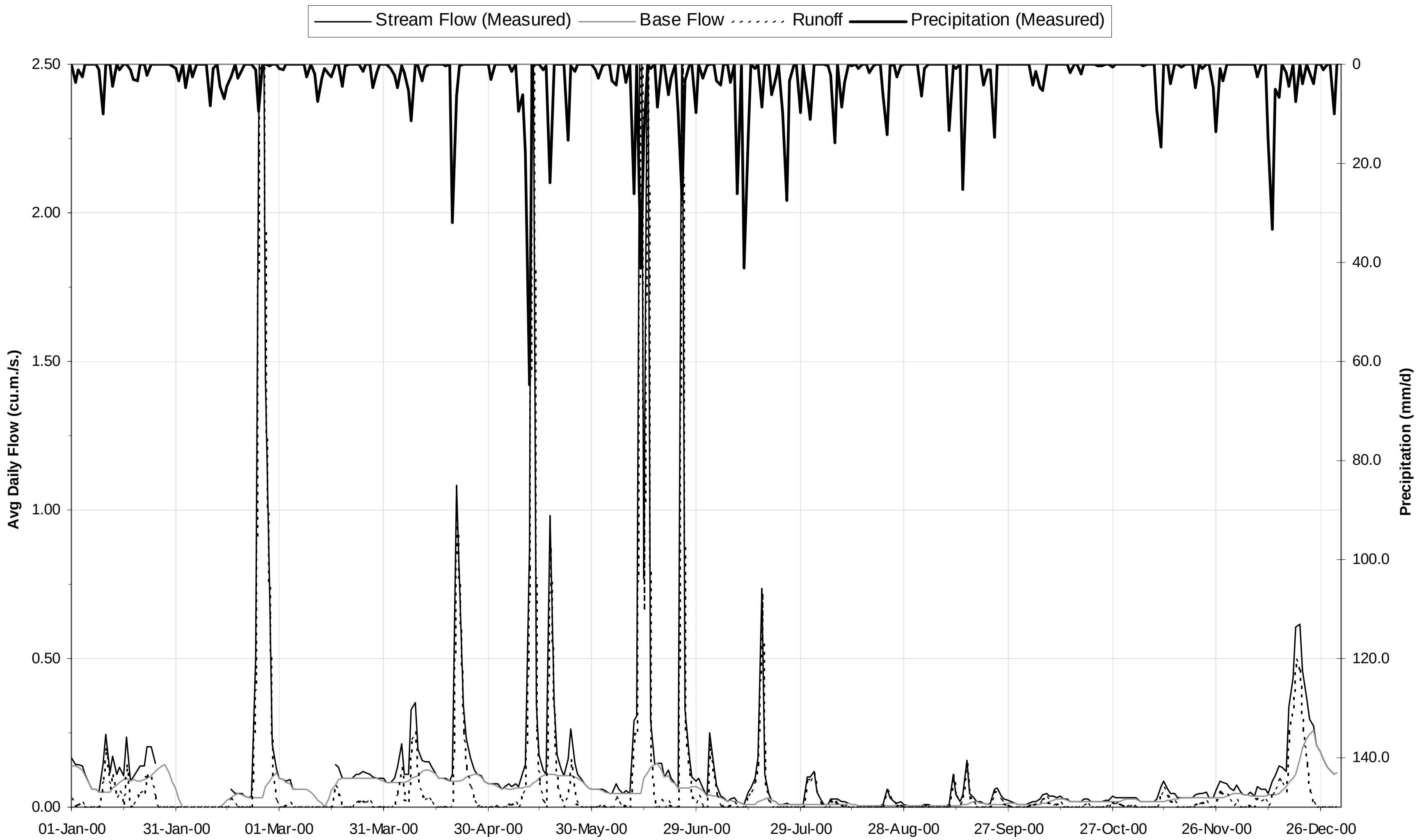
27-Dec-99

02HC037


Stream Flow (Measured)
Base Flow
Runoff
Precipitation (Measured)
Avg Daily Flow (cu.m./s.)
Precipitation (mm/d)
2.50
2.00
1.50
1.00
0.50
0.00
0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
01-Jan-00
31-Jan-00
01-Mar-00
31-Mar-00
30-Apr-00
30-May-00
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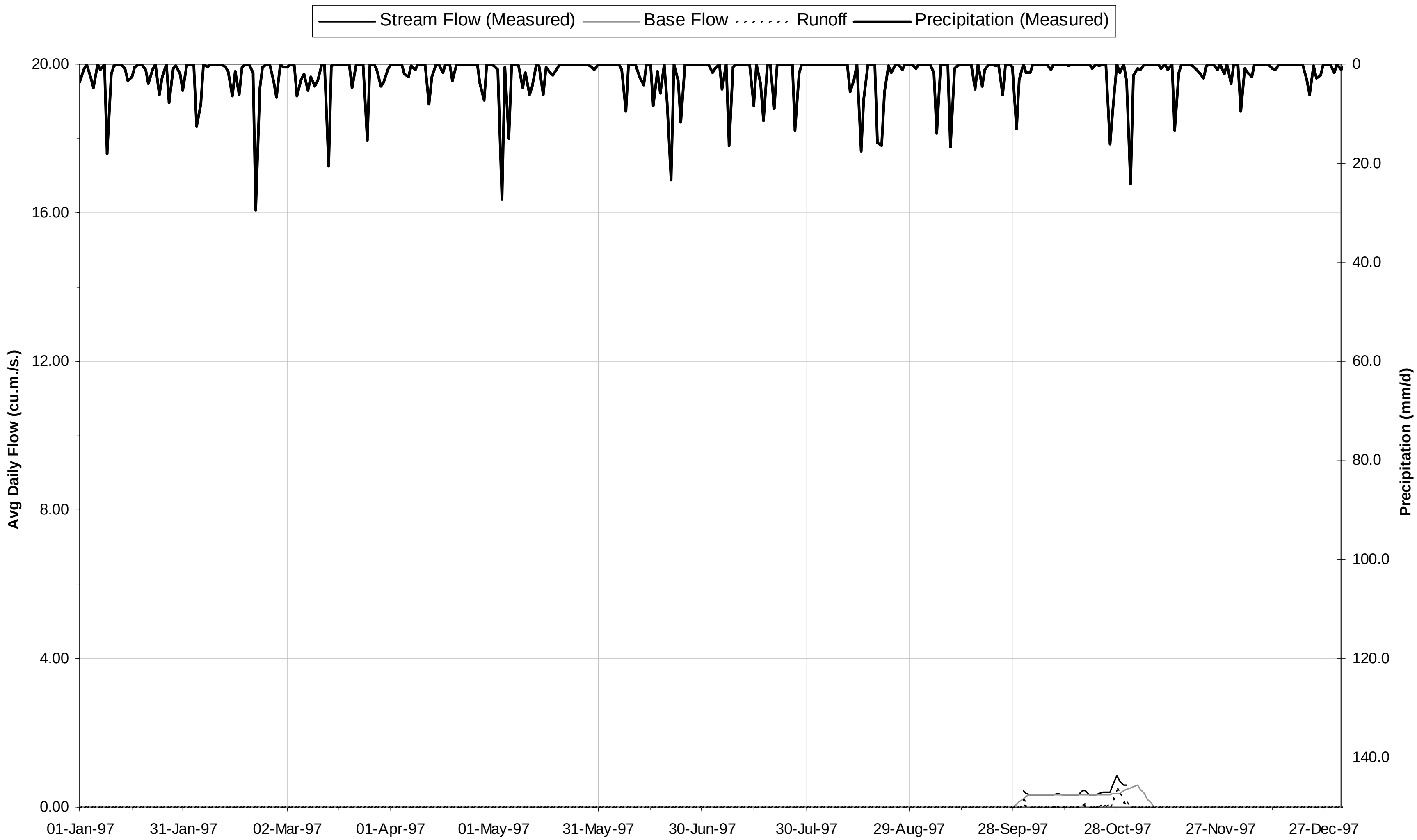
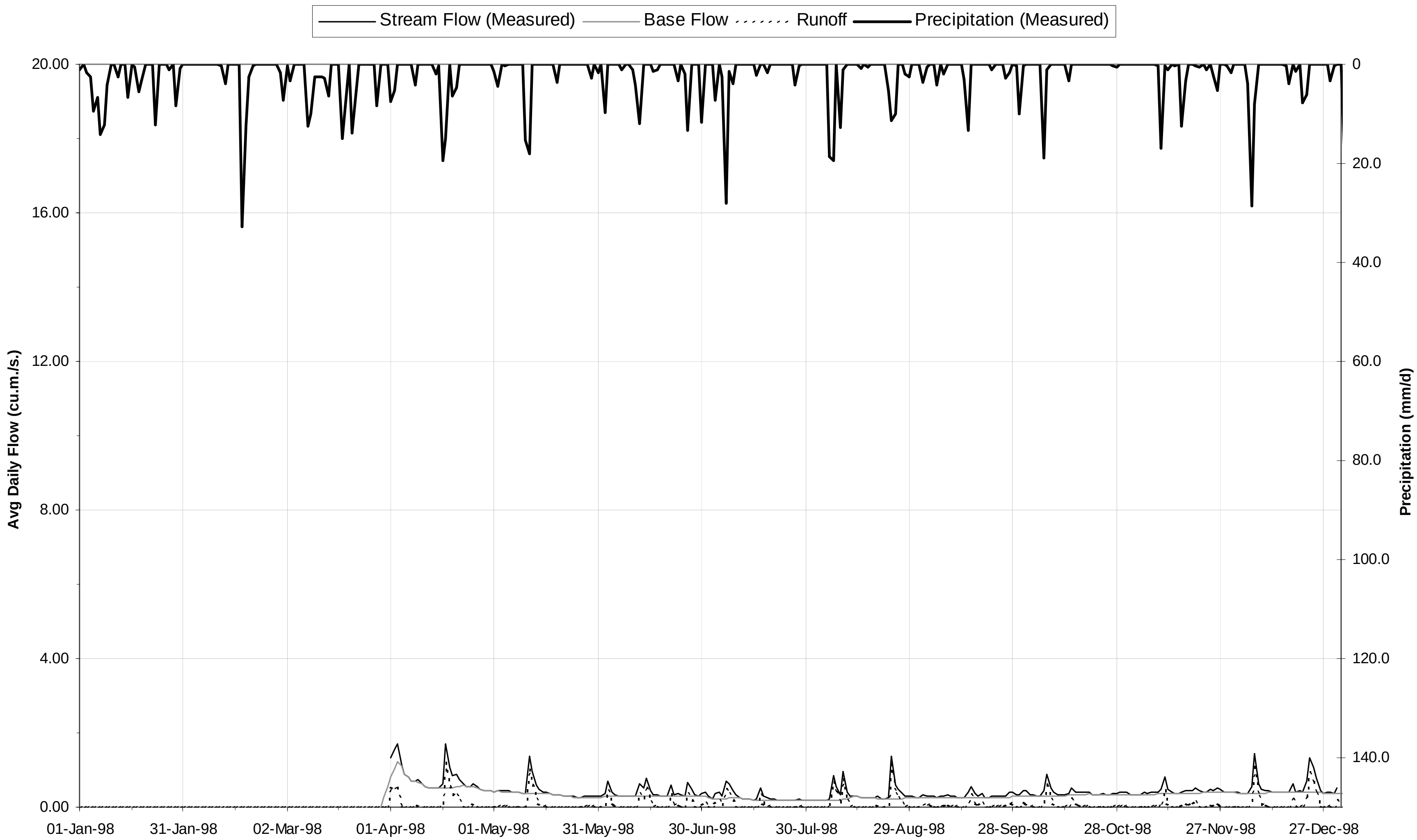
28-Aug-00
27-Sep-00
27-Oct-00
26-Nov-00
26-Dec-00

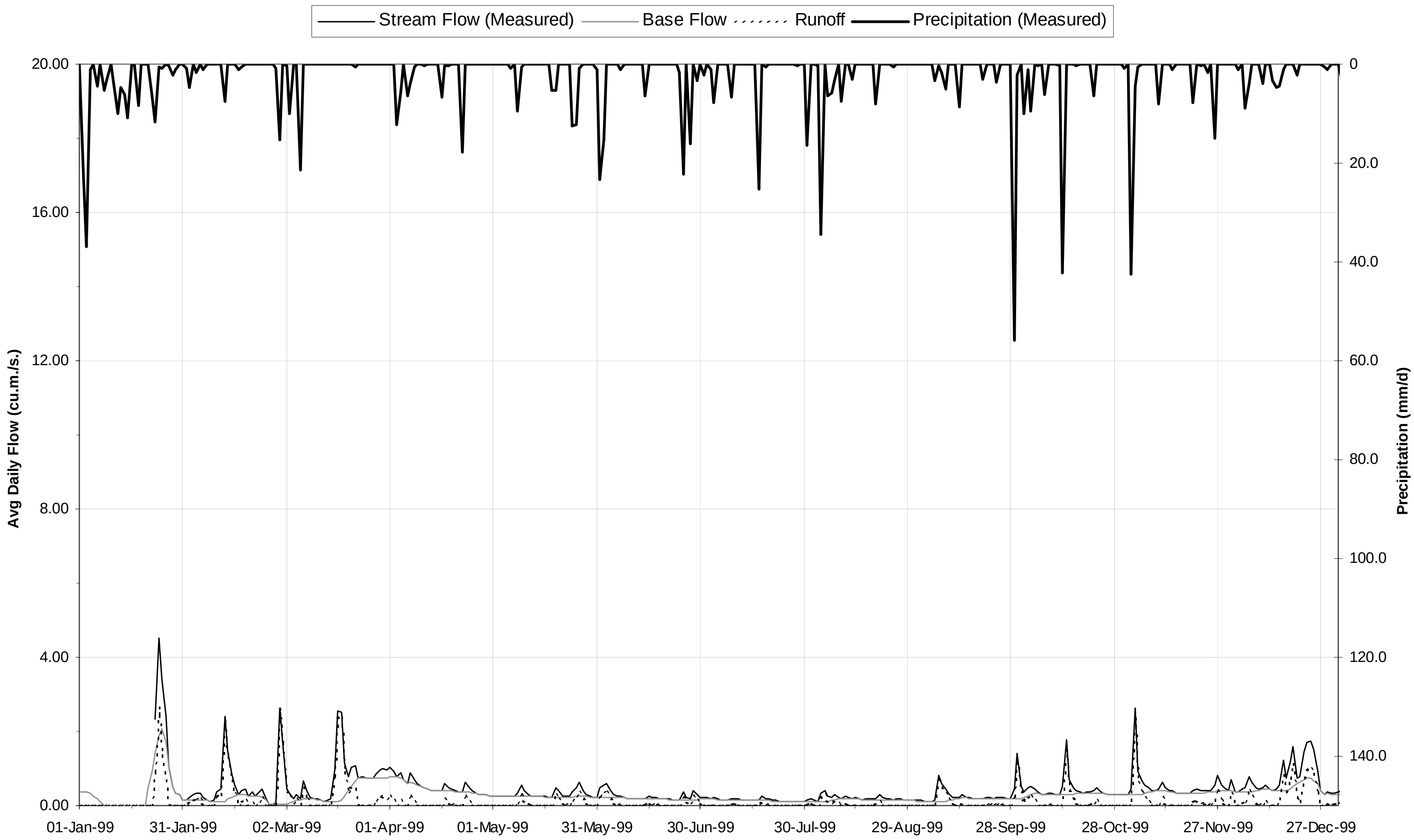
02HC038


Stream Flow (Measured)
Base Flow
Runoff
Precipitation (Measured)
Avg Daily Flow (cu.m./s.)
Precipitation (mm/d)
20.00
16.00
12.00
8.00
4.00
0.00
0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
01-Jan-97
31-Jan-97
02-Mar-97
01-Apr-97
01-May-97
31-May-97
30-Jun-97
30-Jul-97
29-Aug-97
28-Sep-97
28-Oct-97
27-Nov-97
27-Dec-97

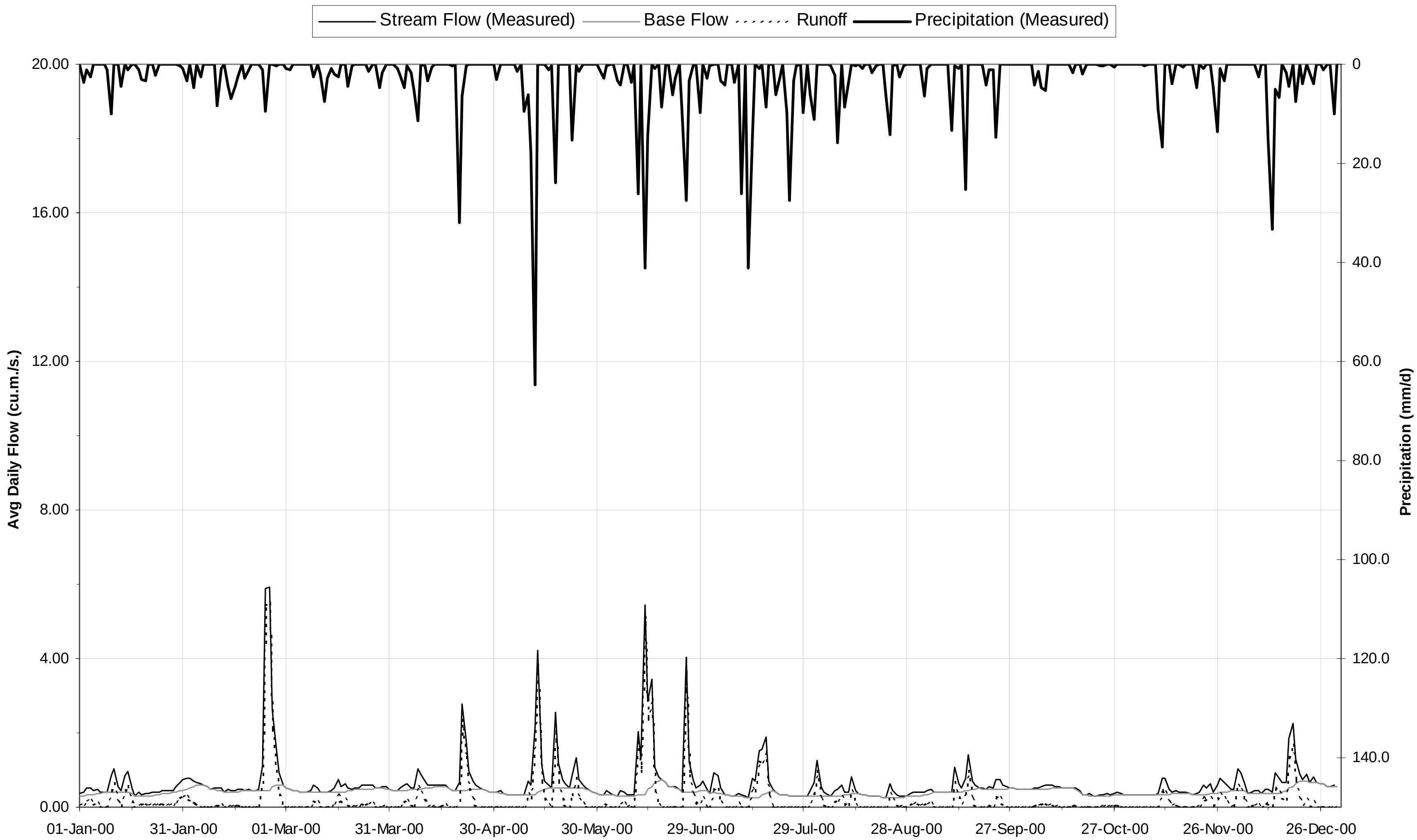
02HC038


Stream Flow (Measured)
Base Flow
Runoff
Precipitation (Measured)
Avg Daily Flow (cu.m./s.)
Precipitation (mm/d)
20.00
16.00
12.00
8.00
4.00
0.00
0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
01-Jan-98
31-Jan-98
02-Mar-98
01-Apr-98
01-May-98
31-May-98
30-Jun-98
30-Jul-98
29-Aug-98
28-Sep-98
28-Oct-98
27-Nov-98
27-Dec-98

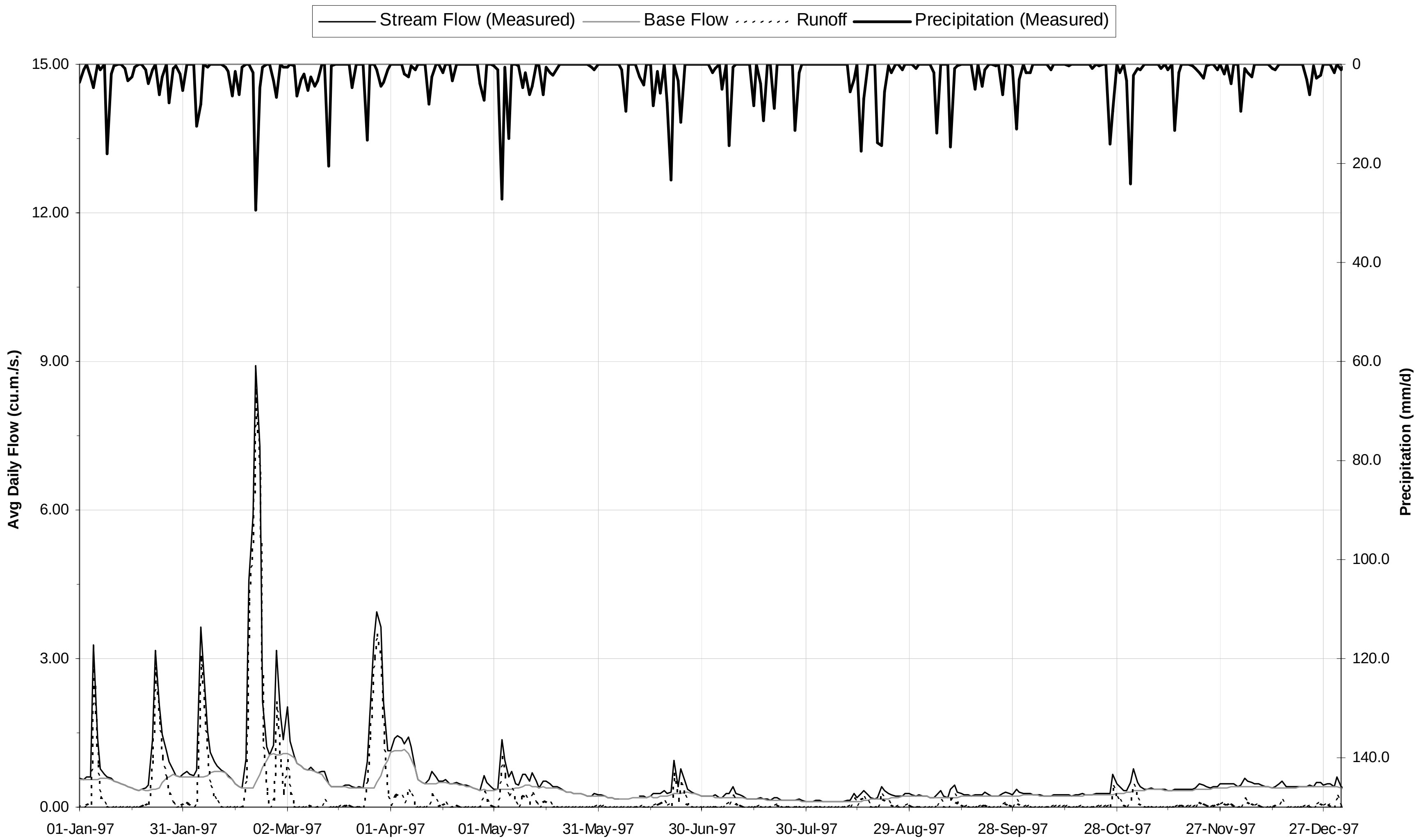
02HC038


Stream Flow (Measured)
Base Flow
Runoff
Precipitation (Measured)
Avg Daily Flow (cu.m./s.)
Precipitation (mm/d)
20.00
16.00
12.00
8.00
4.00
0.00
0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
01-Jan-99
31-Jan-99
02-Mar-99
01-Apr-99
01-May-99
31-May-99
30-Jun-99
30-Jul-99
29-Aug-99
28-Sep-99
28-Oct-99
27-Nov-99
27-Dec-99

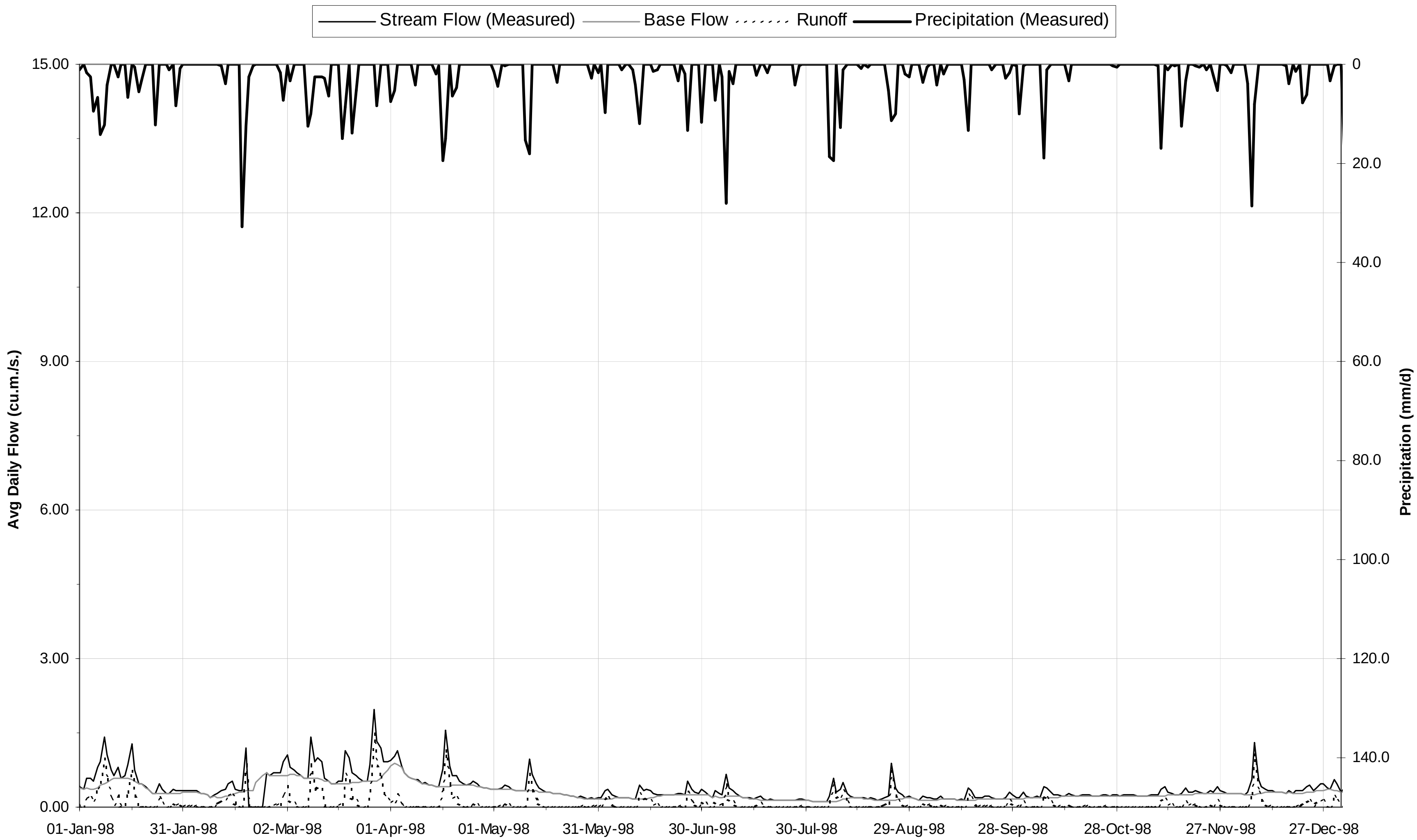
02HC038


Stream Flow (Measured)
Base Flow
Runoff
Precipitation (Measured)
Avg Daily Flow (cu.m./s.)
Precipitation (mm/d)
20.00
16.00
12.00
8.00
4.00
0.00
0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
01-Jan-00
31-Jan-00
01-Mar-00
31-Mar-00
30-Apr-00
30-May-00
29-Jun-00
29-Jul-00
28-Aug-00
27-Sep-00
27-Oct-00
26-Nov-00
26-Dec-00

02HC039


Stream Flow (Measured)
Base Flow
Runoff
Precipitation (Measured)
Avg Daily Flow (cu.m./s.)
Precipitation (mm/d)
15.00
12.00
9.00
6.00
3.00
0.00
0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
01-Jan-97
31-Jan-97
02-Mar-97
01-Apr-97
01-May-97
31-May-97
30-Jun-97
30-Jul-97
29-Aug-97
28-Sep-97
28-Oct-97
27-Nov-97
27-Dec-97

02HC039


Stream Flow (Measured)
Base Flow
Runoff
Precipitation (Measured)
Avg Daily Flow (cu.m./s.)
Precipitation (mm/d)
15.00
12.00
9.00
6.00
3.00
0.00
0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
01-Jan-98
31-Jan-98
02-Mar-98
01-Apr-98
01-May-98
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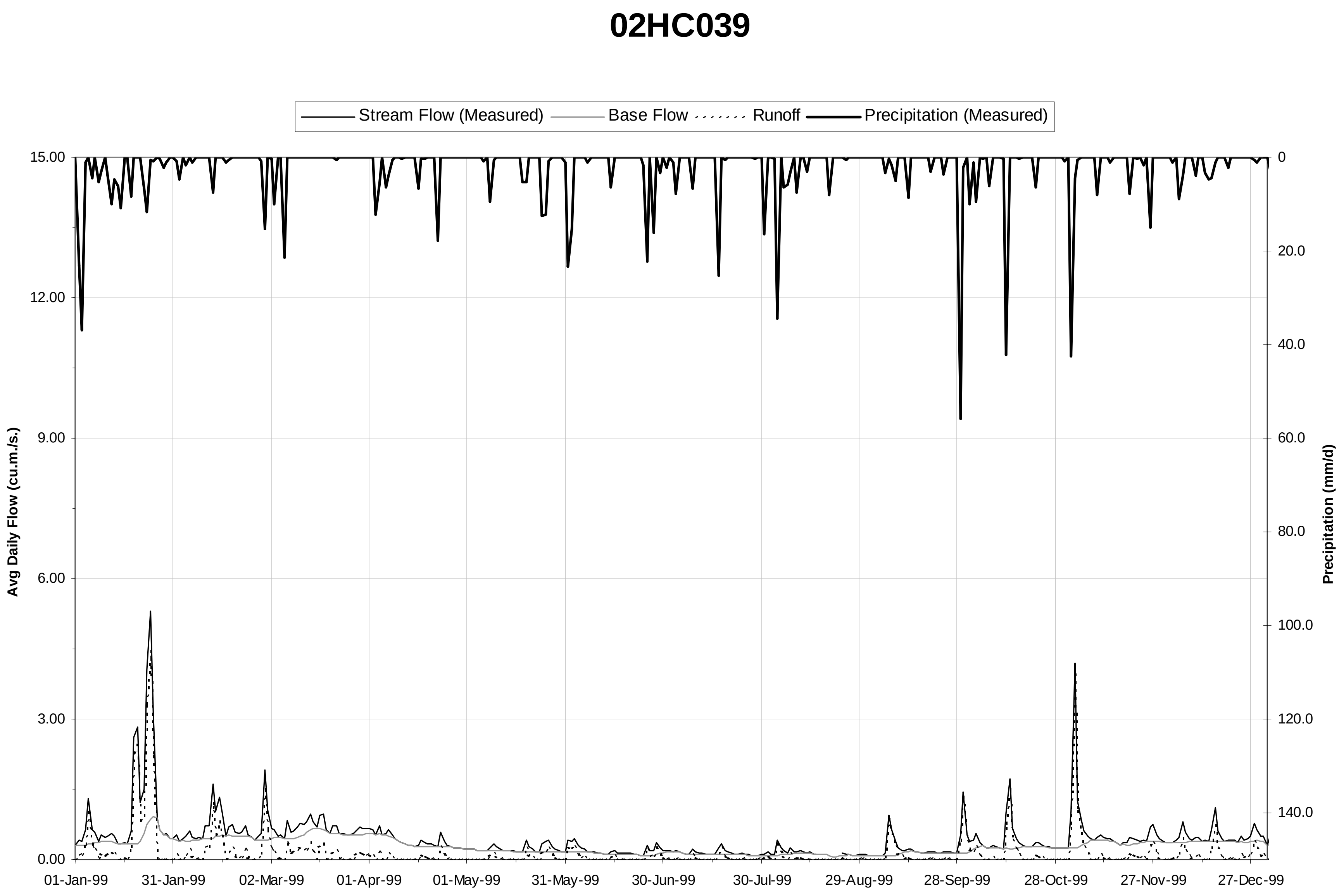
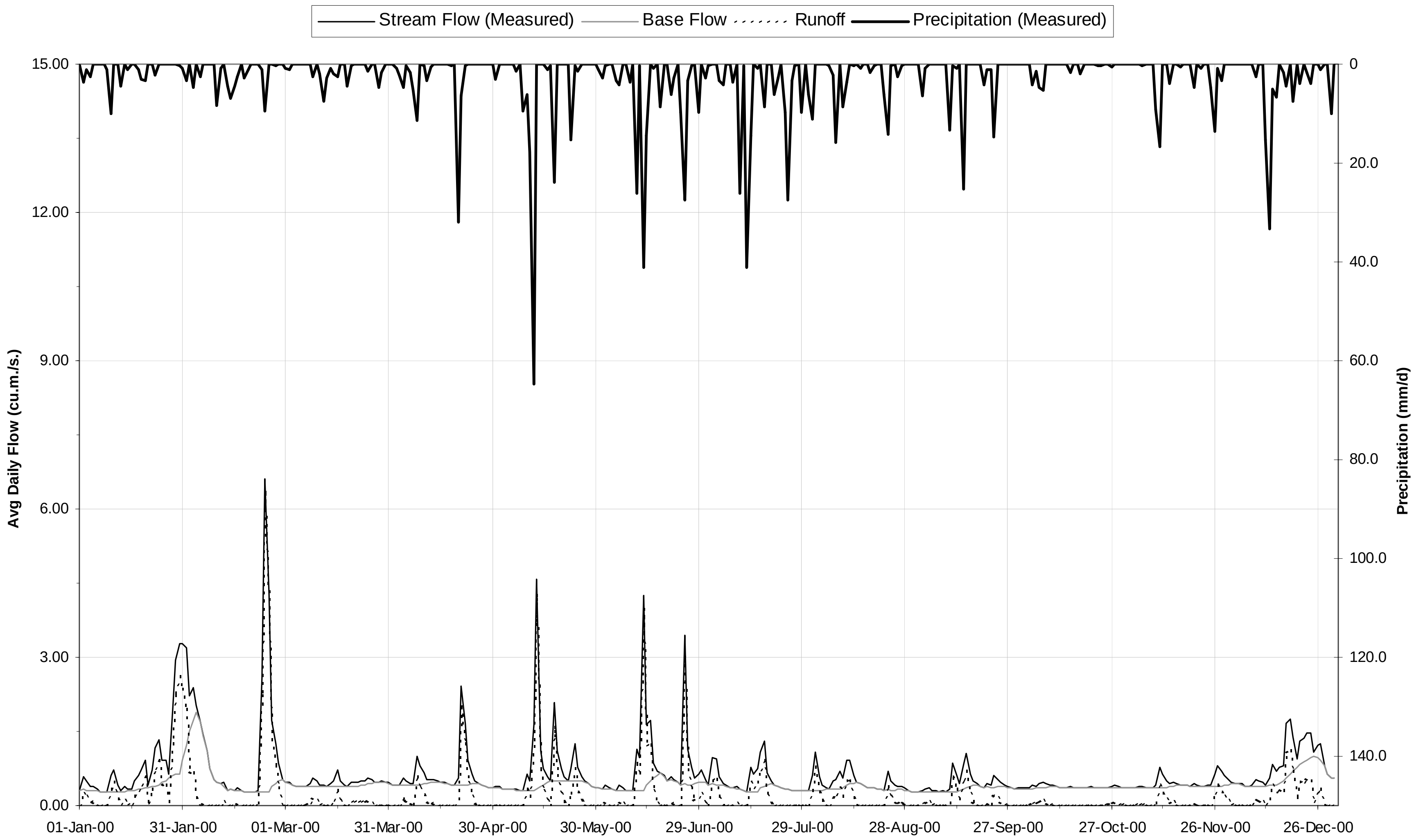
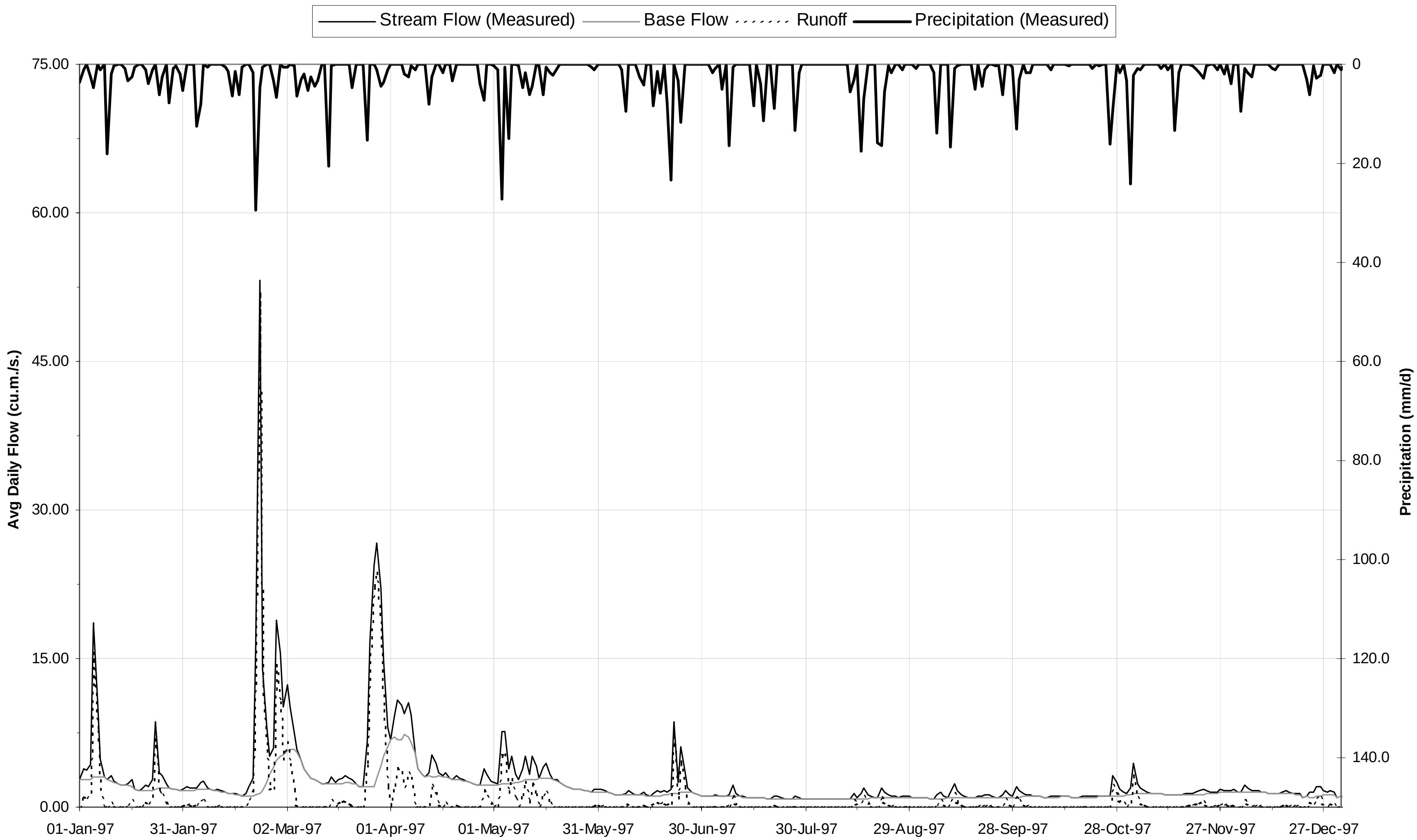
27-Nov-98
27-Dec-98


02HC039
Stream Flow (Measured)
Base Flow
Runoff
Precipitation (Measured)
Avg Daily Flow (cu.m./s.)
15.00
12.00
9.00
6.00
3.00
0.00
Precipitation (mm/d)
0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
01-Jan-99
31-Jan-99
02-Mar-99
01-Apr-99
01-May-99
31-May-99
30-Jun-99
30-Jul-99
29-Aug-99
28-Sep-99
28-Oct-99
27-Nov-99
27-Dec-99

02HC039

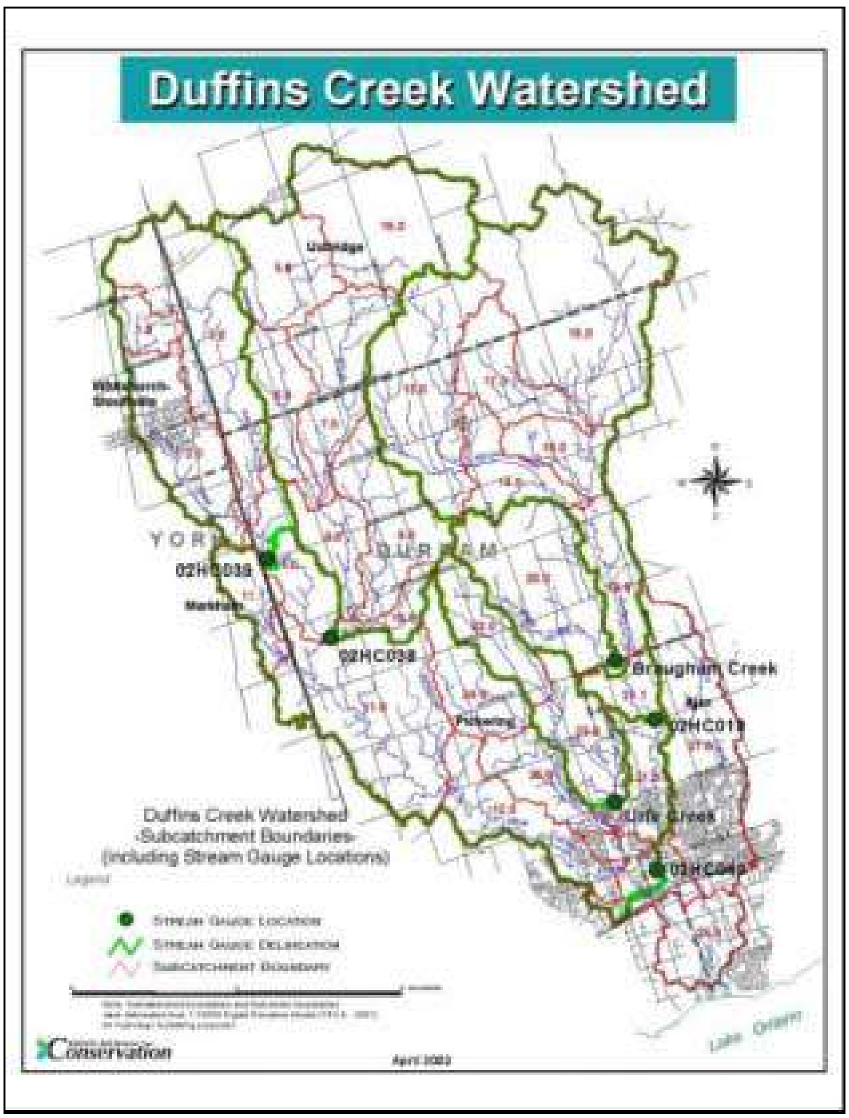

Stream Flow (Measured)
Base Flow
Runoff
Precipitation (Measured)
Avg Daily Flow (cu.m./s.)
Precipitation (mm/d)
15.00
12.00
9.00
6.00
3.00
0.00
0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
01-Jan-00
31-Jan-00
01-Mar-00
31-Mar-00
30-Apr-00
30-May-00
29-Jun-00
29-Jul-00
28-Aug-00
27-Sep-00
27-Oct-00
26-Nov-00
26-Dec-00

02HC049


Stream Flow (Measured)
Base Flow
Runoff
Precipitation (Measured)
Avg Daily Flow (cu.m./s.)
Precipitation (mm/d)
75.00
60.00
45.00
30.00
15.00
0.00
0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
01-Jan-97
31-Jan-97
02-Mar-97
01-Apr-97
01-May-97
31-May-97
30-Jun-97
30-Jul-97
29-Aug-97
28-Sep-97
28-Oct-97
27-Nov-97
27-Dec-97

Appendix C: Calibration

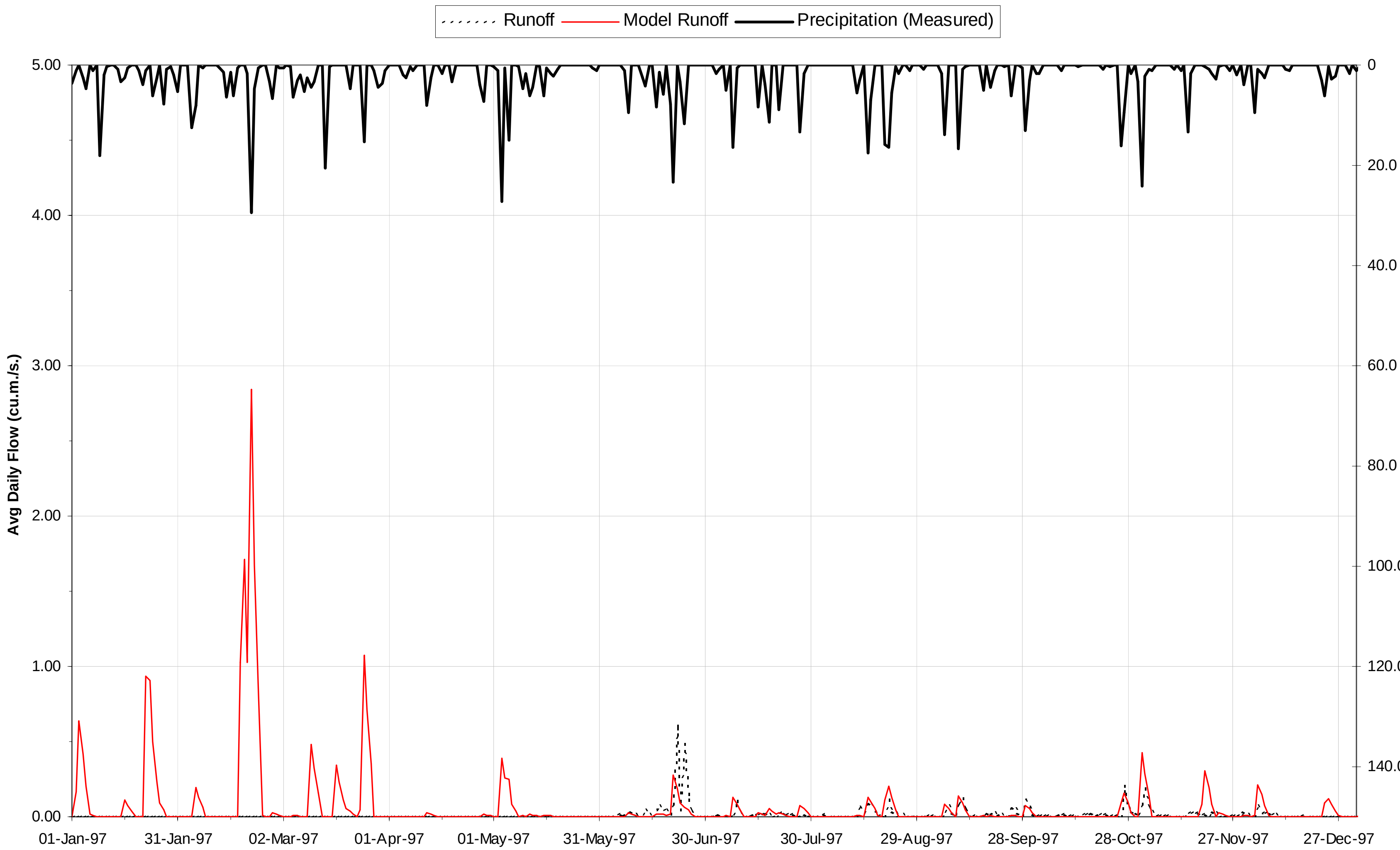
Gauge	Location
02HC019	East Duffins Creek
02HC036	Brougham Creek
02HC037	Urfe Creek
02HC038	Wixon Creek
02HC039	Reesor Creek
02HC049	West Duffins Creek



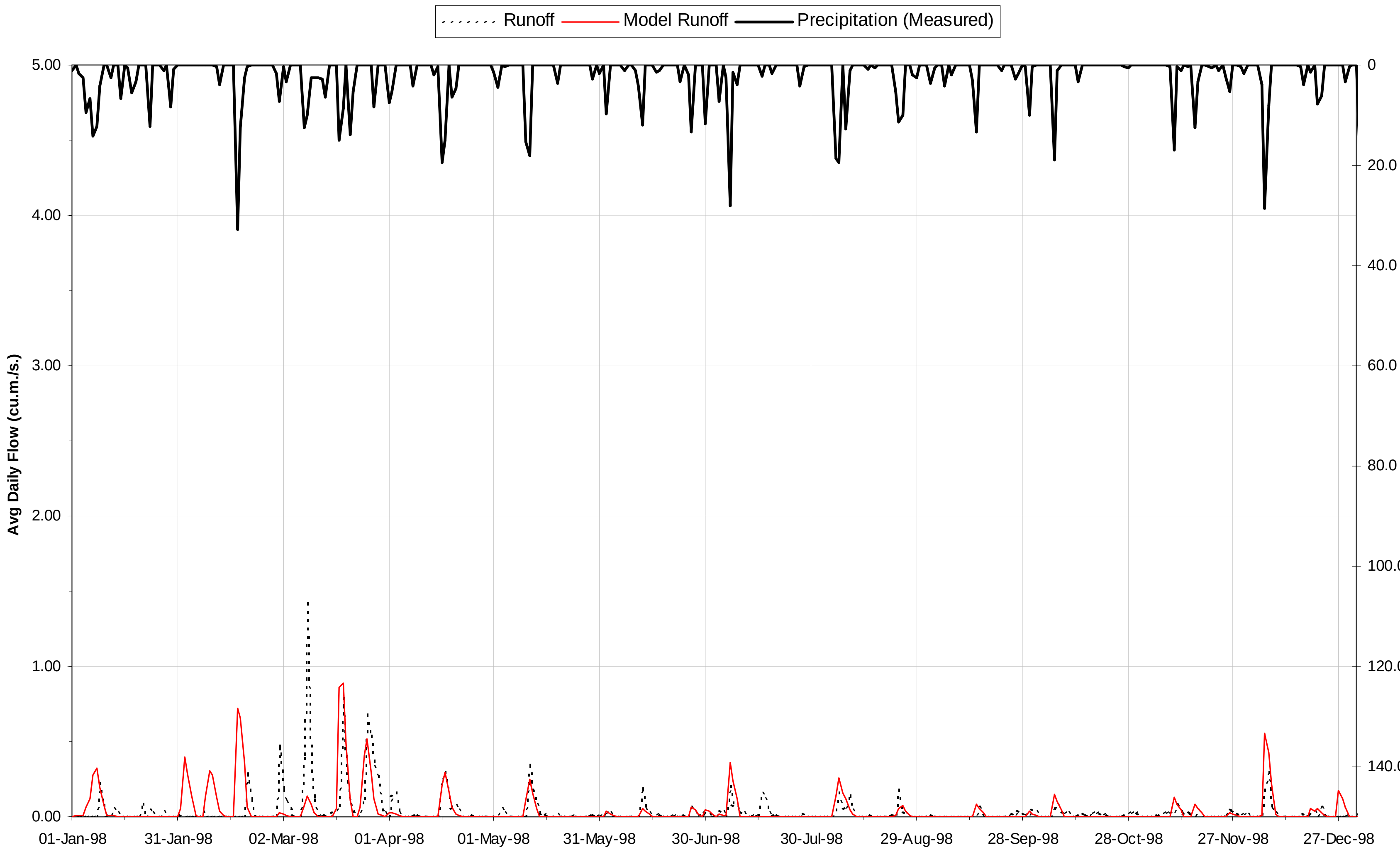
02HC019


Runoff
Model Runoff
Precipitation (Measured)
Avg Daily Flow (cu.m./s.)
30.00
20.00
10.00
0.00
0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
01-Jan-97
31-Jan-97
02-Mar-97
01-Apr-97
01-May-97
31-May-97
30-Jun-97
30-Jul-97
29-Aug-97
28-Sep-97
28-Oct-97
27-Nov-97
27-Dec-97

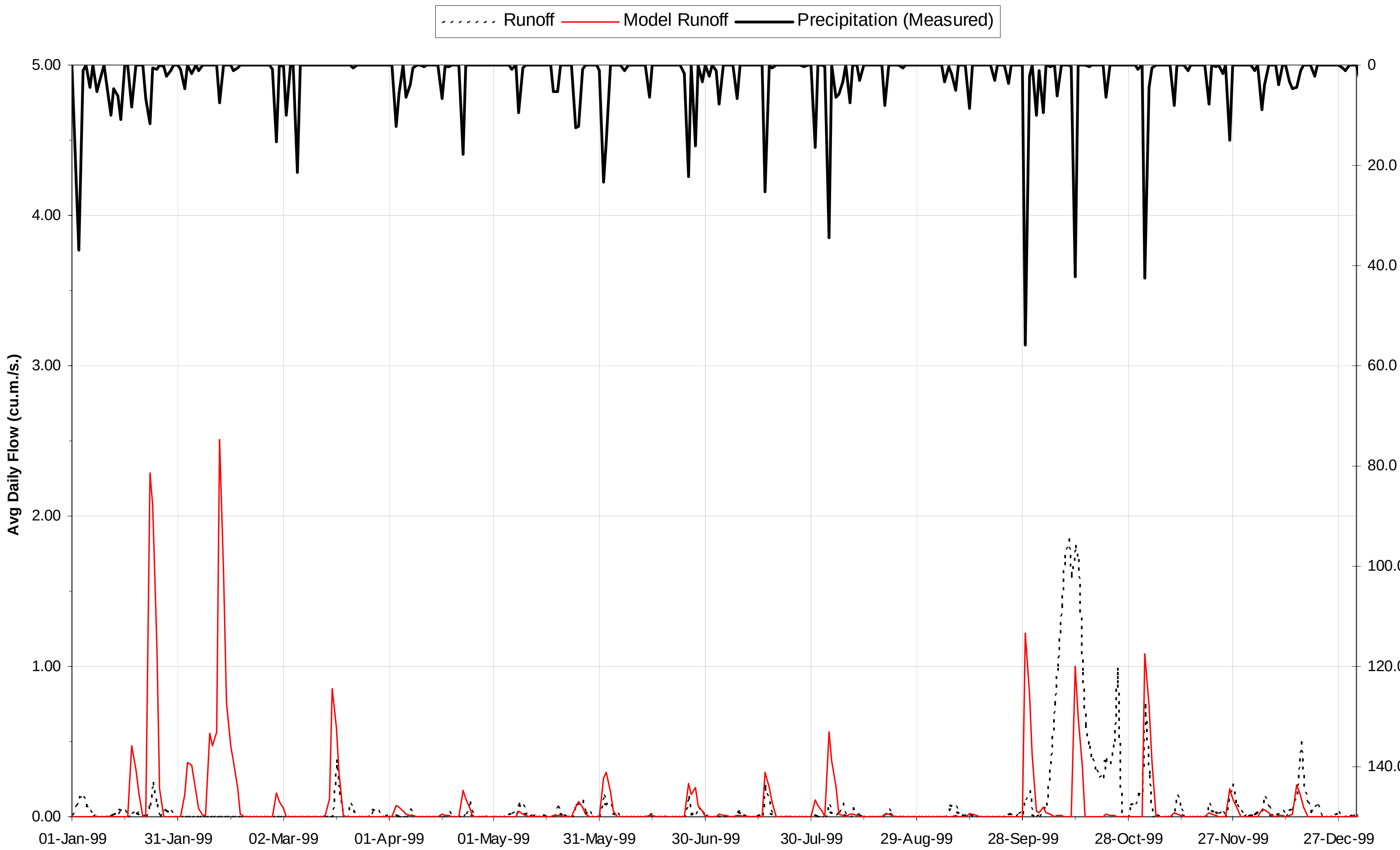
02HC036


Runoff
Model Runoff
Precipitation (Measured)
Avg Daily Flow (cu.m./s.)
5.00
4.00
3.00
2.00
1.00
0.00
0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
01-Jan-97
31-Jan-97
02-Mar-97
01-Apr-97
01-May-97
31-May-97
30-Jun-97
30-Jul-97
29-Aug-97
28-Sep-97
28-Oct-97
27-Nov-97
27-Dec-97

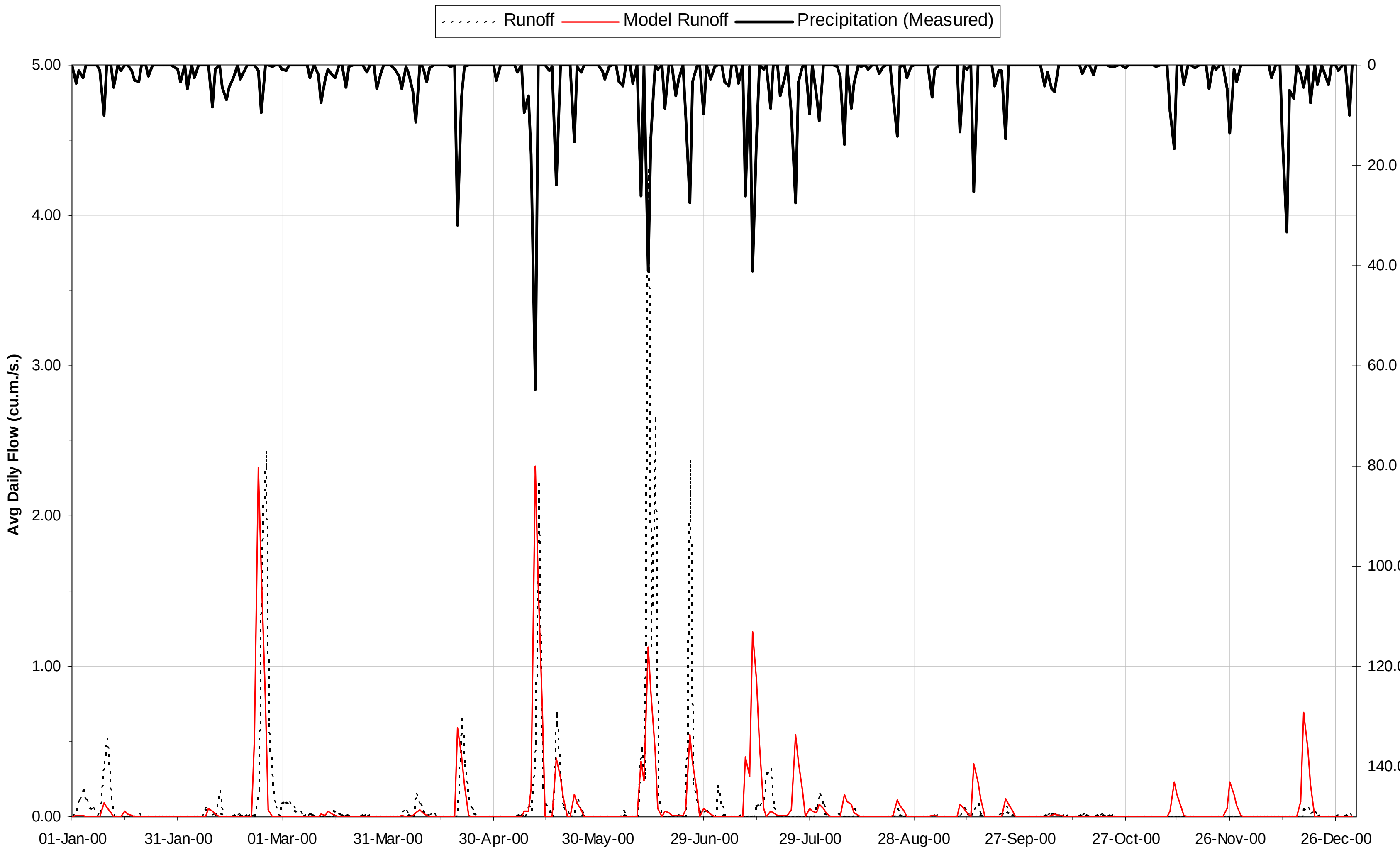
02HC036


Runoff
Model Runoff
Precipitation (Measured)
Avg Daily Flow (cu.m./s.)
5.00
4.00
3.00
2.00
1.00
0.00
0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
01-Jan-98
31-Jan-98
02-Mar-98
01-Apr-98
01-May-98
31-May-98
30-Jun-98
30-Jul-98
29-Aug-98
28-Sep-98
28-Oct-98
27-Nov-98
27-Dec-98

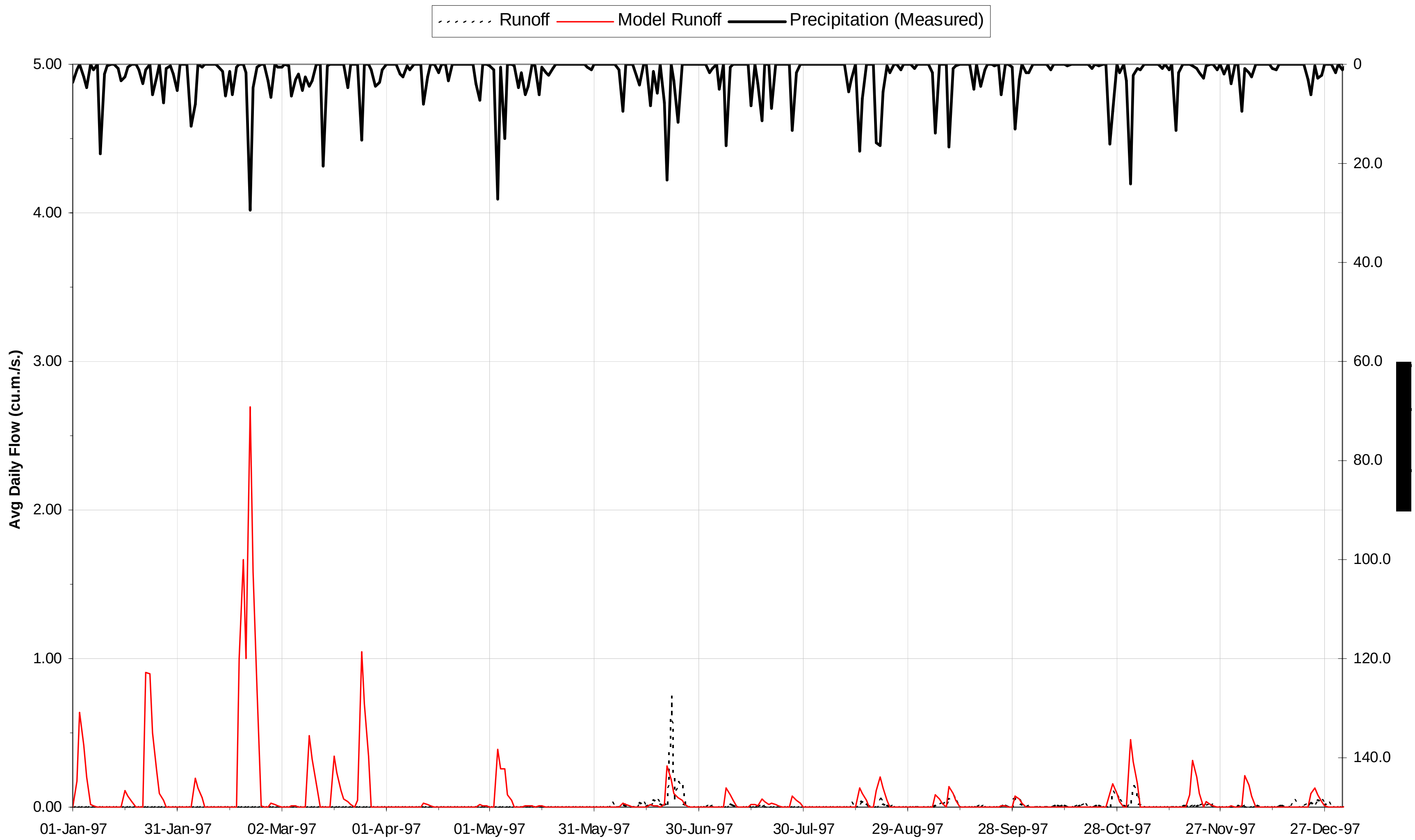
02HC036


Runoff
Model Runoff
Precipitation (Measured)
Avg Daily Flow (cu.m./s.)
5.00
4.00
3.00
2.00
1.00
0.00
0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
01-Jan-99
31-Jan-99
02-Mar-99
01-Apr-99
01-May-99
31-May-99
30-Jun-99
30-Jul-99
29-Aug-99
28-Sep-99
28-Oct-99
27-Nov-99
27-Dec-99

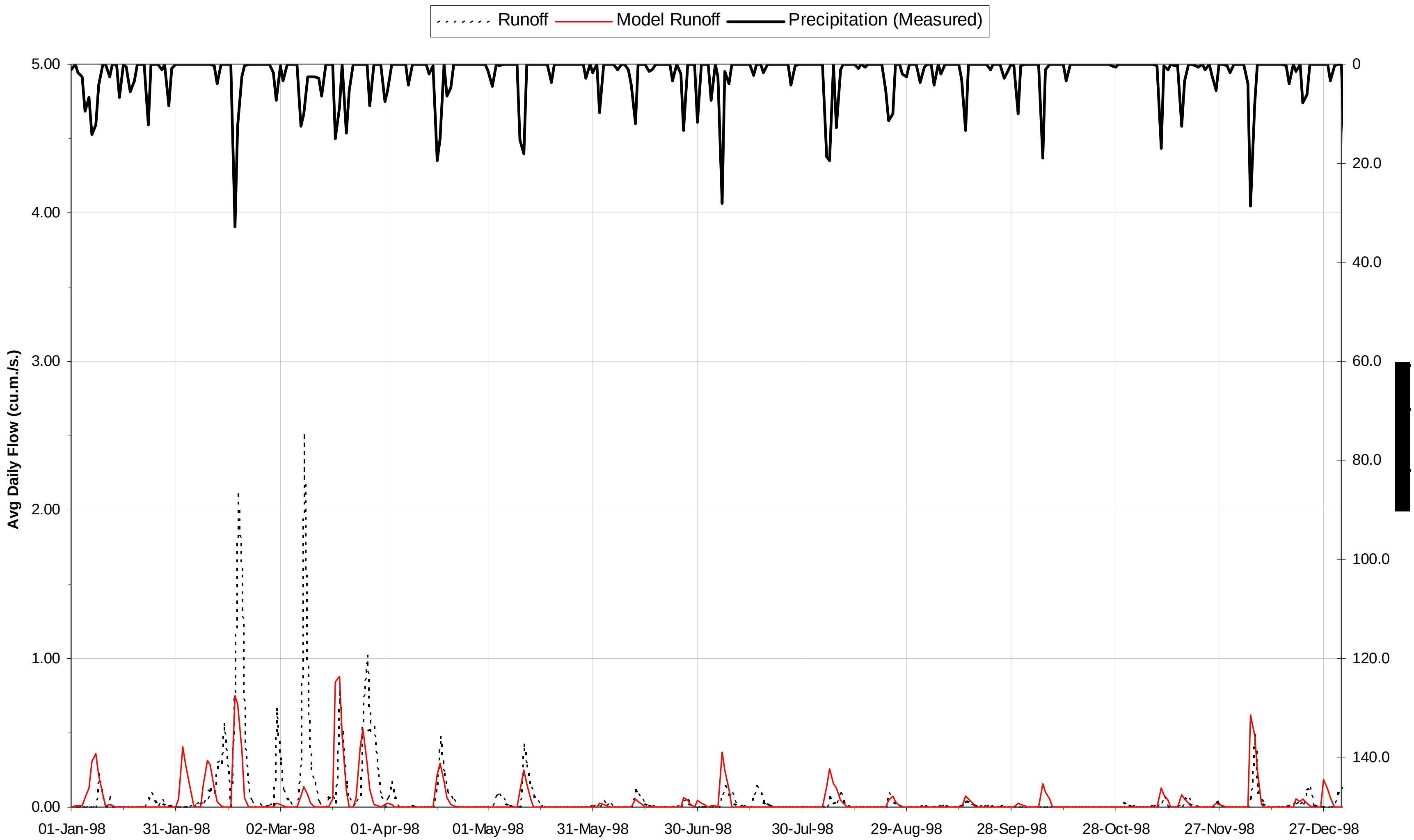
02HC036


Runoff
Model Runoff
Precipitation (Measured)
Avg Daily Flow (cu.m./s.)
5.00
4.00
3.00
2.00
1.00
0.00
0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
01-Jan-00
31-Jan-00
01-Mar-00
31-Mar-00
30-Apr-00
30-May-00
29-Jun-00
29-Jul-00
28-Aug-00
27-Sep-00
27-Oct-00
26-Nov-00
26-Dec-00

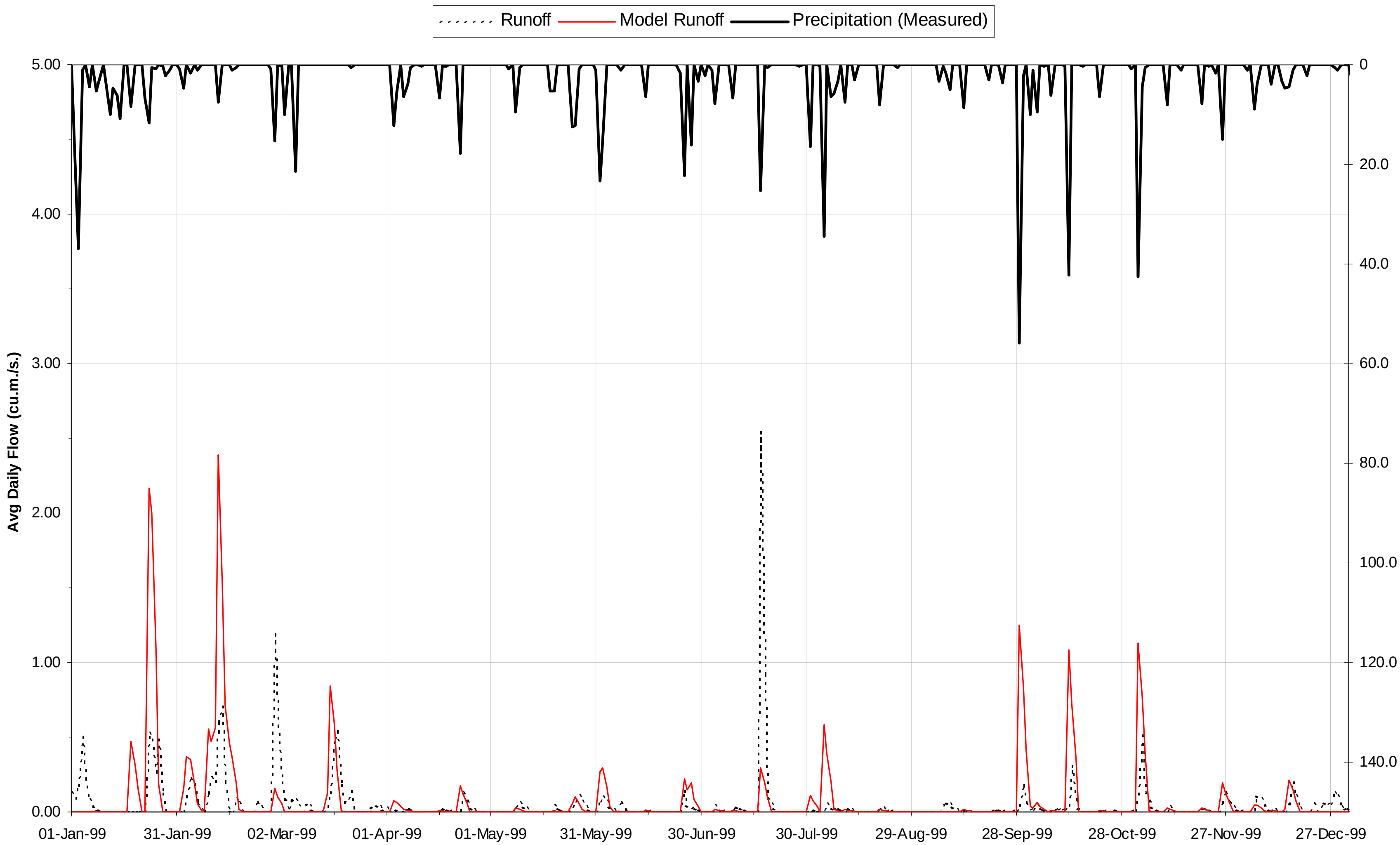
02HC037


Runoff
Model Runoff
Precipitation (Measured)
Avg Daily Flow (cu.m./s.)
5.00
4.00
3.00
2.00
1.00
0.00
0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
01-Jan-97
31-Jan-97
02-Mar-97
01-Apr-97
01-May-97
31-May-97
30-Jun-97
30-Jul-97
29-Aug-97
28-Sep-97
28-Oct-97
27-Nov-97
27-Dec-97

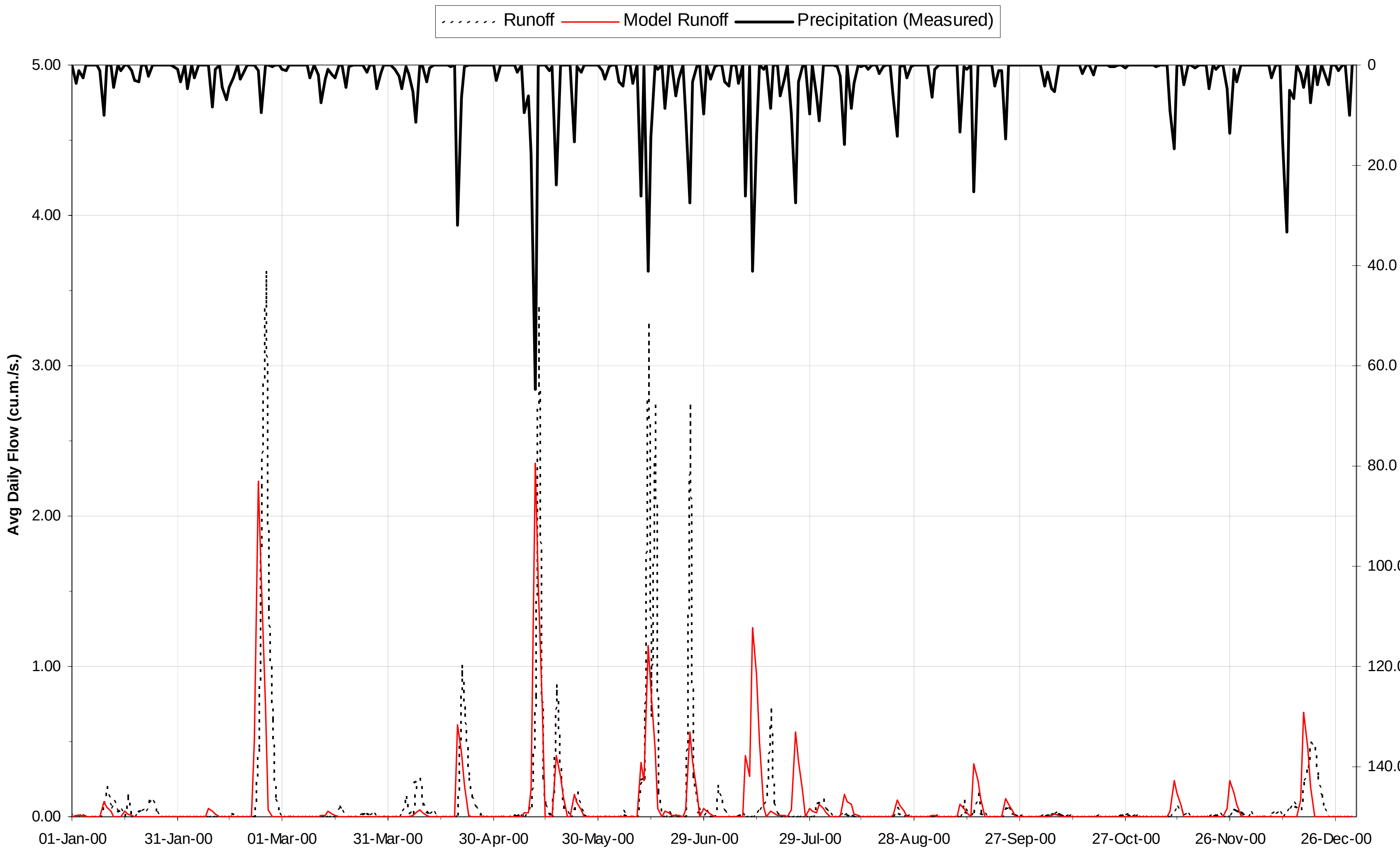
02HC037


Runoff
Model Runoff
Precipitation (Measured)
Avg Daily Flow (cu.m./s.)
5.00
4.00
3.00
2.00
1.00
0.00
0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
01-Jan-98
31-Jan-98
02-Mar-98
01-Apr-98
01-May-98
31-May-98
30-Jun-98
30-Jul-98
29-Aug-98
28-Sep-98
28-Oct-98
27-Nov-98
27-Dec-98

02HC037


Runoff
Model Runoff
Precipitation (Measured)
Avg Daily Flow (cu.m./s.)
5.00
4.00
3.00
2.00
1.00
0.00
0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
01-Jan-99
31-Jan-99
02-Mar-99
01-Apr-99
01-May-99
31-May-99
30-Jun-99
30-Jul-99
29-Aug-99
28-Sep-99
28-Oct-99
27-Nov-99
27-Dec-99

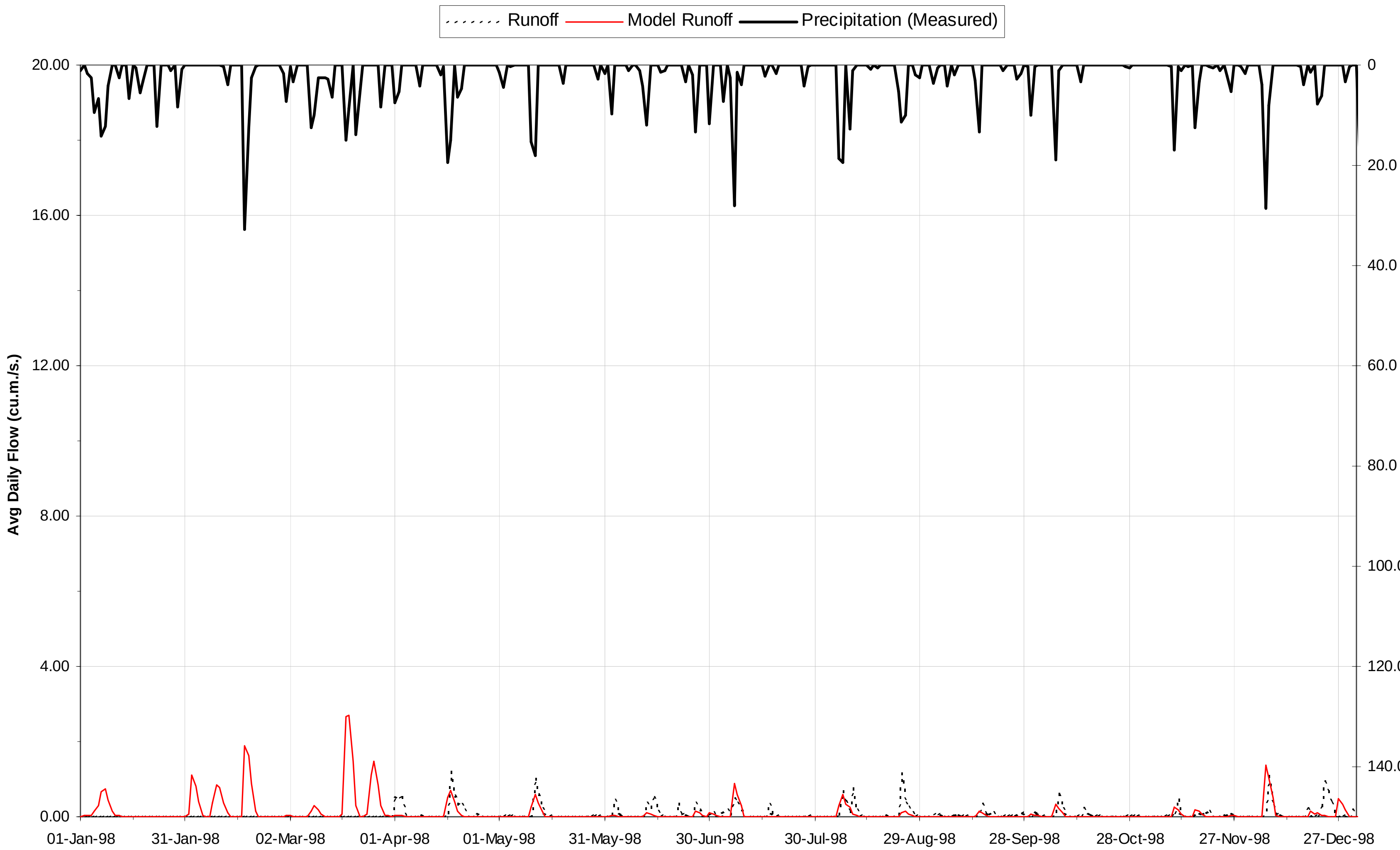
02HC037


Runoff
Model Runoff
Precipitation (Measured)
Avg Daily Flow (cu.m./s.)
5.00
4.00
3.00
2.00
1.00
0.00
0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
01-Jan-00
31-Jan-00
01-Mar-00
31-Mar-00
30-Apr-00
30-May-00
29-Jun-00
29-Jul-00
28-Aug-00
27-Sep-00
27-Oct-00
26-Nov-00
26-Dec-00

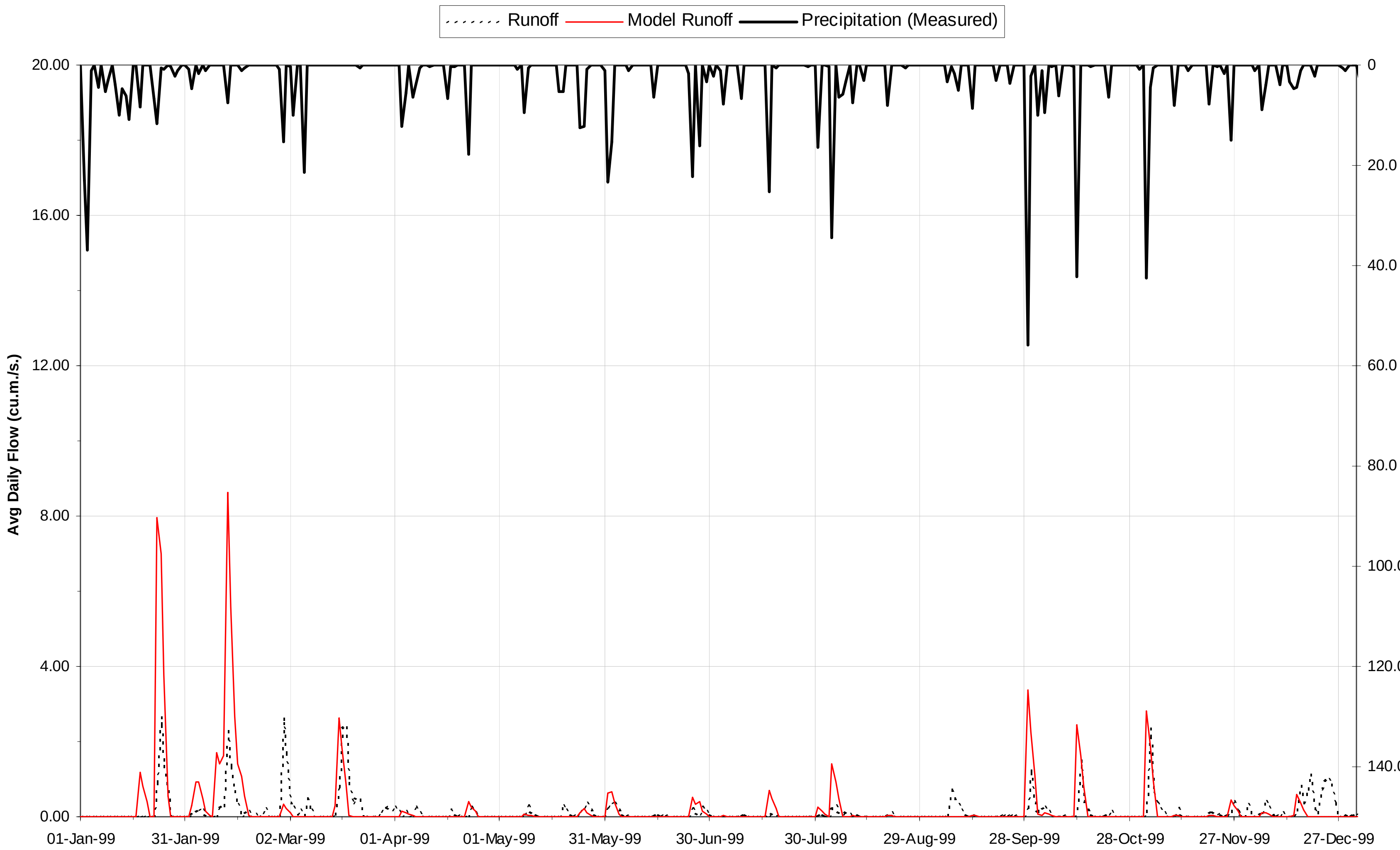
02HC038


Runoff
Model Runoff
Precipitation (Measured)
Avg Daily Flow (cu.m./s.)
20.00
16.00
12.00
8.00
4.00
0.00
0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
01-Jan-97
31-Jan-97
02-Mar-97
01-Apr-97
01-May-97
31-May-97
30-Jun-97
30-Jul-97
29-Aug-97
28-Sep-97
28-Oct-97
27-Nov-97
27-Dec-97

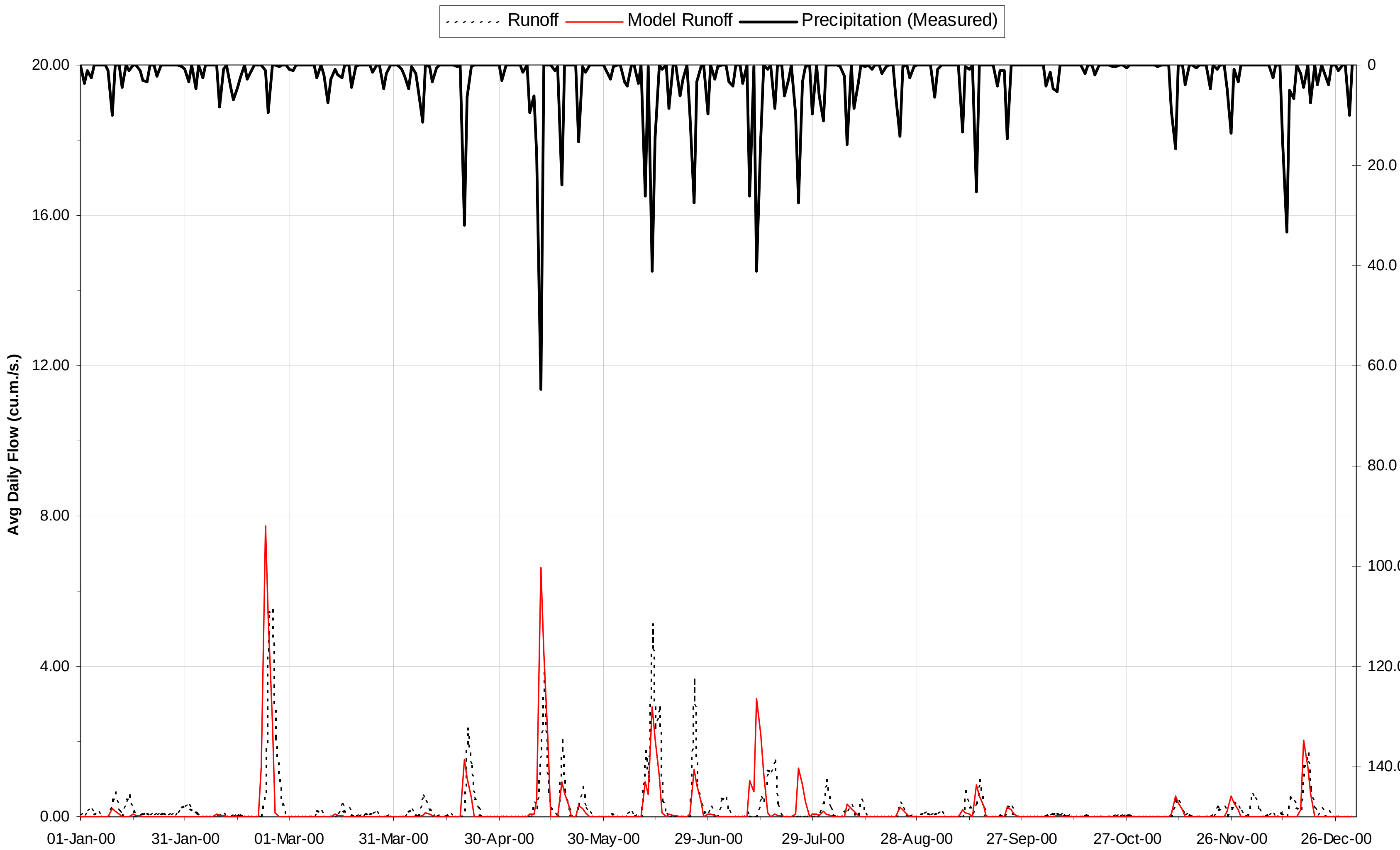
02HC038


Runoff
Model Runoff
Precipitation (Measured)
Avg Daily Flow (cu.m./s.)
20.00
16.00
12.00
8.00
4.00
0.00
0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
01-Jan-98
31-Jan-98
02-Mar-98
01-Apr-98
01-May-98
31-May-98
30-Jun-98
30-Jul-98
29-Aug-98
28-Sep-98
28-Oct-98
27-Nov-98
27-Dec-98

02HC038


Runoff
Model Runoff
Precipitation (Measured)
Avg Daily Flow (cu.m./s.)
20.00
16.00
12.00
8.00
4.00
0.00
0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
01-Jan-99
31-Jan-99
02-Mar-99
01-Apr-99
01-May-99
31-May-99
30-Jun-99
30-Jul-99
29-Aug-99
28-Sep-99
28-Oct-99
27-Nov-99
27-Dec-99

02HC038


Runoff
Model Runoff
Precipitation (Measured)
Avg Daily Flow (cu.m./s.)
20.00
16.00
12.00
8.00
4.00
0.00
0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
01-Jan-00
31-Jan-00
01-Mar-00
31-Mar-00
30-Apr-00
30-May-00
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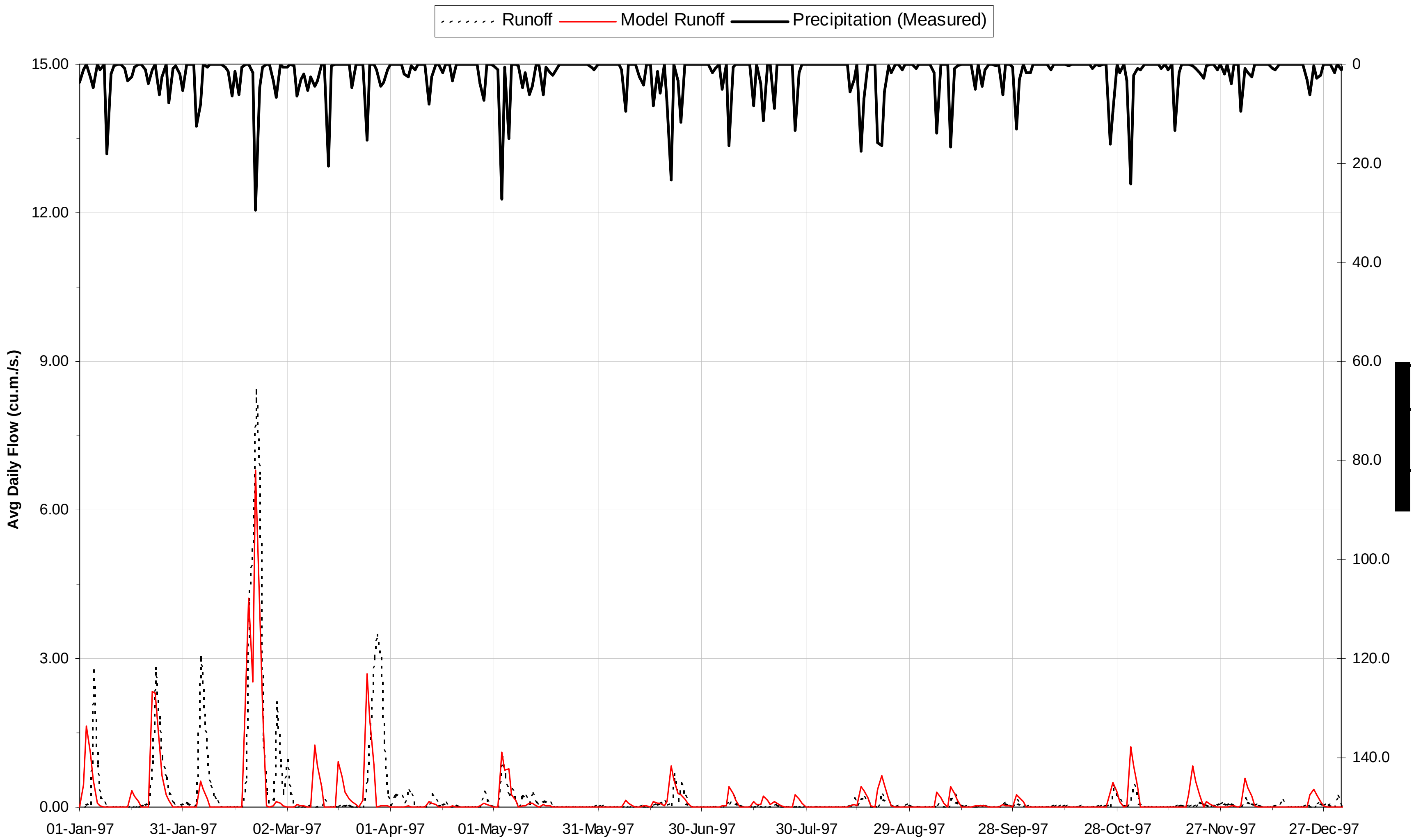
29-Jul-00
28-Aug-00
27-Sep-00
27-Oct-00
26-Nov-00
26-Dec-00

02HC039


Runoff
Model Runoff
Precipitation (Measured)
Avg Daily Flow (cu.m./s.)
15.00
12.00
9.00
6.00
3.00
0.00
0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
01-Jan-97
31-Jan-97
02-Mar-97
01-Apr-97
01-May-97
31-May-97
30-Jun-97
30-Jul-97
29-Aug-97
28-Sep-97
28-Oct-97
27-Nov-97
27-Dec-97

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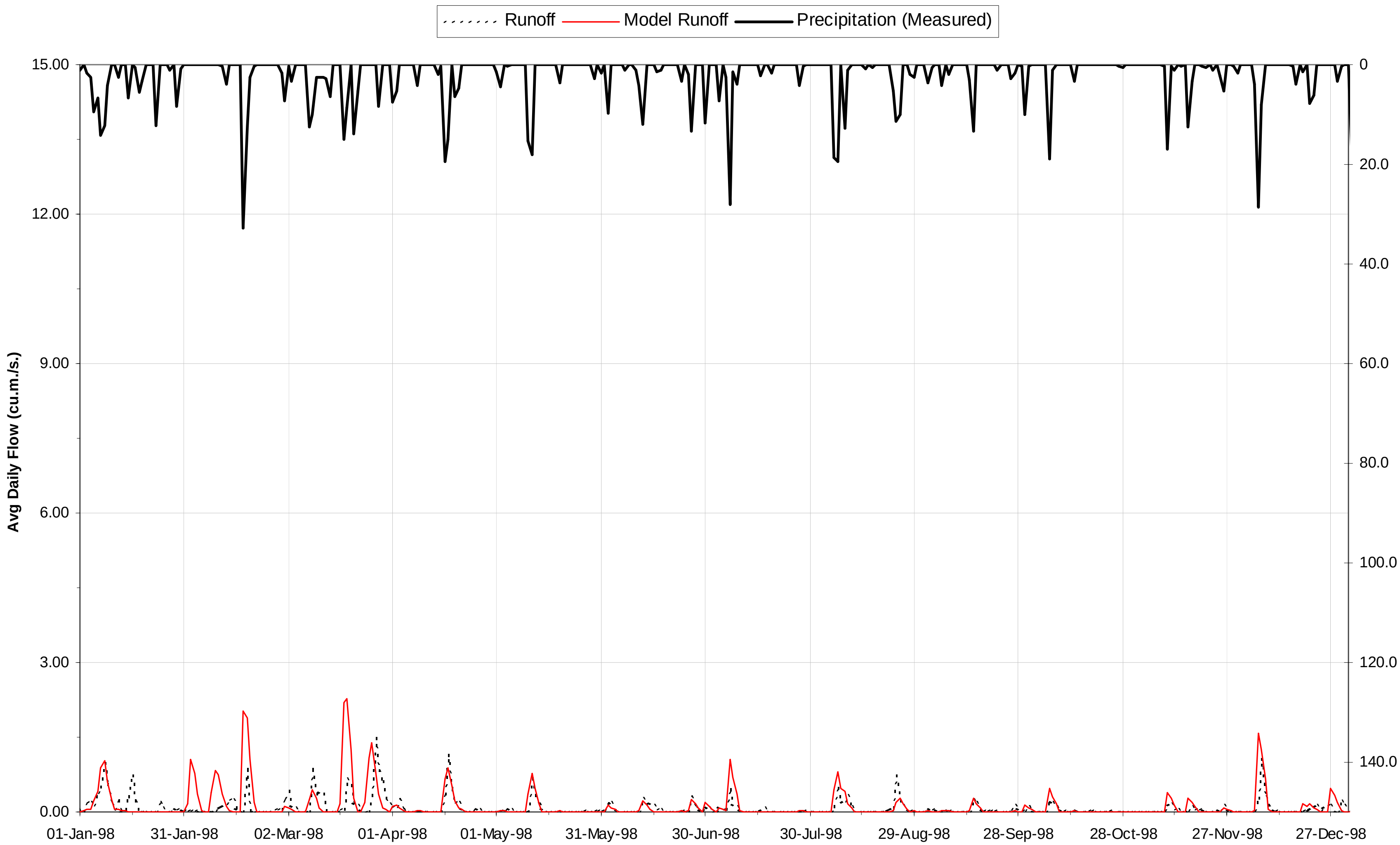
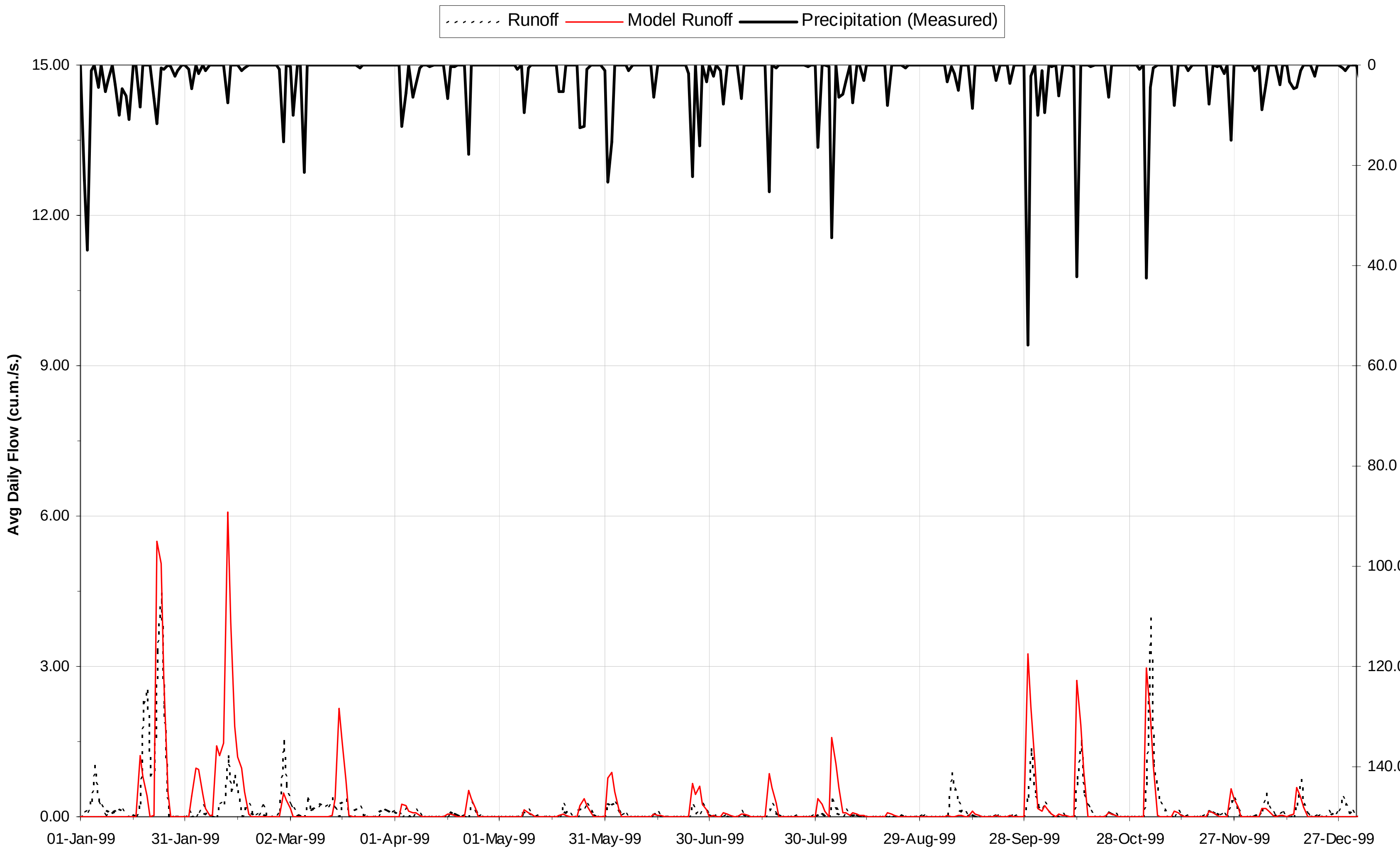
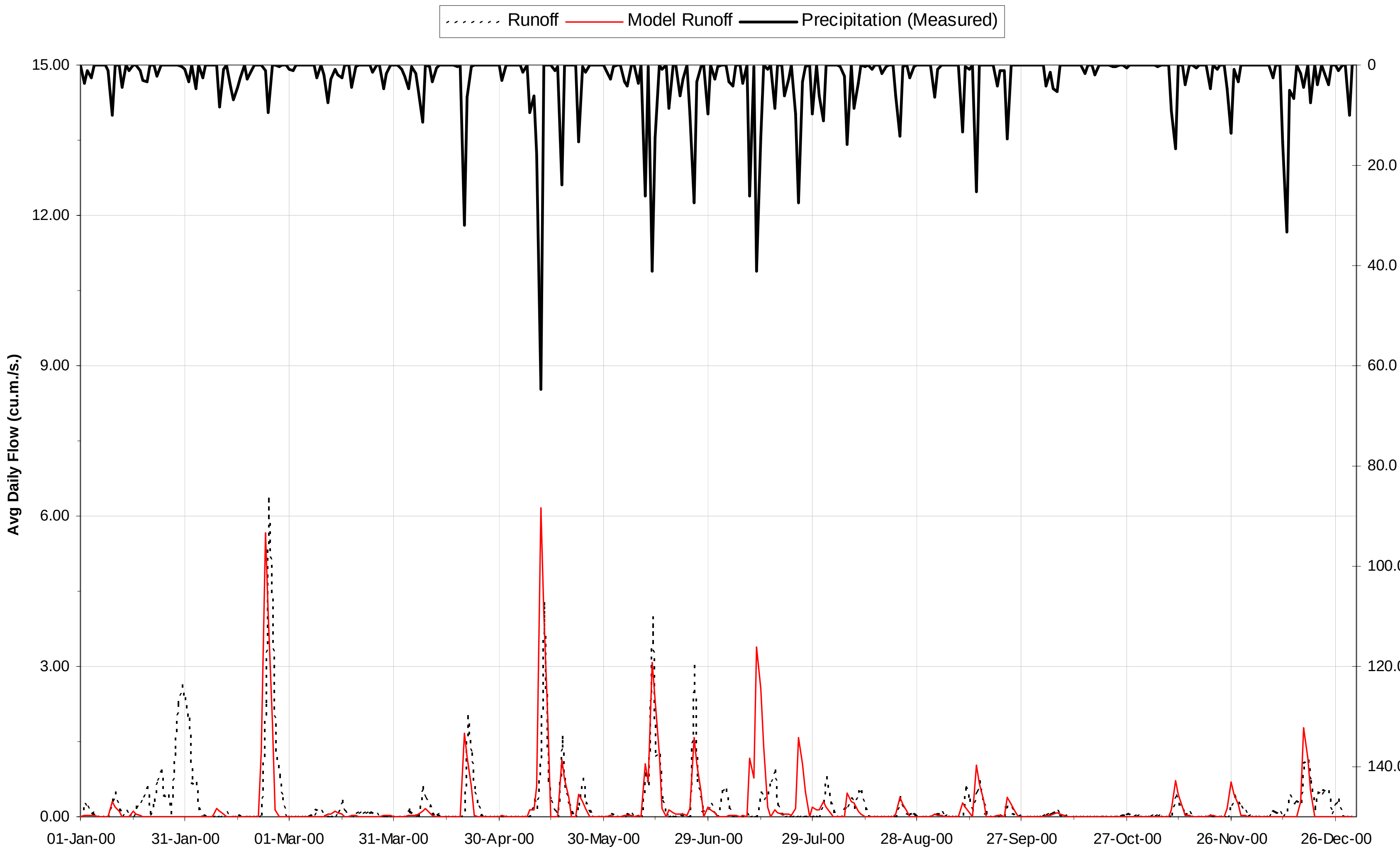

Runoff
Model Runoff
Precipitation (Measured)
Avg Daily Flow (cu.m./s.)
15.00
12.00
9.00
6.00
3.00
0.00
0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
01-Jan-98
31-Jan-98
02-Mar-98
01-Apr-98
01-May-98
31-May-98
30-Jun-98
30-Jul-98
29-Aug-98
28-Sep-98
28-Oct-98
27-Nov-98
27-Dec-98

02HC039


Runoff
Model Runoff
Precipitation (Measured)
Avg Daily Flow (cu.m./s.)
15.00
12.00
9.00
6.00
3.00
0.00
0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
01-Jan-99
31-Jan-99
02-Mar-99
01-Apr-99
01-May-99
31-May-99
30-Jun-99
30-Jul-99
29-Aug-99
28-Sep-99
28-Oct-99
27-Nov-99
27-Dec-99

02HC039


Runoff
Model Runoff
Precipitation (Measured)
Avg Daily Flow (cu.m./s.)
15.00
12.00
9.00
6.00
3.00
0.00
0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
01-Jan-00
31-Jan-00
01-Mar-00
31-Mar-00
30-Apr-00
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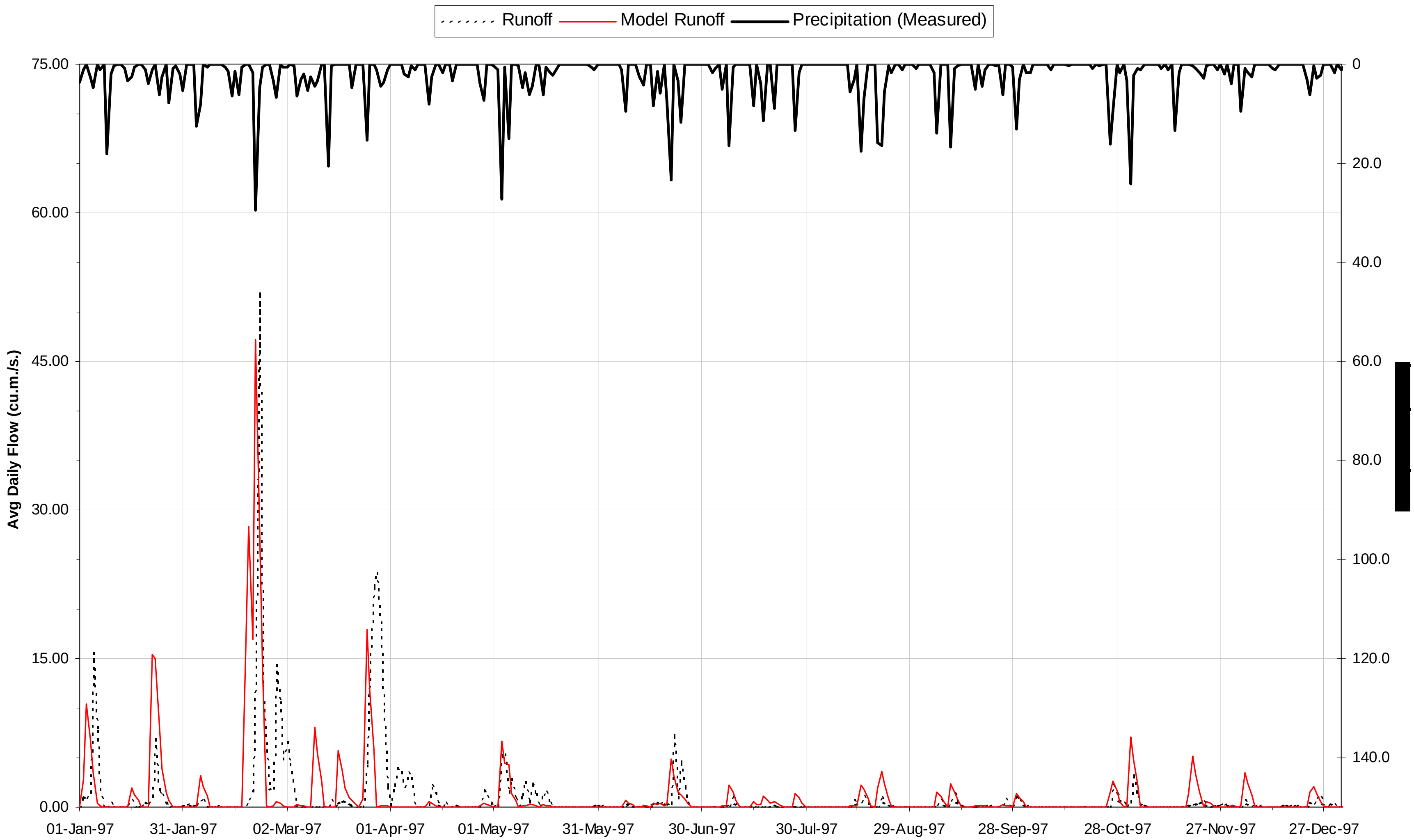
26-Dec-00

02HC049


Runoff
Model Runoff
Precipitation (Measured)
Avg Daily Flow (cu.m./s.)
75.00
60.00
45.00
30.00
15.00
0.00
0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
01-Jan-97
31-Jan-97
02-Mar-97
01-Apr-97
01-May-97
31-May-97
30-Jun-97
30-Jul-97
29-Aug-97
28-Sep-97
28-Oct-97
27-Nov-97
27-Dec-97

Appendix D: Climate Normals Comparison

Annual Precipitation and Computed Rain and Snow in Long-term Water Balance Analysis

Year	Days in Record	Precipitation [mm]	Rain [mm]	Snow [mm]
1986	223	833	784	48
1987	365	823	697	127
1988	366	676	570	107
1989	365	776	643	133
1990	365	921	765	156
1991	365	752	619	133
1992	366	1065	935	130
1993	365	799	677	122
1994	365	754	580	174
1995	365	925	785	140
1996	366	1034	909	125
1997	365	762	567	194
1998	365	734	627	107
1999	365	805	650	155
2000	366	984	803	181
Averages		**844**	**702**	**142**

TORONTO, Ontario
43°40'-N 79°40'-W
112 m
1840 to 1990

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rainfall (mm)	22.7	25.2	41	58.1	67.8	67	71	82.5	76.2	62.7	70.2	44.8	689.3
Snowfall (cm)	35.5	28.6	22.7	7.3	0.1	0	0	0	0	0.5	6.1	34.1	135
Precipitation (mm)	55.2	52.6	65.2	65.4	68	67	71	82.5	76.2	63.3	76.1	76.5	818.9

TORONTO PEARSON INT'L A, Ontario
43°40'-N 79°40'-W
173 m
1937 to 1990

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rainfall (mm)	18.5	20.8	35.1	56	65.8	68.9	76.6	84.2	74.2	62	64.3	38.3	664.7
Snowfall (cm)	32.3	25.9	19.9	7.3	0.1	0	0	0	0	1.1	6.4	31.1	124.2
Precipitation (mm)	45.6	45.5	56.9	64	66	68.9	76.6	84.2	74.2	63	70.3	65.5	780.8

TORONTO MET RES STN, Ontario
43°48'-N 79°48'-W
194 m
1965 to 1988

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rainfall (mm)	18.5	22.3	40.5	57.1	65.9	72.7	74.2	85.7	78.1	61.8	64.8	40.4	682
Snowfall (cm)	32.2	23.8	19.9	6.5	0	0	0	0	0	1.3	8.2	35.8	127.8
Precipitation (mm)	50.6	45.7	61.8	63.6	65.9	72.7	74.2	85.7	78.1	63.1	73	76	810.6

TORONTO ISLAND A, Ontario
43°38'-N 79°38'-W
77 m
1957 to 1990

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rainfall (mm)	22.5	25.5	40.2	57	66.8	68	68.5	79.9	75.5	60.3	66.6	44.8	675.5
Snowfall (cm)	29.3	24.7	19.1	5.8	0	0	0	0	0	0.2	4.8	27.3	111.2
Precipitation (mm)	51.3	49.5	59.7	62.8	66.8	68	68.5	79.9	75.5	60.5	71.2	73.2	786.8

ALBION, Ontario
43°56'-N 79°56'-W
274 m
1956 to 1990

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rainfall (mm)	15.6	18.3	33.4	55.2	68.6	71.4	77.2	85.9	75.7	67.2	62.3	30.3	661
Snowfall (cm)	35.6	28.1	26.7	9	0.4	0	0	0	0	3.2	11.7	37.2	151.9
Precipitation (mm)	51.2	47.5	59.4	64.2	69	71.4	77.2	85.9	75.7	70.5	74.2	67.5	813.8

HAMILTON A, Ontario
43°10'-N 79°10'-W
237 m
1959 to 1990

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rainfall (mm)	22.2	24.6	50.5	66.5	70.1	78.4	81	84.7	83.5	65.8	69.6	46.4	743.3
Snowfall (cm)	41.8	32	22.3	7.3	0.5	0	0	0	0	1.1	9.8	37.6	152.4
Precipitation (mm)	61.3	53.5	73.7	74.3	70.7	78.4	81	84.7	83.5	66.3	80.2	82.8	890.4

OTTAWA INT'L A, Ontario
45°19'-N 75°19'-W
116 m
1938 to 1990

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rainfall (mm)	15.3	16.4	32	58	74.8	76.9	88.1	92	82.9	70.3	62.5	32.6	701.8
Snowfall (cm)	49.6	45.2	32.3	9.1	1.2	0	0	0	0	4.1	24.2	55.8	221.5
Precipitation (mm)	58	58.6	64.8	69	76.4	76.9	88.1	92	82.9	74.8	86.4	82.5	910.5

PETERBOROUGH A, Ontario
44°14'-N 78°14'-W
191 m
1969 to 1990

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rainfall (mm)	16	22.1	40.7	56.2	70.4	71.1	69.4	81.1	73.8	68.4	62.2	33.9	665.5
Snowfall (cm)	39.3	33.4	22.1	7.8	0.1	0	0	0	0	1.8	14.3	41.5	160.3
Precipitation (mm)	49.5	55.1	66.3	66.3	70.8	71.1	69.4	81.1	74.8	70.8	77.3	76.2	828.8

RICHMOND HILL, Ontario
43°53'-N 79°53'-W
233 m
1959 to 1990

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rainfall (mm)	20.1	22.5	37.5	56.1	70.6	76.5	71.6	92.2	74.1	64.9	66	37	689
Snowfall (cm)	37.5	31	25.1	9.9	0.3	0	0	0	0	2.2	12.5	39.7	158.1
Precipitation (mm)	57.5	53.9	62.5	66	70.9	76.5	71.6	92.2	74.1	67	78.5	76.7	847.4

WATERLOO WELLINGTON A, Ontario
43°27'-N 80°27'-W
314 m
1966 to 1990

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rainfall (mm)	20.2	26.5	49.2	64.4	75.8	79.5	90.4	93.3	89.6	69.8	71.8	43.1	773.6
Snowfall (cm)	39.9	33.4	21.9	8.1	0.4	0	0	0	0	0.6	12.7	41	158
Precipitation (mm)	54.3	55.6	72.7	72.6	76.3	79.5	90.4	93.3	89.6	70.4	83.1	79.2	917

Appendix E: Water Balance Results Tables

Watershed Physical Input Parameters

Parameter	Description [Units]
AREA	Basin area [Hectares]
TIMP	Basin imperviousness [Fraction]
XIMP	Directly connected imperviousness [Fraction]
IA_imp	Depression storage/Interception Storage over impervious areas [millimetres]
IA_per	Depression storage/Interception Storage over pervious areas [millimetres]
CN*	Modified Soil Conservation Service (SCS) Curve Number [no units]
VEG_K3	Watershed vegetation cover function [mm]
K	Saturated hydraulic conductivity [mm/day]

Notes: Z_IMP = 0.2
CN* = Starting value prior to calibration.
K = Starting value prior to calibration.

Summary Input Parameters

Scenario	Basin	Area, A [ha]	TIMP [Frac]	XIMP [Frac]	IA_imp [mm]	IA_per [mm]	CN [#]	Hyd. Cond, K [mm/d]	VEG_K3 [mm]
Existing	1	281.55	0.022	0.000	0.8	3.0	79.5	64.79	6.09
Existing	2	1085.19	0.091	0.071	0.8	3.0	83.7	59.95	5.86
Existing	3	1897.99	0.023	0.017	0.8	3.0	78.1	97.55	6.14
Existing	4	681.59	0.000	0.000	0.8	3.0	80.7	54.99	6.24
Existing	5	920.64	0.000	0.000	0.8	4.0	59.8	313.26	6.66
Existing	6	643.98	0.000	0.000	0.8	4.0	80.0	60.48	6.22
Existing	7	1082.14	0.000	0.000	0.8	4.0	71.4	180.38	6.33
Existing	8	516.51	0.000	0.000	0.8	4.0	75.4	166.26	6.21
Existing	9	1073.12	0.000	0.000	0.8	4.0	79.5	54.73	6.05
Existing	10	262.69	0.000	0.000	0.8	4.0	73.8	86.40	6.04
Existing	11	2068.58	0.004	0.003	0.8	3.0	80.4	64.10	6.15
Existing	11.1	425.03	0.000	0.000	0.8	3.0	83.9	40.31	6.05
Existing	12	895.05	0.053	0.043	0.8	3.0	75.3	156.66	6.39
Existing	13	1736.50	0.016	0.012	0.8	3.0	78.6	108.97	6.20
Existing	14	622.51	0.023	0.018	0.8	3.0	78.1	103.95	6.27
Existing	15	1702.66	0.000	0.000	0.8	4.0	61.7	493.98	6.42
Existing	16	2625.02	0.000	0.000	0.8	3.0	72.3	284.89	6.90
Existing	17	707.88	0.002	0.001	0.8	3.0	72.5	173.38	6.57
Existing	18	506.83	0.000	0.000	0.8	3.0	76.8	135.35	6.51
Existing	19	618.84	0.021	0.016	0.8	3.0	75.0	154.22	6.54
Existing	20	1547.47	0.007	0.005	0.8	3.0	78.1	123.56	6.13
Existing	21	509.20	0.134	0.101	0.8	3.0	86.4	140.40	5.88
Existing	21.1	327.44	0.000	0.000	0.8	3.0	71.1	271.75	6.80
Existing	22	632.59	0.000	0.000	0.8	3.0	85.3	70.84	6.21
Existing	23	803.91	0.008	0.006	0.8	3.0	80.9	223.21	6.57
Existing	24	713.77	0.000	0.000	0.8	3.0	78.9	64.80	6.13
Existing	25	590.88	0.022	0.017	0.8	3.0	74.5	212.43	6.47
Existing	26	522.68	0.337	0.298	0.8	3.0	90.6	120.32	5.55
Existing	27	1698.16	0.230	0.172	0.8	4.0	79.2	256.03	5.84
Existing	28	600.84	0.230	0.229	0.8	4.0	74.8	56.02	5.82
		28301							

Summary Input Parameters

Scenario	Basin	Area, A [ha]	TIMP [Frac]	XIMP [Frac]	IA_imp [mm]	IA_per [mm]	CN [#]	Hyd. Cond, K [mm/d]	VEG_K3 [mm]
Future	1	281.55	0.022	0.000	0.8	3.0	79.5	64.79	6.09
Future	2	1085.19	0.182	0.139	0.8	3.0	86.9	59.95	5.64
Future	3	1897.99	0.034	0.027	0.8	3.0	78.7	97.55	6.10
Future	4	681.59	0.000	0.000	0.8	3.0	80.7	54.99	6.24
Future	5	920.64	0.000	0.000	0.8	4.0	59.8	313.26	6.66
Future	6	643.98	0.000	0.000	0.8	4.0	80.0	60.48	6.22
Future	7	1082.14	0.000	0.000	0.8	4.0	71.4	180.38	6.33
Future	8	516.51	0.000	0.000	0.8	4.0	75.4	166.26	6.21
Future	9	1073.12	0.000	0.000	0.8	4.0	79.5	54.73	6.05
Future	10	262.69	0.000	0.000	0.8	4.0	73.8	86.40	6.04
Future	11	2068.58	0.025	0.019	0.8	3.0	80.6	64.10	6.04
Future	11.1	425.03	0.000	0.000	0.8	3.0	83.9	40.31	6.05
Future	12	895.05	0.192	0.145	0.8	3.0	80.7	156.66	5.95
Future	13	1736.50	0.016	0.012	0.8	3.0	78.6	108.97	6.20
Future	14	622.51	0.023	0.018	0.8	3.0	78.1	103.95	6.27
Future	15	1702.66	0.000	0.000	0.8	4.0	61.7	493.98	6.42
Future	16	2625.02	0.000	0.000	0.8	3.0	72.3	284.89	6.90
Future	17	707.88	0.002	0.001	0.8	3.0	72.5	173.38	6.57
Future	18	506.83	0.000	0.000	0.8	3.0	76.8	135.35	6.51
Future	19	618.84	0.021	0.016	0.8	3.0	75.0	154.22	6.54
Future	20	1547.47	0.007	0.005	0.8	3.0	78.1	123.56	6.13
Future	21	509.20	0.231	0.174	0.8	3.0	88.5	140.40	5.58
Future	21.1	327.44	0.007	0.005	0.8	3.0	71.4	271.75	6.78
Future	22	632.59	0.028	0.021	0.8	3.0	86.0	70.84	6.13
Future	23	803.91	0.222	0.167	0.8	3.0	90.1	223.21	5.78
Future	24	713.77	0.119	0.090	0.8	3.0	82.0	64.80	5.77
Future	25	590.88	0.255	0.191	0.8	3.0	84.3	212.43	5.74
Future	26	522.68	0.337	0.283	0.8	3.0	90.0	120.32	5.43
Future	27	1698.16	0.271	0.212	0.8	4.0	80.3	256.03	5.57
Future	28	600.84	0.416	0.389	0.8	4.0	82.1	56.02	5.61
		28301							

Summary Input Parameters

Scenario	Basin	Area, A [ha]	TIMP [Frac]	XIMP [Frac]	IA_imp [mm]	IA_per [mm]	CN [#]	Hyd. Cond, K [mm/d]	VEG_K3 [mm]
Future + Nat Heritage	1	281.55	0.022	0.000	0.8	3.0	76.4	64.79	6.55
Future + Nat Heritage	2	1085.19	0.182	0.139	0.8	3.0	84.9	59.95	5.83
Future + Nat Heritage	3	1897.99	0.034	0.027	0.8	3.0	76.6	97.55	6.47
Future + Nat Heritage	4	681.59	0.000	0.000	0.8	3.0	80.5	54.99	6.27
Future + Nat Heritage	5	920.64	0.000	0.000	0.8	4.0	55.0	313.26	7.40
Future + Nat Heritage	6	643.98	0.000	0.000	0.8	4.0	77.4	60.48	6.95
Future + Nat Heritage	7	1082.14	0.000	0.000	0.8	4.0	67.9	180.38	6.83
Future + Nat Heritage	8	516.51	0.000	0.000	0.8	4.0	75.2	166.26	6.25
Future + Nat Heritage	9	1073.12	0.000	0.000	0.8	4.0	79.0	54.73	6.20
Future + Nat Heritage	10	262.69	0.000	0.000	0.8	4.0	73.8	86.40	6.04
Future + Nat Heritage	11	2068.58	0.025	0.019	0.8	3.0	80.1	64.10	6.15
Future + Nat Heritage	11.1	425.03	0.000	0.000	0.8	3.0	83.2	40.31	6.20
Future + Nat Heritage	12	895.05	0.192	0.145	0.8	3.0	80.7	156.66	5.91
Future + Nat Heritage	13	1736.50	0.016	0.012	0.8	3.0	73.1	108.97	6.78
Future + Nat Heritage	14	622.51	0.023	0.018	0.8	3.0	75.7	103.95	6.60
Future + Nat Heritage	15	1702.66	0.000	0.000	0.8	4.0	52.1	493.98	7.35
Future + Nat Heritage	16	2625.02	0.000	0.000	0.8	3.0	68.8	284.89	7.43
Future + Nat Heritage	17	707.88	0.002	0.001	0.8	3.0	67.5	173.38	7.17
Future + Nat Heritage	18	506.83	0.000	0.000	0.8	3.0	69.9	135.35	7.35
Future + Nat Heritage	19	618.84	0.021	0.016	0.8	3.0	73.4	154.22	6.85
Future + Nat Heritage	20	1547.47	0.007	0.005	0.8	3.0	77.6	123.56	6.35
Future + Nat Heritage	21	509.20	0.231	0.174	0.8	3.0	88.5	140.40	5.57
Future + Nat Heritage	21.1	327.44	0.007	0.005	0.8	3.0	71.6	271.75	7.10
Future + Nat Heritage	22	632.59	0.028	0.021	0.8	3.0	85.7	70.84	6.19
Future + Nat Heritage	23	803.91	0.222	0.167	0.8	3.0	90.1	223.21	5.76
Future + Nat Heritage	24	713.77	0.119	0.090	0.8	3.0	81.8	64.80	5.81
Future + Nat Heritage	25	590.88	0.255	0.191	0.8	3.0	84.3	212.43	5.69
Future + Nat Heritage	26	522.68	0.337	0.283	0.8	3.0	90.0	120.32	5.47
Future + Nat Heritage	27	1698.16	0.271	0.212	0.8	4.0	80.2	256.03	5.61
Future + Nat Heritage	28	600.84	0.416	0.389	0.8	4.0	82.1	56.02	5.65

Summary Output

Scenario	Basin	PRECIP [mm]	RAIN [mm]	SNOW [mm]	RO [mm]	C_{per} [Frac]	C_{imp} [Frac]	C [Frac]	GWI [mm]	ET [mm]	Qout [mm]	Mass Balance (PRECIP-Qout)	
												[mm]	[%]
Existing	1	844	702	142	156	0.17	0.88	0.18	200	483	839	-4.1	-0.38%
Existing	2	844	702	142	219	0.20	0.88	0.26	177	443	839	-4.2	-0.41%
Existing	3	844	702	142	145	0.16	0.88	0.17	208	485	839	-4.6	-0.44%
Existing	4	844	702	142	150	0.18	0.00	0.18	197	492	839	-4.7	-0.46%
Existing	5	844	702	142	60	0.07	0.00	0.07	231	549	839	-4.2	-0.30%
Existing	6	844	702	142	139	0.16	0.00	0.16	185	515	839	-4.7	-0.45%
Existing	7	844	702	142	95	0.11	0.00	0.11	215	530	839	-4.6	-0.42%
Existing	8	844	702	142	108	0.13	0.00	0.13	210	521	839	-4.7	-0.44%
Existing	9	844	702	142	140	0.16	0.00	0.16	184	514	839	-4.7	-0.45%
Existing	10	844	702	142	109	0.13	0.00	0.13	208	522	839	-4.5	-0.41%
Existing	11	844	702	142	149	0.17	0.88	0.18	200	489	839	-4.7	-0.46%
Existing	11.1	844	702	142	177	0.21	0.00	0.21	180	482	839	-4.8	-0.48%
Existing	12	844	702	142	145	0.13	0.88	0.17	214	480	839	-4.5	-0.43%
Existing	13	844	702	142	142	0.16	0.88	0.17	210	488	839	-4.7	-0.45%
Existing	14	844	702	142	143	0.15	0.88	0.17	209	487	839	-4.6	-0.44%
Existing	15	844	702	142	62	0.07	0.00	0.07	237	540	839	-4.4	-0.37%
Existing	16	844	702	142	94	0.11	0.00	0.11	232	513	839	-4.7	-0.44%
Existing	17	844	702	142	102	0.12	0.88	0.12	228	509	839	-4.6	-0.42%
Existing	18	844	702	142	120	0.14	0.00	0.14	217	502	839	-4.7	-0.45%
Existing	19	844	702	142	125	0.13	0.88	0.15	217	497	839	-4.6	-0.43%
Existing	20	844	702	142	132	0.15	0.88	0.15	217	490	839	-4.7	-0.45%
Existing	21	844	702	142	247	0.20	0.88	0.29	175	418	840	-3.9	-0.38%
Existing	21.1	844	702	142	90	0.11	0.00	0.11	236	513	839	-4.6	-0.42%
Existing	22	844	702	142	175	0.21	0.00	0.21	185	478	839	-4.9	-0.50%
Existing	23	844	702	142	135	0.15	0.88	0.16	216	488	839	-4.8	-0.48%
Existing	24	844	702	142	140	0.16	0.00	0.16	206	494	839	-4.7	-0.45%
Existing	25	844	702	142	119	0.12	0.88	0.14	226	494	839	-4.6	-0.44%
Existing	26	844	702	142	392	0.26	0.88	0.46	120	328	840	-3.5	-0.35%
Existing	27	844	702	142	257	0.14	0.88	0.30	171	412	840	-3.6	-0.34%
Existing	28	844	702	142	258	0.13	0.88	0.30	161	420	839	-4.6	-0.43%
					145			**0.17**	**206**	**489**			

Summary Output

Scenario	Basin	PRECIP [mm]	RAIN [mm]	SNOW [mm]	RO [mm]	C_{per} [Frac]	C_{imp} [Frac]	C [Frac]	GWI [mm]	ET [mm]	Qout [mm]	Mass Balance (PRECIP-Qout)	
												[mm]	[%]
Future	1	844	702	142	156	0.17	0.88	0.18	200	483	839	-4.1	-0.38%
Future	2	844	702	142	290	0.23	0.88	0.34	151	398	840	-3.4	-0.32%
Future	3	844	702	142	155	0.16	0.88	0.18	205	479	839	-4.6	-0.44%
Future	4	844	702	142	150	0.18	0.00	0.18	197	492	839	-4.7	-0.46%
Future	5	844	702	142	60	0.07	0.00	0.07	231	549	839	-4.2	-0.30%
Future	6	844	702	142	139	0.16	0.00	0.16	185	515	839	-4.7	-0.45%
Future	7	844	702	142	95	0.11	0.00	0.11	215	530	839	-4.6	-0.42%
Future	8	844	702	142	108	0.13	0.00	0.13	210	521	839	-4.7	-0.44%
Future	9	844	702	142	140	0.16	0.00	0.16	184	514	839	-4.7	-0.45%
Future	10	844	702	142	109	0.13	0.00	0.13	208	522	839	-4.5	-0.41%
Future	11	844	702	142	163	0.17	0.88	0.19	198	479	839	-4.6	-0.44%
Future	11.1	844	702	142	177	0.21	0.00	0.21	180	482	839	-4.8	-0.48%
Future	12	844	702	142	250	0.16	0.88	0.30	180	410	840	-3.7	-0.35%
Future	13	844	702	142	142	0.16	0.88	0.17	210	488	839	-4.7	-0.45%
Future	14	844	702	142	143	0.15	0.88	0.17	209	487	839	-4.6	-0.44%
Future	15	844	702	142	62	0.07	0.00	0.07	237	540	839	-4.4	-0.37%
Future	16	844	702	142	94	0.11	0.00	0.11	232	513	839	-4.7	-0.44%
Future	17	844	702	142	102	0.12	0.88	0.12	228	509	839	-4.6	-0.42%
Future	18	844	702	142	120	0.14	0.00	0.14	217	502	839	-4.7	-0.45%
Future	19	844	702	142	125	0.13	0.88	0.15	217	497	839	-4.6	-0.43%
Future	20	844	702	142	132	0.15	0.88	0.15	217	490	839	-4.7	-0.45%
Future	21	844	702	142	316	0.23	0.88	0.37	151	373	841	-2.9	-0.27%
Future	21.1	844	702	142	95	0.11	0.88	0.11	235	509	839	-4.6	-0.42%
Future	22	844	702	142	196	0.21	0.88	0.23	179	465	839	-4.7	-0.47%
Future	23	844	702	142	320	0.24	0.88	0.38	150	371	841	-2.9	-0.28%
Future	24	844	702	142	225	0.19	0.88	0.27	179	435	840	-4.0	-0.38%
Future	25	844	702	142	300	0.19	0.88	0.35	165	375	840	-3.1	-0.29%
Future	26	844	702	142	388	0.25	0.88	0.46	124	329	841	-2.9	-0.27%
Future	27	844	702	142	287	0.15	0.88	0.34	163	390	840	-3.5	-0.33%
Future	28	844	702	142	393	0.17	0.88	0.46	115	331	839	-4.2	-0.42%
					170			**0.20**	**197**	**472**			

Summary Output

Scenario	Basin	PRECIP [mm]	RAIN [mm]	SNOW [mm]	RO [mm]	C_{per} [Frac]	C_{imp} [Frac]	C [Frac]	GWI [mm]	ET [mm]	Qout [mm]	Mass Balance (PRECIP-Qout)	
												[mm]	[%]
Future + Nat Heritage	1	844	702	142	141	0.15	0.88	0.17	201	498	839	-4.1	-0.37%
Future + Nat Heritage	2	844	702	142	277	0.21	0.88	0.33	157	406	840	-3.5	-0.33%
Future + Nat Heritage	3	844	702	142	145	0.15	0.88	0.17	204	489	839	-4.5	-0.43%
Future + Nat Heritage	4	844	702	142	149	0.17	0.00	0.17	197	493	839	-4.7	-0.46%
Future + Nat Heritage	5	844	702	142	51	0.06	0.00	0.06	218	571	840	-3.9	-0.20%
Future + Nat Heritage	6	844	702	142	125	0.15	0.00	0.15	181	533	839	-4.6	-0.43%
Future + Nat Heritage	7	844	702	142	84	0.10	0.00	0.10	210	545	839	-4.4	-0.38%
Future + Nat Heritage	8	844	702	142	107	0.13	0.00	0.13	209	522	839	-4.7	-0.44%
Future + Nat Heritage	9	844	702	142	137	0.16	0.00	0.16	183	518	839	-4.7	-0.45%
Future + Nat Heritage	10	844	702	142	109	0.13	0.00	0.13	208	522	839	-4.5	-0.41%
Future + Nat Heritage	11	844	702	142	160	0.17	0.88	0.19	197	482	839	-4.6	-0.44%
Future + Nat Heritage	11.1	844	702	142	172	0.20	0.00	0.20	181	487	839	-4.8	-0.47%
Future + Nat Heritage	12	844	702	142	250	0.16	0.88	0.30	180	409	840	-3.7	-0.35%
Future + Nat Heritage	13	844	702	142	119	0.13	0.88	0.14	212	508	839	-4.5	-0.41%
Future + Nat Heritage	14	844	702	142	133	0.14	0.88	0.16	209	497	839	-4.6	-0.43%
Future + Nat Heritage	15	844	702	142	46	0.05	0.00	0.05	222	572	840	-4.0	-0.20%
Future + Nat Heritage	16	844	702	142	83	0.10	0.00	0.10	228	528	839	-4.5	-0.40%
Future + Nat Heritage	17	844	702	142	87	0.10	0.88	0.10	225	528	839	-4.4	-0.37%
Future + Nat Heritage	18	844	702	142	95	0.11	0.00	0.11	215	529	839	-4.5	-0.39%
Future + Nat Heritage	19	844	702	142	118	0.12	0.88	0.14	216	505	839	-4.5	-0.42%
Future + Nat Heritage	20	844	702	142	129	0.15	0.88	0.15	215	495	839	-4.7	-0.45%
Future + Nat Heritage	21	844	702	142	316	0.23	0.88	0.37	151	373	841	-2.9	-0.27%
Future + Nat Heritage	21.1	844	702	142	95	0.11	0.88	0.11	229	514	839	-4.6	-0.42%
Future + Nat Heritage	22	844	702	142	193	0.21	0.88	0.23	179	466	839	-4.7	-0.47%
Future + Nat Heritage	23	844	702	142	320	0.24	0.88	0.38	150	370	841	-2.9	-0.28%
Future + Nat Heritage	24	844	702	142	224	0.18	0.88	0.26	180	436	840	-4.0	-0.38%
Future + Nat Heritage	25	844	702	142	300	0.19	0.88	0.35	166	375	840	-3.1	-0.29%
Future + Nat Heritage	26	844	702	142	388	0.25	0.88	0.46	124	329	841	-2.9	-0.27%
Future + Nat Heritage	27	844	702	142	287	0.15	0.88	0.34	163	390	840	-3.5	-0.33%
Future + Nat Heritage	28	844	702	142	393	0.17	0.88	0.46	114	332	839	-4.2	-0.42%
					162			**0.19**	**195**	**481**			

Appendix F: Annual Water Balance Detailed Tables

(By Year)

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	$P-Q_{out}$ [mm/yr]
Existing	1	1986	223	832.5	784.0	48.5	198.4	0.24	252.5	344.4	-37.2
Existing	1	1987	365	823.2	696.6	126.6	161.1	0.20	189.3	473.4	0.7
Existing	1	1988	366	676.4	569.5	106.9	90.0	0.13	161.1	419.1	-6.2
Existing	1	1989	365	775.6	643.1	132.5	111.9	0.14	174.9	479.4	-9.4
Existing	1	1990	365	920.9	765.1	155.8	188.8	0.21	243.7	495.6	7.2
Existing	1	1991	365	751.8	618.6	133.2	139.1	0.19	172.2	447.4	6.9
Existing	1	1992	366	1064.9	934.7	130.2	209.8	0.20	358.4	494.0	-2.8
Existing	1	1993	365	798.7	676.6	122.1	128.6	0.16	186.3	497.2	13.4
Existing	1	1994	365	754.4	580.0	174.4	131.2	0.17	129.6	488.1	-5.5
Existing	1	1995	365	925.3	784.8	140.5	192.9	0.21	232.4	488.1	-11.8
Existing	1	1996	366	1033.9	908.7	125.2	191.3	0.19	321.0	519.6	-2.0
Existing	1	1997	365	761.9	567.5	194.4	159.3	0.21	126.7	494.4	18.6
Existing	1	1998	365	733.8	627.2	106.6	105.0	0.14	163.7	463.1	-1.9
Existing	1	1999	365	804.6	649.5	155.1	191.4	0.24	148.5	471.6	6.9
Existing	1	2000	366	984.2	803.3	180.9	177.3	0.18	199.0	536.2	-71.6
Existing	2	1986	223	832.5	784.0	48.5	265.2	0.32	214.8	310.7	-41.9
Existing	2	1987	365	823.2	696.6	126.6	222.8	0.27	167.0	433.9	0.4
Existing	2	1988	366	676.4	569.5	106.9	140.1	0.21	149.7	380.9	-5.7
Existing	2	1989	365	775.6	643.1	132.5	169.9	0.22	155.1	438.9	-11.7
Existing	2	1990	365	920.9	765.1	155.8	260.3	0.28	215.2	456.5	11.0
Existing	2	1991	365	751.8	618.6	133.2	195.2	0.26	154.4	406.6	4.5
Existing	2	1992	366	1064.9	934.7	130.2	295.2	0.28	311.6	456.6	-1.6
Existing	2	1993	365	798.7	676.6	122.1	189.7	0.24	164.3	455.8	11.1
Existing	2	1994	365	754.4	580.0	174.4	185.0	0.25	116.5	447.8	-5.1
Existing	2	1995	365	925.3	784.8	140.5	265.6	0.29	201.4	446.1	-12.2
Existing	2	1996	366	1033.9	908.7	125.2	271.7	0.26	280.6	482.0	0.4
Existing	2	1997	365	761.9	567.5	194.4	212.4	0.28	110.2	455.9	16.6
Existing	2	1998	365	733.8	627.2	106.6	161.3	0.22	149.4	421.6	-1.6
Existing	2	1999	365	804.6	649.5	155.1	252.4	0.31	130.5	428.2	6.5
Existing	2	2000	366	984.2	803.3	180.9	246.7	0.25	167.4	498.0	-72.1
Existing	3	1986	223	832.5	784.0	48.5	184.2	0.22	269.3	350.0	-29.0
Existing	3	1987	365	823.2	696.6	126.6	151.0	0.18	196.7	475.6	0.1
Existing	3	1988	366	676.4	569.5	106.9	84.2	0.12	164.0	421.5	-6.8
Existing	3	1989	365	775.6	643.1	132.5	104.4	0.13	180.4	481.3	-9.6
Existing	3	1990	365	920.9	765.1	155.8	176.4	0.19	253.8	497.1	6.4
Existing	3	1991	365	751.8	618.6	133.2	130.4	0.17	178.5	449.7	6.7
Existing	3	1992	366	1064.9	934.7	130.2	193.7	0.18	373.0	494.8	-3.5

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	$P-Q_{out}$ [mm/yr]
Existing	3	1993	365	798.7	676.6	122.1	119.5	0.15	193.5	498.9	13.2
Existing	3	1994	365	754.4	580.0	174.4	123.7	0.16	134.7	490.0	-6.0
Existing	3	1995	365	925.3	784.8	140.5	179.3	0.19	243.0	490.7	-12.4
Existing	3	1996	366	1033.9	908.7	125.2	177.5	0.17	333.5	520.3	-2.6
Existing	3	1997	365	761.9	567.5	194.4	151.4	0.20	132.6	496.0	18.1
Existing	3	1998	365	733.8	627.2	106.6	97.9	0.13	168.5	465.3	-2.2
Existing	3	1999	365	804.6	649.5	155.1	181.1	0.23	155.6	474.3	6.4
Existing	3	2000	366	984.2	803.3	180.9	165.3	0.17	209.9	536.6	-72.3
Existing	4	1986	223	832.5	784.0	48.5	194.0	0.23	245.6	351.0	-41.8
Existing	4	1987	365	823.2	696.6	126.6	155.2	0.19	186.0	482.0	0.0
Existing	4	1988	366	676.4	569.5	106.9	84.4	0.12	161.5	424.0	-6.4
Existing	4	1989	365	775.6	643.1	132.5	105.4	0.14	171.7	488.6	-9.9
Existing	4	1990	365	920.9	765.1	155.8	182.5	0.20	239.4	505.4	6.3
Existing	4	1991	365	751.8	618.6	133.2	133.9	0.18	170.7	453.5	6.3
Existing	4	1992	366	1064.9	934.7	130.2	203.8	0.19	353.3	504.2	-3.6
Existing	4	1993	365	798.7	676.6	122.1	122.2	0.15	181.3	508.1	13.0
Existing	4	1994	365	754.4	580.0	174.4	125.1	0.17	126.5	496.8	-6.0
Existing	4	1995	365	925.3	784.8	140.5	187.5	0.20	228.7	496.5	-12.6
Existing	4	1996	366	1033.9	908.7	125.2	184.1	0.18	314.6	532.3	-2.9
Existing	4	1997	365	761.9	567.5	194.4	153.5	0.20	124.1	502.1	17.9
Existing	4	1998	365	733.8	627.2	106.6	99.1	0.14	163.3	469.1	-2.4
Existing	4	1999	365	804.6	649.5	155.1	186.1	0.23	146.9	477.8	6.1
Existing	4	2000	366	984.2	803.3	180.9	170.9	0.17	190.3	550.8	-72.2
Existing	5	1986	223	832.5	784.0	48.5	75.4	0.09	424.2	412.7	79.8
Existing	5	1987	365	823.2	696.6	126.6	64.6	0.08	221.5	536.2	-0.9
Existing	5	1988	366	676.4	569.5	106.9	29.1	0.04	153.6	489.3	-4.4
Existing	5	1989	365	775.6	643.1	132.5	37.4	0.05	197.2	537.8	-3.2
Existing	5	1990	365	920.9	765.1	155.8	75.0	0.08	282.9	554.8	-8.2
Existing	5	1991	365	751.8	618.6	133.2	55.1	0.07	200.0	518.8	22.1
Existing	5	1992	366	1064.9	934.7	130.2	75.6	0.07	424.0	552.4	-12.9
Existing	5	1993	365	798.7	676.6	122.1	43.2	0.05	210.1	564.7	19.3
Existing	5	1994	365	754.4	580.0	174.4	52.3	0.07	142.2	551.9	-8.0
Existing	5	1995	365	925.3	784.8	140.5	74.2	0.08	287.6	552.8	-10.7
Existing	5	1996	366	1033.9	908.7	125.2	69.1	0.07	376.4	578.4	-10.1
Existing	5	1997	365	761.9	567.5	194.4	72.8	0.10	157.6	560.6	29.1
Existing	5	1998	365	733.8	627.2	106.6	35.1	0.05	175.7	537.1	14.0
Existing	5	1999	365	804.6	649.5	155.1	86.4	0.11	157.7	546.8	-13.7

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	$P-Q_{out}$ [mm/yr]
Existing	5	2000	366	984.2	803.3	180.9	66.7	0.07	244.6	602.3	-70.6
Existing	6	1986	223	832.5	784.0	48.5	181.5	0.22	235.7	372.8	-42.5
Existing	6	1987	365	823.2	696.6	126.6	144.6	0.18	175.8	502.9	0.1
Existing	6	1988	366	676.4	569.5	106.9	76.5	0.11	151.1	442.4	-6.4
Existing	6	1989	365	775.6	643.1	132.5	95.8	0.12	161.8	508.3	-9.8
Existing	6	1990	365	920.9	765.1	155.8	171.2	0.19	227.8	528.1	6.2
Existing	6	1991	365	751.8	618.6	133.2	125.4	0.17	161.3	471.3	6.3
Existing	6	1992	366	1064.9	934.7	130.2	191.2	0.18	341.9	528.0	-3.7
Existing	6	1993	365	798.7	676.6	122.1	111.4	0.14	164.7	535.6	13.0
Existing	6	1994	365	754.4	580.0	174.4	114.8	0.15	113.0	520.7	-5.9
Existing	6	1995	365	925.3	784.8	140.5	177.1	0.19	219.8	516.2	-12.2
Existing	6	1996	366	1033.9	908.7	125.2	171.1	0.17	297.6	562.0	-3.2
Existing	6	1997	365	761.9	567.5	194.4	142.6	0.19	112.8	524.3	17.8
Existing	6	1998	365	733.8	627.2	106.6	91.3	0.12	154.5	486.0	-2.0
Existing	6	1999	365	804.6	649.5	155.1	174.7	0.22	137.5	498.2	5.7
Existing	6	2000	366	984.2	803.3	180.9	156.1	0.16	165.8	590.7	-71.6
Existing	7	1986	223	832.5	784.0	48.5	123.0	0.15	311.1	397.2	-1.2
Existing	7	1987	365	823.2	696.6	126.6	100.5	0.12	205.2	517.5	0.1
Existing	7	1988	366	676.4	569.5	106.9	48.9	0.07	156.9	463.5	-7.1
Existing	7	1989	365	775.6	643.1	132.5	62.1	0.08	184.8	521.6	-7.1
Existing	7	1990	365	920.9	765.1	155.8	117.9	0.13	264.9	539.6	1.4
Existing	7	1991	365	751.8	618.6	133.2	86.2	0.11	183.4	492.4	10.3
Existing	7	1992	366	1064.9	934.7	130.2	124.3	0.12	398.0	537.3	-5.3
Existing	7	1993	365	798.7	676.6	122.1	72.5	0.09	193.5	548.0	15.3
Existing	7	1994	365	754.4	580.0	174.4	81.0	0.11	131.5	535.0	-6.9
Existing	7	1995	365	925.3	784.8	140.5	119.1	0.13	261.4	533.3	-11.5
Existing	7	1996	366	1033.9	908.7	125.2	113.0	0.11	347.6	567.7	-5.7
Existing	7	1997	365	761.9	567.5	194.4	106.2	0.14	136.1	540.2	20.6
Existing	7	1998	365	733.8	627.2	106.6	58.5	0.08	167.8	508.1	0.7
Existing	7	1999	365	804.6	649.5	155.1	128.3	0.16	159.1	520.2	3.0
Existing	7	2000	366	984.2	803.3	180.9	106.3	0.11	213.4	592.8	-71.7
Existing	8	1986	223	832.5	784.0	48.5	140.5	0.17	287.6	389.4	-15.0
Existing	8	1987	365	823.2	696.6	126.6	113.9	0.14	199.8	509.4	0.0
Existing	8	1988	366	676.4	569.5	106.9	57.2	0.08	160.6	451.4	-7.2
Existing	8	1989	365	775.6	643.1	132.5	72.2	0.09	181.0	513.8	-8.7
Existing	8	1990	365	920.9	765.1	155.8	134.0	0.15	258.8	532.5	4.4
Existing	8	1991	365	751.8	618.6	133.2	98.2	0.13	181.3	480.2	7.8

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	$P-Q_{out}$ [mm/yr]
Existing	8	1992	366	1064.9	934.7	130.2	143.5	0.13	386.6	530.6	-4.3
Existing	8	1993	365	798.7	676.6	122.1	84.1	0.11	188.8	540.0	14.1
Existing	8	1994	365	754.4	580.0	174.4	91.7	0.12	129.1	527.0	-6.6
Existing	8	1995	365	925.3	784.8	140.5	136.3	0.15	252.7	524.4	-11.9
Existing	8	1996	366	1033.9	908.7	125.2	129.9	0.13	337.1	562.9	-4.0
Existing	8	1997	365	761.9	567.5	194.4	117.9	0.15	131.6	530.9	18.6
Existing	8	1998	365	733.8	627.2	106.6	68.2	0.09	168.6	495.2	-1.7
Existing	8	1999	365	804.6	649.5	155.1	143.5	0.18	158.6	508.3	5.7
Existing	8	2000	366	984.2	803.3	180.9	121.2	0.12	201.8	589.3	-71.9
Existing	9	1986	223	832.5	784.0	48.5	183.4	0.22	235.4	369.2	-44.4
Existing	9	1987	365	823.2	696.6	126.6	145.9	0.18	175.5	501.8	0.0
Existing	9	1988	366	676.4	569.5	106.9	76.9	0.11	149.2	444.0	-6.3
Existing	9	1989	365	775.6	643.1	132.5	96.8	0.12	162.3	506.9	-9.6
Existing	9	1990	365	920.9	765.1	155.8	172.8	0.19	227.4	526.6	6.0
Existing	9	1991	365	751.8	618.6	133.2	126.3	0.17	159.4	472.4	6.3
Existing	9	1992	366	1064.9	934.7	130.2	193.3	0.18	341.7	526.2	-3.6
Existing	9	1993	365	798.7	676.6	122.1	112.7	0.14	165.7	533.3	13.0
Existing	9	1994	365	754.4	580.0	174.4	115.6	0.15	112.7	520.1	-6.0
Existing	9	1995	365	925.3	784.8	140.5	178.8	0.19	218.9	515.5	-12.1
Existing	9	1996	366	1033.9	908.7	125.2	173.1	0.17	298.9	558.5	-3.4
Existing	9	1997	365	761.9	567.5	194.4	143.4	0.19	111.9	524.5	17.9
Existing	9	1998	365	733.8	627.2	106.6	92.0	0.13	152.6	487.6	-1.7
Existing	9	1999	365	804.6	649.5	155.1	175.4	0.22	135.4	499.3	5.5
Existing	9	2000	366	984.2	803.3	180.9	157.9	0.16	169.1	585.8	-71.5
Existing	10	1986	223	832.5	784.0	48.5	142.6	0.17	283.7	385.4	-20.8
Existing	10	1987	365	823.2	696.6	126.6	114.7	0.14	198.9	509.8	0.2
Existing	10	1988	366	676.4	569.5	106.9	57.0	0.08	156.8	456.2	-6.3
Existing	10	1989	365	775.6	643.1	132.5	72.4	0.09	182.3	513.7	-7.1
Existing	10	1990	365	920.9	765.1	155.8	135.0	0.15	254.6	532.5	1.2
Existing	10	1991	365	751.8	618.6	133.2	98.5	0.13	178.2	485.2	10.1
Existing	10	1992	366	1064.9	934.7	130.2	145.1	0.14	382.8	531.9	-5.2
Existing	10	1993	365	798.7	676.6	122.1	84.6	0.11	190.1	539.0	15.0
Existing	10	1994	365	754.4	580.0	174.4	91.7	0.12	128.6	527.5	-6.6
Existing	10	1995	365	925.3	784.8	140.5	137.6	0.15	251.4	524.7	-11.5
Existing	10	1996	366	1033.9	908.7	125.2	131.2	0.13	335.9	560.6	-6.2
Existing	10	1997	365	761.9	567.5	194.4	118.2	0.16	131.5	533.3	21.0
Existing	10	1998	365	733.8	627.2	106.6	68.3	0.09	164.0	501.3	-0.2

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	$P-Q_{out}$ [mm/yr]
Existing	10	1999	365	804.6	649.5	155.1	143.2	0.18	152.9	512.2	3.7
Existing	10	2000	366	984.2	803.3	180.9	122.0	0.12	205.2	585.7	-71.2
Existing	11	1986	223	832.5	784.0	48.5	192.8	0.23	251.0	349.1	-39.6
Existing	11	1987	365	823.2	696.6	126.6	155.0	0.19	189.0	479.2	0.0
Existing	11	1988	366	676.4	569.5	106.9	84.7	0.13	163.2	422.1	-6.4
Existing	11	1989	365	775.6	643.1	132.5	105.7	0.14	174.3	485.6	-10.1
Existing	11	1990	365	920.9	765.1	155.8	181.9	0.20	243.5	502.1	6.7
Existing	11	1991	365	751.8	618.6	133.2	133.7	0.18	173.1	451.1	6.1
Existing	11	1992	366	1064.9	934.7	130.2	202.4	0.19	358.2	500.7	-3.6
Existing	11	1993	365	798.7	676.6	122.1	122.3	0.15	185.1	504.3	12.9
Existing	11	1994	365	754.4	580.0	174.4	125.4	0.17	129.2	493.9	-5.9
Existing	11	1995	365	925.3	784.8	140.5	186.6	0.20	232.2	493.9	-12.6
Existing	11	1996	366	1033.9	908.7	125.2	183.4	0.18	319.7	528.1	-2.7
Existing	11	1997	365	761.9	567.5	194.4	153.6	0.20	126.4	499.7	17.8
Existing	11	1998	365	733.8	627.2	106.6	99.2	0.14	165.3	466.9	-2.4
Existing	11	1999	365	804.6	649.5	155.1	185.9	0.23	149.2	475.8	6.3
Existing	11	2000	366	984.2	803.3	180.9	170.5	0.17	195.3	546.1	-72.3
Existing	11.1	1986	223	832.5	784.0	48.5	227.8	0.27	216.6	335.2	-52.9
Existing	11.1	1987	365	823.2	696.6	126.6	181.6	0.22	169.9	471.4	-0.2
Existing	11.1	1988	366	676.4	569.5	106.9	102.9	0.15	154.3	413.2	-6.0
Existing	11.1	1989	365	775.6	643.1	132.5	128.1	0.17	157.7	478.3	-11.6
Existing	11.1	1990	365	920.9	765.1	155.8	214.5	0.23	219.5	496.0	9.1
Existing	11.1	1991	365	751.8	618.6	133.2	157.8	0.21	157.0	441.3	4.3
Existing	11.1	1992	366	1064.9	934.7	130.2	245.7	0.23	320.8	495.6	-2.9
Existing	11.1	1993	365	798.7	676.6	122.1	147.5	0.18	165.3	497.4	11.5
Existing	11.1	1994	365	754.4	580.0	174.4	145.9	0.19	116.1	486.8	-5.6
Existing	11.1	1995	365	925.3	784.8	140.5	222.3	0.24	204.8	485.2	-12.9
Existing	11.1	1996	366	1033.9	908.7	125.2	220.6	0.21	287.7	524.4	-1.3
Existing	11.1	1997	365	761.9	567.5	194.4	173.9	0.23	111.1	493.3	16.4
Existing	11.1	1998	365	733.8	627.2	106.6	121.0	0.16	153.1	457.5	-2.2
Existing	11.1	1999	365	804.6	649.5	155.1	212.5	0.26	132.6	465.5	6.0
Existing	11.1	2000	366	984.2	803.3	180.9	202.0	0.21	165.8	544.0	-72.4
Existing	12	1986	223	832.5	784.0	48.5	177.5	0.21	289.2	355.0	-10.8
Existing	12	1987	365	823.2	696.6	126.6	150.0	0.18	202.0	471.5	0.3
Existing	12	1988	366	676.4	569.5	106.9	87.7	0.13	163.5	418.2	-7.0
Existing	12	1989	365	775.6	643.1	132.5	107.1	0.14	182.7	476.7	-9.0
Existing	12	1990	365	920.9	765.1	155.8	174.3	0.19	259.9	492.0	5.3

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	P-Q_{out} [mm/yr]
Existing	12	1991	365	751.8	618.6	133.2	130.3	0.17	183.0	446.4	8.0
Existing	12	1992	366	1064.9	934.7	130.2	189.4	0.18	382.5	489.3	-3.8
Existing	12	1993	365	798.7	676.6	122.1	120.4	0.15	197.4	494.7	13.8
Existing	12	1994	365	754.4	580.0	174.4	125.0	0.17	137.9	485.1	-6.4
Existing	12	1995	365	925.3	784.8	140.5	175.0	0.19	251.9	486.3	-12.1
Existing	12	1996	366	1033.9	908.7	125.2	175.9	0.17	340.2	514.6	-3.1
Existing	12	1997	365	761.9	567.5	194.4	151.6	0.20	138.9	490.3	18.9
Existing	12	1998	365	733.8	627.2	106.6	100.9	0.14	169.8	461.1	-2.1
Existing	12	1999	365	804.6	649.5	155.1	178.6	0.22	162.3	470.0	6.3
Existing	12	2000	366	984.2	803.3	180.9	163.3	0.17	218.7	529.9	-72.4
Existing	13	1986	223	832.5	784.0	48.5	180.1	0.22	271.0	353.2	-28.3
Existing	13	1987	365	823.2	696.6	126.6	147.2	0.18	197.9	478.1	0.0
Existing	13	1988	366	676.4	569.5	106.9	81.1	0.12	166.4	422.0	-6.8
Existing	13	1989	365	775.6	643.1	132.5	100.7	0.13	181.1	483.8	-9.9
Existing	13	1990	365	920.9	765.1	155.8	172.0	0.19	255.8	499.9	6.8
Existing	13	1991	365	751.8	618.6	133.2	127.0	0.17	180.5	450.7	6.3
Existing	13	1992	366	1064.9	934.7	130.2	188.6	0.18	375.4	497.4	-3.5
Existing	13	1993	365	798.7	676.6	122.1	115.7	0.14	194.1	502.1	13.1
Existing	13	1994	365	754.4	580.0	174.4	120.4	0.16	135.5	492.5	-6.0
Existing	13	1995	365	925.3	784.8	140.5	175.0	0.19	244.6	493.2	-12.5
Existing	13	1996	366	1033.9	908.7	125.2	172.4	0.17	334.7	524.3	-2.5
Existing	13	1997	365	761.9	567.5	194.4	148.1	0.19	133.5	498.1	17.8
Existing	13	1998	365	733.8	627.2	106.6	94.4	0.13	170.9	466.0	-2.5
Existing	13	1999	365	804.6	649.5	155.1	177.9	0.22	157.6	475.7	6.5
Existing	13	2000	366	984.2	803.3	180.9	161.0	0.16	209.5	541.3	-72.4
Existing	14	1986	223	832.5	784.0	48.5	181.4	0.22	270.3	353.8	-27.0
Existing	14	1987	365	823.2	696.6	126.6	148.9	0.18	196.8	477.6	0.2
Existing	14	1988	366	676.4	569.5	106.9	83.1	0.12	164.8	421.8	-6.8
Existing	14	1989	365	775.6	643.1	132.5	102.7	0.13	179.9	483.3	-9.6
Existing	14	1990	365	920.9	765.1	155.8	173.9	0.19	253.8	499.3	6.1
Existing	14	1991	365	751.8	618.6	133.2	128.7	0.17	179.5	450.6	7.0
Existing	14	1992	366	1064.9	934.7	130.2	190.6	0.18	373.7	497.0	-3.6
Existing	14	1993	365	798.7	676.6	122.1	117.6	0.15	192.6	501.8	13.3
Existing	14	1994	365	754.4	580.0	174.4	122.1	0.16	134.5	491.7	-6.0
Existing	14	1995	365	925.3	784.8	140.5	176.6	0.19	243.7	492.5	-12.5
Existing	14	1996	366	1033.9	908.7	125.2	174.7	0.17	332.8	523.7	-2.7
Existing	14	1997	365	761.9	567.5	194.4	149.8	0.20	133.2	497.1	18.2

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	P-Q_{out} [mm/yr]
Existing	14	1998	365	733.8	627.2	106.6	96.5	0.13	169.3	465.7	-2.3
Existing	14	1999	365	804.6	649.5	155.1	179.1	0.22	156.8	475.1	6.4
Existing	14	2000	366	984.2	803.3	180.9	162.8	0.17	208.6	540.4	-72.4
Existing	15	1986	223	832.5	784.0	48.5	78.2	0.09	425.2	405.1	76.0
Existing	15	1987	365	823.2	696.6	126.6	67.1	0.08	227.9	528.1	-0.1
Existing	15	1988	366	676.4	569.5	106.9	30.6	0.05	159.0	480.0	-6.9
Existing	15	1989	365	775.6	643.1	132.5	39.2	0.05	201.6	530.5	-4.2
Existing	15	1990	365	920.9	765.1	155.8	77.9	0.08	291.2	547.4	-4.4
Existing	15	1991	365	751.8	618.6	133.2	57.4	0.08	202.2	508.3	16.1
Existing	15	1992	366	1064.9	934.7	130.2	78.7	0.07	433.7	544.3	-8.3
Existing	15	1993	365	798.7	676.6	122.1	45.3	0.06	215.3	555.9	17.9
Existing	15	1994	365	754.4	580.0	174.4	54.5	0.07	147.3	544.6	-7.9
Existing	15	1995	365	925.3	784.8	140.5	77.2	0.08	292.3	544.9	-10.9
Existing	15	1996	366	1033.9	908.7	125.2	71.9	0.07	382.9	571.1	-8.0
Existing	15	1997	365	761.9	567.5	194.4	75.3	0.10	158.6	552.3	24.3
Existing	15	1998	365	733.8	627.2	106.6	36.7	0.05	178.0	526.3	7.2
Existing	15	1999	365	804.6	649.5	155.1	90.1	0.11	173.0	537.1	-4.4
Existing	15	2000	366	984.2	803.3	180.9	69.4	0.07	248.6	594.7	-71.5
Existing	16	1986	223	832.5	784.0	48.5	119.8	0.14	338.5	389.2	14.9
Existing	16	1987	365	823.2	696.6	126.6	99.5	0.12	219.6	504.1	-0.1
Existing	16	1988	366	676.4	569.5	106.9	49.8	0.07	174.5	444.5	-7.7
Existing	16	1989	365	775.6	643.1	132.5	62.4	0.08	195.5	510.0	-7.7
Existing	16	1990	365	920.9	765.1	155.8	115.4	0.13	283.4	524.6	2.4
Existing	16	1991	365	751.8	618.6	133.2	85.2	0.11	200.5	475.8	9.8
Existing	16	1992	366	1064.9	934.7	130.2	120.8	0.11	418.4	520.8	-4.9
Existing	16	1993	365	798.7	676.6	122.1	72.0	0.09	210.3	531.6	15.2
Existing	16	1994	365	754.4	580.0	174.4	81.4	0.11	148.8	517.2	-7.0
Existing	16	1995	365	925.3	784.8	140.5	115.4	0.12	277.5	520.4	-12.0
Existing	16	1996	366	1033.9	908.7	125.2	110.8	0.11	368.0	550.4	-4.7
Existing	16	1997	365	761.9	567.5	194.4	106.8	0.14	154.5	520.3	19.8
Existing	16	1998	365	733.8	627.2	106.6	58.2	0.08	183.4	490.2	-2.1
Existing	16	1999	365	804.6	649.5	155.1	127.9	0.16	181.3	501.4	6.0
Existing	16	2000	366	984.2	803.3	180.9	106.2	0.11	237.5	568.0	-72.6
Existing	17	1986	223	832.5	784.0	48.5	131.6	0.16	322.3	378.7	0.1
Existing	17	1987	365	823.2	696.6	126.6	108.1	0.13	215.9	499.2	0.1
Existing	17	1988	366	676.4	569.5	106.9	54.8	0.08	169.7	444.8	-7.1
Existing	17	1989	365	775.6	643.1	132.5	68.8	0.09	194.4	505.0	-7.4

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	$P-Q_{out}$ [mm/yr]
Existing	17	1990	365	920.9	765.1	155.8	125.7	0.14	277.6	519.5	1.9
Existing	17	1991	365	751.8	618.6	133.2	92.5	0.12	194.5	474.8	10.1
Existing	17	1992	366	1064.9	934.7	130.2	132.9	0.12	410.7	516.1	-5.2
Existing	17	1993	365	798.7	676.6	122.1	79.7	0.10	210.2	524.2	15.3
Existing	17	1994	365	754.4	580.0	174.4	88.3	0.12	146.4	512.9	-6.8
Existing	17	1995	365	925.3	784.8	140.5	126.2	0.14	271.5	515.6	-12.0
Existing	17	1996	366	1033.9	908.7	125.2	121.9	0.12	364.9	542.0	-5.1
Existing	17	1997	365	761.9	567.5	194.4	114.4	0.15	150.0	517.9	20.3
Existing	17	1998	365	733.8	627.2	106.6	64.1	0.09	177.8	490.4	-1.6
Existing	17	1999	365	804.6	649.5	155.1	136.7	0.17	173.4	499.9	5.4
Existing	17	2000	366	984.2	803.3	180.9	116.2	0.12	237.3	558.4	-72.3
Existing	18	1986	223	832.5	784.0	48.5	155.1	0.19	287.5	370.4	-19.4
Existing	18	1987	365	823.2	696.6	126.6	125.9	0.15	204.7	492.7	0.0
Existing	18	1988	366	676.4	569.5	106.9	65.6	0.10	169.2	434.5	-7.1
Existing	18	1989	365	775.6	643.1	132.5	82.1	0.11	185.6	498.8	-9.1
Existing	18	1990	365	920.9	765.1	155.8	147.0	0.16	264.6	514.3	5.1
Existing	18	1991	365	751.8	618.6	133.2	108.1	0.14	186.7	464.5	7.5
Existing	18	1992	366	1064.9	934.7	130.2	158.7	0.15	390.8	511.3	-4.1
Existing	18	1993	365	798.7	676.6	122.1	95.3	0.12	198.6	518.7	13.9
Existing	18	1994	365	754.4	580.0	174.4	102.5	0.14	138.8	506.8	-6.3
Existing	18	1995	365	925.3	784.8	140.5	149.0	0.16	255.4	508.4	-12.5
Existing	18	1996	366	1033.9	908.7	125.2	144.7	0.14	345.9	539.8	-3.4
Existing	18	1997	365	761.9	567.5	194.4	129.9	0.17	139.5	511.0	18.4
Existing	18	1998	365	733.8	627.2	106.6	76.8	0.10	175.2	479.5	-2.2
Existing	18	1999	365	804.6	649.5	155.1	156.3	0.19	164.7	489.9	6.3
Existing	18	2000	366	984.2	803.3	180.9	136.7	0.14	217.4	557.5	-72.6
Existing	19	1986	223	832.5	784.0	48.5	157.5	0.19	295.1	368.1	-11.7
Existing	19	1987	365	823.2	696.6	126.6	130.4	0.16	205.5	487.6	0.2
Existing	19	1988	366	676.4	569.5	106.9	71.1	0.11	166.0	432.1	-7.1
Existing	19	1989	365	775.6	643.1	132.5	88.0	0.11	185.6	493.3	-8.7
Existing	19	1990	365	920.9	765.1	155.8	151.8	0.16	265.1	508.4	4.4
Existing	19	1991	365	751.8	618.6	133.2	112.4	0.15	186.2	461.5	8.3
Existing	19	1992	366	1064.9	934.7	130.2	163.5	0.15	391.9	505.2	-4.3
Existing	19	1993	365	798.7	676.6	122.1	100.7	0.13	199.7	512.7	14.3
Existing	19	1994	365	754.4	580.0	174.4	107.3	0.14	139.1	501.4	-6.5
Existing	19	1995	365	925.3	784.8	140.5	152.9	0.17	257.1	503.1	-12.2
Existing	19	1996	366	1033.9	908.7	125.2	150.6	0.15	347.6	532.2	-3.5

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	P-Q_{out} [mm/yr]
Existing	19	1997	365	761.9	567.5	194.4	134.1	0.18	140.8	506.0	19.0
Existing	19	1998	365	733.8	627.2	106.6	82.5	0.11	172.9	476.3	-2.1
Existing	19	1999	365	804.6	649.5	155.1	159.6	0.20	165.1	486.1	6.1
Existing	19	2000	366	984.2	803.3	180.9	141.4	0.14	221.8	548.6	-72.4
Existing	20	1986	223	832.5	784.0	48.5	168.7	0.20	282.8	356.5	-24.5
Existing	20	1987	365	823.2	696.6	126.6	137.4	0.17	205.0	480.8	0.0
Existing	20	1988	366	676.4	569.5	106.9	73.8	0.11	171.0	424.7	-7.0
Existing	20	1989	365	775.6	643.1	132.5	92.1	0.12	187.3	486.5	-9.7
Existing	20	1990	365	920.9	765.1	155.8	160.5	0.17	264.0	502.4	6.0
Existing	20	1991	365	751.8	618.6	133.2	118.2	0.16	186.9	453.6	7.0
Existing	20	1992	366	1064.9	934.7	130.2	174.6	0.16	386.7	499.9	-3.7
Existing	20	1993	365	798.7	676.6	122.1	106.3	0.13	201.5	504.3	13.4
Existing	20	1994	365	754.4	580.0	174.4	112.1	0.15	141.0	495.0	-6.3
Existing	20	1995	365	925.3	784.8	140.5	163.2	0.18	253.4	496.2	-12.5
Existing	20	1996	366	1033.9	908.7	125.2	159.5	0.15	345.2	526.4	-2.8
Existing	20	1997	365	761.9	567.5	194.4	139.7	0.18	139.1	501.1	18.0
Existing	20	1998	365	733.8	627.2	106.6	86.2	0.12	175.8	469.4	-2.4
Existing	20	1999	365	804.6	649.5	155.1	168.4	0.21	163.5	479.2	6.5
Existing	20	2000	366	984.2	803.3	180.9	149.7	0.15	218.6	543.4	-72.5
Existing	21	1986	223	832.5	784.0	48.5	290.5	0.35	211.2	295.0	-35.8
Existing	21	1987	365	823.2	696.6	126.6	249.3	0.30	165.2	409.2	0.5
Existing	21	1988	366	676.4	569.5	106.9	164.0	0.24	151.8	355.6	-5.1
Existing	21	1989	365	775.6	643.1	132.5	196.4	0.25	153.3	412.4	-13.6
Existing	21	1990	365	920.9	765.1	155.8	289.8	0.31	215.2	430.5	14.6
Existing	21	1991	365	751.8	618.6	133.2	219.6	0.29	155.5	380.1	3.4
Existing	21	1992	366	1064.9	934.7	130.2	328.8	0.31	302.8	433.2	-0.2
Existing	21	1993	365	798.7	676.6	122.1	216.5	0.27	162.1	430.0	9.8
Existing	21	1994	365	754.4	580.0	174.4	209.9	0.28	119.0	420.9	-4.6
Existing	21	1995	365	925.3	784.8	140.5	295.3	0.32	198.8	419.3	-11.9
Existing	21	1996	366	1033.9	908.7	125.2	304.5	0.29	273.1	459.3	3.0
Existing	21	1997	365	761.9	567.5	194.4	236.8	0.31	108.6	432.2	15.7
Existing	21	1998	365	733.8	627.2	106.6	187.4	0.26	150.8	394.8	-0.8
Existing	21	1999	365	804.6	649.5	155.1	280.5	0.35	131.0	399.5	6.4
Existing	21	2000	366	984.2	803.3	180.9	275.4	0.28	160.6	476.1	-72.0
Existing	21.1	1986	223	832.5	784.0	48.5	114.9	0.14	350.2	388.0	20.5
Existing	21.1	1987	365	823.2	696.6	126.6	95.7	0.12	223.4	504.2	0.0
Existing	21.1	1988	366	676.4	569.5	106.9	47.4	0.07	175.1	446.4	-7.5

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	$P-Q_{out}$ [mm/yr]
Existing	21.1	1989	365	775.6	643.1	132.5	59.7	0.08	199.2	509.8	-7.0
Existing	21.1	1990	365	920.9	765.1	155.8	110.9	0.12	286.8	524.3	1.1
Existing	21.1	1991	365	751.8	618.6	133.2	81.8	0.11	203.1	477.6	10.7
Existing	21.1	1992	366	1064.9	934.7	130.2	115.5	0.11	423.3	520.9	-5.2
Existing	21.1	1993	365	798.7	676.6	122.1	68.8	0.09	215.0	530.6	15.7
Existing	21.1	1994	365	754.4	580.0	174.4	78.3	0.10	152.1	517.1	-7.0
Existing	21.1	1995	365	925.3	784.8	140.5	110.7	0.12	282.1	520.5	-12.0
Existing	21.1	1996	366	1033.9	908.7	125.2	106.0	0.10	373.7	548.7	-5.4
Existing	21.1	1997	365	761.9	567.5	194.4	103.3	0.14	158.2	521.0	20.6
Existing	21.1	1998	365	733.8	627.2	106.6	55.5	0.08	184.1	492.5	-1.8
Existing	21.1	1999	365	804.6	649.5	155.1	123.5	0.15	183.7	503.0	5.6
Existing	21.1	2000	366	984.2	803.3	180.9	101.8	0.10	244.0	565.9	-72.5
Existing	22	1986	223	832.5	784.0	48.5	223.6	0.27	223.8	336.6	-48.5
Existing	22	1987	365	823.2	696.6	126.6	179.7	0.22	174.6	468.4	-0.4
Existing	22	1988	366	676.4	569.5	106.9	102.8	0.15	161.3	406.3	-6.1
Existing	22	1989	365	775.6	643.1	132.5	127.0	0.16	161.2	474.7	-12.7
Existing	22	1990	365	920.9	765.1	155.8	211.6	0.23	227.2	493.0	10.8
Existing	22	1991	365	751.8	618.6	133.2	156.4	0.21	164.4	434.4	3.4
Existing	22	1992	366	1064.9	934.7	130.2	241.0	0.23	328.4	492.9	-2.6
Existing	22	1993	365	798.7	676.6	122.1	145.7	0.18	169.3	494.7	11.0
Existing	22	1994	365	754.4	580.0	174.4	145.3	0.19	121.2	482.3	-5.6
Existing	22	1995	365	925.3	784.8	140.5	219.3	0.24	211.2	481.6	-13.2
Existing	22	1996	366	1033.9	908.7	125.2	216.3	0.21	293.1	524.4	-0.1
Existing	22	1997	365	761.9	567.5	194.4	173.3	0.23	114.4	489.6	15.5
Existing	22	1998	365	733.8	627.2	106.6	120.6	0.16	160.7	450.6	-2.0
Existing	22	1999	365	804.6	649.5	155.1	213.1	0.26	138.4	458.9	5.8
Existing	22	2000	366	984.2	803.3	180.9	198.6	0.20	166.5	546.3	-72.8
Existing	23	1986	223	832.5	784.0	48.5	171.6	0.21	276.5	362.8	-21.7
Existing	23	1987	365	823.2	696.6	126.6	140.8	0.17	202.5	479.6	-0.2
Existing	23	1988	366	676.4	569.5	106.9	77.3	0.11	177.4	414.7	-7.0
Existing	23	1989	365	775.6	643.1	132.5	95.4	0.12	183.7	485.0	-11.6
Existing	23	1990	365	920.9	765.1	155.8	164.3	0.18	263.6	502.0	9.0
Existing	23	1991	365	751.8	618.6	133.2	121.7	0.16	190.5	444.7	5.2
Existing	23	1992	366	1064.9	934.7	130.2	179.1	0.17	383.0	499.8	-3.1
Existing	23	1993	365	798.7	676.6	122.1	109.2	0.14	196.1	505.6	12.3
Existing	23	1994	365	754.4	580.0	174.4	115.4	0.15	140.8	492.3	-5.9
Existing	23	1995	365	925.3	784.8	140.5	167.2	0.18	251.3	493.9	-12.9

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	P-Q_{out} [mm/yr]
Existing	23	1996	366	1033.9	908.7	125.2	163.1	0.16	337.0	532.7	-1.1
Existing	23	1997	365	761.9	567.5	194.4	143.1	0.19	138.3	496.9	16.5
Existing	23	1998	365	733.8	627.2	106.6	89.9	0.12	182.0	459.5	-2.3
Existing	23	1999	365	804.6	649.5	155.1	173.6	0.22	166.6	470.8	6.4
Existing	23	2000	366	984.2	803.3	180.9	153.0	0.16	205.1	553.3	-72.9
Existing	24	1986	223	832.5	784.0	48.5	181.5	0.22	261.0	353.4	-36.7
Existing	24	1987	365	823.2	696.6	126.6	145.6	0.18	194.3	483.4	0.1
Existing	24	1988	366	676.4	569.5	106.9	77.7	0.11	164.1	428.1	-6.5
Existing	24	1989	365	775.6	643.1	132.5	97.5	0.13	179.1	489.7	-9.3
Existing	24	1990	365	920.9	765.1	155.8	170.7	0.19	249.7	505.8	5.3
Existing	24	1991	365	751.8	618.6	133.2	125.1	0.17	176.7	457.2	7.1
Existing	24	1992	366	1064.9	934.7	130.2	188.5	0.18	368.2	504.2	-4.0
Existing	24	1993	365	798.7	676.6	122.1	113.3	0.14	190.9	508.0	13.5
Existing	24	1994	365	754.4	580.0	174.4	117.6	0.16	132.6	498.2	-6.1
Existing	24	1995	365	925.3	784.8	140.5	174.7	0.19	239.5	498.5	-12.6
Existing	24	1996	366	1033.9	908.7	125.2	171.0	0.17	329.3	530.2	-3.4
Existing	24	1997	365	761.9	567.5	194.4	145.7	0.19	130.4	504.2	18.4
Existing	24	1998	365	733.8	627.2	106.6	91.2	0.12	167.1	473.1	-2.3
Existing	24	1999	365	804.6	649.5	155.1	176.0	0.22	152.9	481.9	6.2
Existing	24	2000	366	984.2	803.3	180.9	159.7	0.16	204.7	547.6	-72.3
Existing	25	1986	223	832.5	784.0	48.5	148.9	0.18	313.1	369.0	-1.5
Existing	25	1987	365	823.2	696.6	126.6	124.4	0.15	213.5	485.4	0.1
Existing	25	1988	366	676.4	569.5	106.9	67.8	0.10	172.3	429.0	-7.3
Existing	25	1989	365	775.6	643.1	132.5	83.9	0.11	192.3	490.7	-8.7
Existing	25	1990	365	920.9	765.1	155.8	144.4	0.16	274.9	505.9	4.3
Existing	25	1991	365	751.8	618.6	133.2	107.3	0.14	194.4	458.6	8.5
Existing	25	1992	366	1064.9	934.7	130.2	154.4	0.15	403.5	502.8	-4.2
Existing	25	1993	365	798.7	676.6	122.1	95.5	0.12	207.9	509.6	14.2
Existing	25	1994	365	754.4	580.0	174.4	102.7	0.14	146.4	498.8	-6.5
Existing	25	1995	365	925.3	784.8	140.5	145.0	0.16	267.2	500.9	-12.2
Existing	25	1996	366	1033.9	908.7	125.2	142.5	0.14	357.9	529.7	-3.7
Existing	25	1997	365	761.9	567.5	194.4	129.0	0.17	148.5	503.5	19.0
Existing	25	1998	365	733.8	627.2	106.6	78.6	0.11	179.4	473.4	-2.4
Existing	25	1999	365	804.6	649.5	155.1	153.5	0.19	174.1	483.7	6.6
Existing	25	2000	366	984.2	803.3	180.9	134.2	0.14	231.2	546.2	-72.6
Existing	26	1986	223	832.5	784.0	48.5	437.7	0.53	139.9	230.8	-24.2
Existing	26	1987	365	823.2	696.6	126.6	390.2	0.47	115.1	318.6	0.7

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	P-Q_{out} [mm/yr]
Existing	26	1988	366	676.4	569.5	106.9	282.8	0.42	109.5	280.6	-3.5
Existing	26	1989	365	775.6	643.1	132.5	333.3	0.43	107.4	319.7	-15.2
Existing	26	1990	365	920.9	765.1	155.8	451.8	0.49	150.4	337.5	18.7
Existing	26	1991	365	751.8	618.6	133.2	348.3	0.46	108.1	297.6	2.2
Existing	26	1992	366	1064.9	934.7	130.2	519.2	0.49	201.0	346.8	2.1
Existing	26	1993	365	798.7	676.6	122.1	358.4	0.45	111.0	336.0	6.7
Existing	26	1994	365	754.4	580.0	174.4	335.7	0.44	84.2	330.3	-4.2
Existing	26	1995	365	925.3	784.8	140.5	457.1	0.49	133.9	322.7	-11.5
Existing	26	1996	366	1033.9	908.7	125.2	488.5	0.47	186.6	365.0	6.2
Existing	26	1997	365	761.9	567.5	194.4	359.2	0.47	74.1	343.5	14.9
Existing	26	1998	365	733.8	627.2	106.6	319.5	0.44	104.5	310.1	0.3
Existing	26	1999	365	804.6	649.5	155.1	414.8	0.52	90.3	305.0	5.6
Existing	26	2000	366	984.2	803.3	180.9	433.2	0.44	103.5	375.6	-72.0
Existing	27	1986	223	832.5	784.0	48.5	290.0	0.35	225.6	304.6	-12.3
Existing	27	1987	365	823.2	696.6	126.6	259.1	0.31	161.9	403.2	1.1
Existing	27	1988	366	676.4	569.5	106.9	179.0	0.26	137.3	354.4	-5.6
Existing	27	1989	365	775.6	643.1	132.5	211.6	0.27	148.4	404.1	-11.6
Existing	27	1990	365	920.9	765.1	155.8	300.2	0.33	209.8	423.4	12.5
Existing	27	1991	365	751.8	618.6	133.2	230.4	0.31	150.1	376.7	5.4
Existing	27	1992	366	1064.9	934.7	130.2	335.3	0.31	306.2	423.3	-0.1
Existing	27	1993	365	798.7	676.6	122.1	229.0	0.29	156.2	424.1	10.5
Existing	27	1994	365	754.4	580.0	174.4	222.2	0.29	109.4	418.0	-4.8
Existing	27	1995	365	925.3	784.8	140.5	300.5	0.32	201.3	412.7	-10.9
Existing	27	1996	366	1033.9	908.7	125.2	317.1	0.31	269.3	449.3	1.8
Existing	27	1997	365	761.9	567.5	194.4	247.4	0.32	108.2	423.4	17.1
Existing	27	1998	365	733.8	627.2	106.6	202.6	0.28	142.1	388.2	-0.9
Existing	27	1999	365	804.6	649.5	155.1	284.6	0.35	130.6	396.6	7.2
Existing	27	2000	366	984.2	803.3	180.9	283.5	0.29	162.2	467.1	-71.4
Existing	28	1986	223	832.5	784.0	48.5	291.9	0.35	214.0	306.6	-20.1
Existing	28	1987	365	823.2	696.6	126.6	260.2	0.32	154.1	408.9	0.1
Existing	28	1988	366	676.4	569.5	106.9	180.1	0.27	124.1	367.3	-5.0
Existing	28	1989	365	775.6	643.1	132.5	212.9	0.27	142.8	410.6	-9.3
Existing	28	1990	365	920.9	765.1	155.8	301.4	0.33	194.8	429.2	4.4
Existing	28	1991	365	751.8	618.6	133.2	231.2	0.31	139.0	390.1	8.5
Existing	28	1992	366	1064.9	934.7	130.2	337.6	0.32	291.6	431.9	-3.8
Existing	28	1993	365	798.7	676.6	122.1	230.5	0.29	149.0	430.8	11.6
Existing	28	1994	365	754.4	580.0	174.4	222.6	0.30	101.2	424.1	-6.5

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	$P-Q_{out}$ [mm/yr]
Existing	28	1995	365	925.3	784.8	140.5	301.5	0.33	193.8	418.1	-11.9
Existing	28	1996	366	1033.9	908.7	125.2	319.5	0.31	257.4	453.4	-3.7
Existing	28	1997	365	761.9	567.5	194.4	247.6	0.33	103.3	430.8	19.8
Existing	28	1998	365	733.8	627.2	106.6	203.9	0.28	126.9	402.3	-0.7
Existing	28	1999	365	804.6	649.5	155.1	282.3	0.35	119.1	406.8	3.6
Existing	28	2000	366	984.2	803.3	180.9	284.5	0.29	158.6	469.3	-71.8
Future	1	1986	223	832.5	784.0	48.5	198.4	0.24	252.5	344.4	-37.2
Future	1	1987	365	823.2	696.6	126.6	161.1	0.20	189.4	473.4	0.7
Future	1	1988	366	676.4	569.5	106.9	90.0	0.13	161.1	419.1	-6.2
Future	1	1989	365	775.6	643.1	132.5	111.9	0.14	174.9	479.4	-9.4
Future	1	1990	365	920.9	765.1	155.8	188.8	0.21	243.7	495.6	7.2
Future	1	1991	365	751.8	618.6	133.2	139.1	0.19	172.2	447.4	6.9
Future	1	1992	366	1064.9	934.7	130.2	209.8	0.20	358.4	494.0	-2.8
Future	1	1993	365	798.7	676.6	122.1	128.6	0.16	186.3	497.2	13.4
Future	1	1994	365	754.4	580.0	174.4	131.2	0.17	129.6	488.1	-5.5
Future	1	1995	365	925.3	784.8	140.5	192.9	0.21	232.4	488.1	-11.8
Future	1	1996	366	1033.9	908.7	125.2	191.3	0.19	321.0	519.6	-2.0
Future	1	1997	365	761.9	567.5	194.4	159.3	0.21	126.7	494.4	18.6
Future	1	1998	365	733.8	627.2	106.6	105.0	0.14	163.7	463.1	-2.0
Future	1	1999	365	804.6	649.5	155.1	191.4	0.24	148.5	471.6	7.0
Future	1	2000	366	984.2	803.3	180.9	177.3	0.18	199.0	536.2	-71.6
Future	2	1986	223	832.5	784.0	48.5	338.0	0.41	179.3	274.2	-41.0
Future	2	1987	365	823.2	696.6	126.6	291.5	0.35	143.7	389.1	1.1
Future	2	1988	366	676.4	569.5	106.9	197.3	0.29	133.3	341.4	-4.4
Future	2	1989	365	775.6	643.1	132.5	236.0	0.30	134.0	392.7	-13.0
Future	2	1990	365	920.9	765.1	155.8	339.5	0.37	186.0	410.8	15.4
Future	2	1991	365	751.8	618.6	133.2	257.8	0.34	133.9	363.7	3.6
Future	2	1992	366	1064.9	934.7	130.2	389.5	0.37	263.0	413.3	0.9
Future	2	1993	365	798.7	676.6	122.1	258.7	0.32	141.1	408.6	9.6
Future	2	1994	365	754.4	580.0	174.4	245.9	0.33	102.3	402.0	-4.2
Future	2	1995	365	925.3	784.8	140.5	345.6	0.37	169.8	398.6	-11.3
Future	2	1996	366	1033.9	908.7	125.2	361.6	0.35	239.7	436.5	3.8
Future	2	1997	365	761.9	567.5	194.4	271.9	0.36	93.1	413.0	16.0
Future	2	1998	365	733.8	627.2	106.6	225.3	0.31	130.4	377.8	-0.3
Future	2	1999	365	804.6	649.5	155.1	319.5	0.40	111.0	380.9	6.8
Future	2	2000	366	984.2	803.3	180.9	323.9	0.33	138.5	450.3	-71.4
Future	3	1986	223	832.5	784.0	48.5	194.2	0.23	263.5	344.7	-30.1

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	P-Q_{out} [mm/yr]
Future	3	1987	365	823.2	696.6	126.6	160.2	0.19	193.7	469.4	0.1
Future	3	1988	366	676.4	569.5	106.9	91.6	0.14	162.6	415.5	-6.7
Future	3	1989	365	775.6	643.1	132.5	112.9	0.15	177.7	474.9	-10.0
Future	3	1990	365	920.9	765.1	155.8	187.1	0.20	249.8	491.1	7.1
Future	3	1991	365	751.8	618.6	133.2	138.7	0.18	176.1	443.4	6.4
Future	3	1992	366	1064.9	934.7	130.2	206.2	0.19	366.5	488.8	-3.3
Future	3	1993	365	798.7	676.6	122.1	128.6	0.16	190.5	492.3	12.8
Future	3	1994	365	754.4	580.0	174.4	131.8	0.17	132.9	483.8	-5.9
Future	3	1995	365	925.3	784.8	140.5	190.0	0.21	238.7	484.2	-12.5
Future	3	1996	366	1033.9	908.7	125.2	189.5	0.18	328.0	514.3	-2.2
Future	3	1997	365	761.9	567.5	194.4	159.5	0.21	130.2	490.0	17.8
Future	3	1998	365	733.8	627.2	106.6	106.1	0.14	166.7	458.8	-2.2
Future	3	1999	365	804.6	649.5	155.1	190.3	0.24	153.1	467.6	6.4
Future	3	2000	366	984.2	803.3	180.9	175.7	0.18	205.7	530.4	-72.4
Future	4	1986	223	832.5	784.0	48.5	194.0	0.23	245.6	351.0	-41.8
Future	4	1987	365	823.2	696.6	126.6	155.2	0.19	186.0	482.0	0.0
Future	4	1988	366	676.4	569.5	106.9	84.4	0.12	161.5	424.0	-6.4
Future	4	1989	365	775.6	643.1	132.5	105.4	0.14	171.7	488.6	-9.9
Future	4	1990	365	920.9	765.1	155.8	182.5	0.20	239.3	505.4	6.3
Future	4	1991	365	751.8	618.6	133.2	133.9	0.18	170.7	453.5	6.3
Future	4	1992	366	1064.9	934.7	130.2	203.8	0.19	353.3	504.2	-3.6
Future	4	1993	365	798.7	676.6	122.1	122.2	0.15	181.3	508.2	13.0
Future	4	1994	365	754.4	580.0	174.4	125.1	0.17	126.5	496.8	-6.0
Future	4	1995	365	925.3	784.8	140.5	187.5	0.20	228.7	496.5	-12.6
Future	4	1996	366	1033.9	908.7	125.2	184.1	0.18	314.6	532.3	-2.9
Future	4	1997	365	761.9	567.5	194.4	153.5	0.20	124.1	502.1	17.9
Future	4	1998	365	733.8	627.2	106.6	99.1	0.14	163.3	469.1	-2.4
Future	4	1999	365	804.6	649.5	155.1	186.1	0.23	146.9	477.8	6.1
Future	4	2000	366	984.2	803.3	180.9	170.9	0.17	190.3	550.8	-72.2
Future	5	1986	223	832.5	784.0	48.5	75.4	0.09	424.2	412.7	79.8
Future	5	1987	365	823.2	696.6	126.6	64.6	0.08	221.5	536.2	-0.9
Future	5	1988	366	676.4	569.5	106.9	29.1	0.04	153.6	489.3	-4.4
Future	5	1989	365	775.6	643.1	132.5	37.4	0.05	197.2	537.8	-3.2
Future	5	1990	365	920.9	765.1	155.8	75.0	0.08	282.9	554.8	-8.2
Future	5	1991	365	751.8	618.6	133.2	55.1	0.07	200.0	518.8	22.1
Future	5	1992	366	1064.9	934.7	130.2	75.6	0.07	424.0	552.4	-12.9
Future	5	1993	365	798.7	676.6	122.1	43.2	0.05	210.1	564.7	19.3

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	P-Q_{out} [mm/yr]
Future	5	1994	365	754.4	580.0	174.4	52.3	0.07	142.2	551.9	-8.0
Future	5	1995	365	925.3	784.8	140.5	74.2	0.08	287.6	552.8	-10.7
Future	5	1996	366	1033.9	908.7	125.2	69.1	0.07	376.4	578.4	-10.1
Future	5	1997	365	761.9	567.5	194.4	72.8	0.10	157.6	560.6	29.1
Future	5	1998	365	733.8	627.2	106.6	35.1	0.05	175.7	537.1	14.0
Future	5	1999	365	804.6	649.5	155.1	86.4	0.11	157.7	546.8	-13.7
Future	5	2000	366	984.2	803.3	180.9	66.7	0.07	244.6	602.3	-70.6
Future	6	1986	223	832.5	784.0	48.5	181.5	0.22	235.7	372.8	-42.5
Future	6	1987	365	823.2	696.6	126.6	144.6	0.18	175.8	502.9	0.1
Future	6	1988	366	676.4	569.5	106.9	76.5	0.11	151.1	442.4	-6.4
Future	6	1989	365	775.6	643.1	132.5	95.8	0.12	161.8	508.3	-9.8
Future	6	1990	365	920.9	765.1	155.8	171.2	0.19	227.8	528.1	6.2
Future	6	1991	365	751.8	618.6	133.2	125.4	0.17	161.3	471.3	6.3
Future	6	1992	366	1064.9	934.7	130.2	191.2	0.18	341.9	528.0	-3.7
Future	6	1993	365	798.7	676.6	122.1	111.4	0.14	164.7	535.6	13.0
Future	6	1994	365	754.4	580.0	174.4	114.8	0.15	113.0	520.7	-5.9
Future	6	1995	365	925.3	784.8	140.5	177.1	0.19	219.8	516.2	-12.2
Future	6	1996	366	1033.9	908.7	125.2	171.1	0.17	297.6	562.0	-3.2
Future	6	1997	365	761.9	567.5	194.4	142.6	0.19	112.8	524.3	17.8
Future	6	1998	365	733.8	627.2	106.6	91.3	0.12	154.5	486.0	-2.0
Future	6	1999	365	804.6	649.5	155.1	174.7	0.22	137.5	498.2	5.7
Future	6	2000	366	984.2	803.3	180.9	156.1	0.16	165.8	590.7	-71.6
Future	7	1986	223	832.5	784.0	48.5	123.0	0.15	311.1	397.2	-1.2
Future	7	1987	365	823.2	696.6	126.6	100.5	0.12	205.2	517.5	0.1
Future	7	1988	366	676.4	569.5	106.9	48.9	0.07	156.9	463.5	-7.1
Future	7	1989	365	775.6	643.1	132.5	62.1	0.08	184.8	521.6	-7.1
Future	7	1990	365	920.9	765.1	155.8	117.9	0.13	264.9	539.6	1.4
Future	7	1991	365	751.8	618.6	133.2	86.2	0.11	183.4	492.4	10.3
Future	7	1992	366	1064.9	934.7	130.2	124.3	0.12	398.0	537.3	-5.3
Future	7	1993	365	798.7	676.6	122.1	72.5	0.09	193.5	548.0	15.3
Future	7	1994	365	754.4	580.0	174.4	81.0	0.11	131.5	535.0	-6.9
Future	7	1995	365	925.3	784.8	140.5	119.1	0.13	261.4	533.3	-11.5
Future	7	1996	366	1033.9	908.7	125.2	113.0	0.11	347.7	567.7	-5.6
Future	7	1997	365	761.9	567.5	194.4	106.2	0.14	136.0	540.1	20.5
Future	7	1998	365	733.8	627.2	106.6	58.5	0.08	167.8	508.1	0.7
Future	7	1999	365	804.6	649.5	155.1	128.3	0.16	159.1	520.2	3.0
Future	7	2000	366	984.2	803.3	180.9	106.3	0.11	213.4	592.8	-71.7

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	$P-Q_{out}$ [mm/yr]
Future	8	1986	223	832.5	784.0	48.5	140.5	0.17	287.6	389.4	-15.0
Future	8	1987	365	823.2	696.6	126.6	113.9	0.14	199.8	509.4	0.0
Future	8	1988	366	676.4	569.5	106.9	57.2	0.08	160.6	451.4	-7.2
Future	8	1989	365	775.6	643.1	132.5	72.2	0.09	181.0	513.8	-8.7
Future	8	1990	365	920.9	765.1	155.8	134.0	0.15	258.7	532.5	4.3
Future	8	1991	365	751.8	618.6	133.2	98.2	0.13	181.3	480.2	7.9
Future	8	1992	366	1064.9	934.7	130.2	143.5	0.13	386.5	530.6	-4.3
Future	8	1993	365	798.7	676.6	122.1	84.1	0.11	188.8	540.0	14.1
Future	8	1994	365	754.4	580.0	174.4	91.7	0.12	129.1	527.0	-6.6
Future	8	1995	365	925.3	784.8	140.5	136.3	0.15	252.7	524.4	-11.9
Future	8	1996	366	1033.9	908.7	125.2	129.9	0.13	337.1	562.9	-4.0
Future	8	1997	365	761.9	567.5	194.4	117.9	0.15	131.6	530.9	18.6
Future	8	1998	365	733.8	627.2	106.6	68.2	0.09	168.6	495.2	-1.7
Future	8	1999	365	804.6	649.5	155.1	143.5	0.18	158.5	508.3	5.7
Future	8	2000	366	984.2	803.3	180.9	121.3	0.12	201.8	589.3	-71.9
Future	9	1986	223	832.5	784.0	48.5	183.4	0.22	235.4	369.2	-44.4
Future	9	1987	365	823.2	696.6	126.6	145.9	0.18	175.5	501.8	0.0
Future	9	1988	366	676.4	569.5	106.9	76.9	0.11	149.2	444.0	-6.3
Future	9	1989	365	775.6	643.1	132.5	96.8	0.12	162.2	506.9	-9.6
Future	9	1990	365	920.9	765.1	155.8	172.8	0.19	227.4	526.7	6.0
Future	9	1991	365	751.8	618.6	133.2	126.3	0.17	159.4	472.4	6.3
Future	9	1992	366	1064.9	934.7	130.2	193.3	0.18	341.7	526.2	-3.6
Future	9	1993	365	798.7	676.6	122.1	112.7	0.14	165.7	533.3	13.0
Future	9	1994	365	754.4	580.0	174.4	115.6	0.15	112.7	520.1	-6.0
Future	9	1995	365	925.3	784.8	140.5	178.8	0.19	218.9	515.5	-12.2
Future	9	1996	366	1033.9	908.7	125.2	173.1	0.17	298.9	558.5	-3.4
Future	9	1997	365	761.9	567.5	194.4	143.4	0.19	111.9	524.5	17.9
Future	9	1998	365	733.8	627.2	106.6	92.0	0.13	152.6	487.6	-1.7
Future	9	1999	365	804.6	649.5	155.1	175.4	0.22	135.4	499.3	5.5
Future	9	2000	366	984.2	803.3	180.9	157.9	0.16	169.0	585.8	-71.5
Future	10	1986	223	832.5	784.0	48.5	142.6	0.17	283.7	385.4	-20.8
Future	10	1987	365	823.2	696.6	126.6	114.7	0.14	198.9	509.7	0.2
Future	10	1988	366	676.4	569.5	106.9	57.0	0.08	156.8	456.2	-6.3
Future	10	1989	365	775.6	643.1	132.5	72.4	0.09	182.3	513.7	-7.1
Future	10	1990	365	920.9	765.1	155.8	135.0	0.15	254.6	532.5	1.2
Future	10	1991	365	751.8	618.6	133.2	98.5	0.13	178.2	485.2	10.1
Future	10	1992	366	1064.9	934.7	130.2	145.1	0.14	382.8	531.9	-5.2

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	$P\text{-}Q_{out}$ [mm/yr]
Future	10	1993	365	798.7	676.6	122.1	84.6	0.11	190.1	539.0	15.0
Future	10	1994	365	754.4	580.0	174.4	91.7	0.12	128.7	527.4	-6.6
Future	10	1995	365	925.3	784.8	140.5	137.6	0.15	251.4	524.7	-11.5
Future	10	1996	366	1033.9	908.7	125.2	131.2	0.13	335.9	560.6	-6.2
Future	10	1997	365	761.9	567.5	194.4	118.2	0.16	131.5	533.3	21.0
Future	10	1998	365	733.8	627.2	106.6	68.3	0.09	164.0	501.3	-0.2
Future	10	1999	365	804.6	649.5	155.1	143.2	0.18	152.9	512.2	3.7
Future	10	2000	366	984.2	803.3	180.9	122.0	0.12	205.2	585.7	-71.2
Future	11	1986	223	832.5	784.0	48.5	205.9	0.25	247.1	340.6	-38.8
Future	11	1987	365	823.2	696.6	126.6	167.9	0.20	186.7	468.8	0.2
Future	11	1988	366	676.4	569.5	106.9	95.5	0.14	161.0	413.6	-6.3
Future	11	1989	365	775.6	643.1	132.5	118.2	0.15	172.5	474.7	-10.2
Future	11	1990	365	920.9	765.1	155.8	196.6	0.21	240.2	491.4	7.3
Future	11	1991	365	751.8	618.6	133.2	145.3	0.19	170.7	441.8	6.0
Future	11	1992	366	1064.9	934.7	130.2	219.3	0.21	352.1	490.2	-3.3
Future	11	1993	365	798.7	676.6	122.1	135.2	0.17	183.5	492.6	12.7
Future	11	1994	365	754.4	580.0	174.4	137.0	0.18	128.2	483.4	-5.8
Future	11	1995	365	925.3	784.8	140.5	201.1	0.22	228.6	483.1	-12.5
Future	11	1996	366	1033.9	908.7	125.2	200.0	0.19	315.3	516.4	-2.2
Future	11	1997	365	761.9	567.5	194.4	165.0	0.22	124.7	489.8	17.7
Future	11	1998	365	733.8	627.2	106.6	111.2	0.15	162.9	457.4	-2.2
Future	11	1999	365	804.6	649.5	155.1	198.3	0.25	146.9	465.8	6.4
Future	11	2000	366	984.2	803.3	180.9	184.9	0.19	193.7	533.4	-72.2
Future	11.1	1986	223	832.5	784.0	48.5	227.8	0.27	216.6	335.2	-52.9
Future	11.1	1987	365	823.2	696.6	126.6	181.6	0.22	169.9	471.4	-0.2
Future	11.1	1988	366	676.4	569.5	106.9	102.9	0.15	154.3	413.2	-6.0
Future	11.1	1989	365	775.6	643.1	132.5	128.1	0.17	157.7	478.3	-11.5
Future	11.1	1990	365	920.9	765.1	155.8	214.5	0.23	219.5	496.0	9.1
Future	11.1	1991	365	751.8	618.6	133.2	157.7	0.21	156.9	441.4	4.3
Future	11.1	1992	366	1064.9	934.7	130.2	245.7	0.23	320.8	495.6	-2.8
Future	11.1	1993	365	798.7	676.6	122.1	147.5	0.18	165.4	497.3	11.5
Future	11.1	1994	365	754.4	580.0	174.4	145.9	0.19	116.1	486.7	-5.6
Future	11.1	1995	365	925.3	784.8	140.5	222.3	0.24	204.8	485.2	-12.9
Future	11.1	1996	366	1033.9	908.7	125.2	220.6	0.21	287.7	524.3	-1.3
Future	11.1	1997	365	761.9	567.5	194.4	173.9	0.23	111.1	493.3	16.4
Future	11.1	1998	365	733.8	627.2	106.6	121.0	0.16	153.1	457.5	-2.2
Future	11.1	1999	365	804.6	649.5	155.1	212.5	0.26	132.6	465.5	6.0

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	P-Q_{out} [mm/yr]
Future	11.1	2000	366	984.2	803.3	180.9	202.0	0.21	165.9	544.0	-72.4
Future	12	1986	223	832.5	784.0	48.5	287.2	0.35	228.8	295.2	-21.2
Future	12	1987	365	823.2	696.6	126.6	252.9	0.31	169.6	401.8	1.1
Future	12	1988	366	676.4	569.5	106.9	171.0	0.25	145.7	354.0	-5.6
Future	12	1989	365	775.6	643.1	132.5	203.3	0.26	156.0	404.7	-11.7
Future	12	1990	365	920.9	765.1	155.8	292.7	0.32	219.2	421.3	12.3
Future	12	1991	365	751.8	618.6	133.2	223.4	0.30	156.1	377.5	5.3
Future	12	1992	366	1064.9	934.7	130.2	327.7	0.31	315.9	420.9	-0.5
Future	12	1993	365	798.7	676.6	122.1	221.8	0.28	167.9	420.0	10.9
Future	12	1994	365	754.4	580.0	174.4	215.9	0.29	119.4	414.2	-4.9
Future	12	1995	365	925.3	784.8	140.5	293.8	0.32	207.5	412.6	-11.4
Future	12	1996	366	1033.9	908.7	125.2	308.7	0.30	283.6	443.5	1.9
Future	12	1997	365	761.9	567.5	194.4	242.4	0.32	114.6	422.1	17.1
Future	12	1998	365	733.8	627.2	106.6	193.6	0.26	148.8	390.5	-1.0
Future	12	1999	365	804.6	649.5	155.1	280.1	0.35	134.9	396.8	7.2
Future	12	2000	366	984.2	803.3	180.9	278.7	0.28	178.4	455.2	-71.9
Future	13	1986	223	832.5	784.0	48.5	180.1	0.22	271.0	353.2	-28.3
Future	13	1987	365	823.2	696.6	126.6	147.2	0.18	197.9	478.1	0.0
Future	13	1988	366	676.4	569.5	106.9	81.1	0.12	166.4	422.0	-6.8
Future	13	1989	365	775.6	643.1	132.5	100.7	0.13	181.1	483.8	-9.9
Future	13	1990	365	920.9	765.1	155.8	172.0	0.19	255.8	499.9	6.8
Future	13	1991	365	751.8	618.6	133.2	127.0	0.17	180.5	450.7	6.3
Future	13	1992	366	1064.9	934.7	130.2	188.6	0.18	375.4	497.4	-3.5
Future	13	1993	365	798.7	676.6	122.1	115.7	0.14	194.1	502.1	13.1
Future	13	1994	365	754.4	580.0	174.4	120.4	0.16	135.5	492.5	-6.0
Future	13	1995	365	925.3	784.8	140.5	174.9	0.19	244.6	493.2	-12.5
Future	13	1996	366	1033.9	908.7	125.2	172.4	0.17	334.7	524.3	-2.5
Future	13	1997	365	761.9	567.5	194.4	148.1	0.19	133.5	498.1	17.8
Future	13	1998	365	733.8	627.2	106.6	94.4	0.13	170.9	466.0	-2.5
Future	13	1999	365	804.6	649.5	155.1	177.9	0.22	157.6	475.7	6.5
Future	13	2000	366	984.2	803.3	180.9	161.0	0.16	209.5	541.3	-72.4
Future	14	1986	223	832.5	784.0	48.5	181.4	0.22	270.3	353.8	-27.0
Future	14	1987	365	823.2	696.6	126.6	148.9	0.18	196.8	477.6	0.2
Future	14	1988	366	676.4	569.5	106.9	83.0	0.12	164.8	421.8	-6.8
Future	14	1989	365	775.6	643.1	132.5	102.7	0.13	179.9	483.3	-9.6
Future	14	1990	365	920.9	765.1	155.8	173.9	0.19	253.8	499.3	6.1
Future	14	1991	365	751.8	618.6	133.2	128.7	0.17	179.5	450.6	7.0

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	$P-Q_{out}$ [mm/yr]
Future	14	1992	366	1064.9	934.7	130.2	190.6	0.18	373.7	497.0	-3.6
Future	14	1993	365	798.7	676.6	122.1	117.6	0.15	192.6	501.8	13.3
Future	14	1994	365	754.4	580.0	174.4	122.1	0.16	134.5	491.7	-6.0
Future	14	1995	365	925.3	784.8	140.5	176.6	0.19	243.7	492.5	-12.5
Future	14	1996	366	1033.9	908.7	125.2	174.7	0.17	332.7	523.7	-2.7
Future	14	1997	365	761.9	567.5	194.4	149.8	0.20	133.2	497.1	18.2
Future	14	1998	365	733.8	627.2	106.6	96.5	0.13	169.3	465.7	-2.3
Future	14	1999	365	804.6	649.5	155.1	179.1	0.22	156.8	475.1	6.4
Future	14	2000	366	984.2	803.3	180.9	162.8	0.17	208.6	540.4	-72.3
Future	15	1986	223	832.5	784.0	48.5	78.2	0.09	425.2	405.1	76.0
Future	15	1987	365	823.2	696.6	126.6	67.1	0.08	227.9	528.1	-0.1
Future	15	1988	366	676.4	569.5	106.9	30.6	0.05	158.9	480.0	-6.9
Future	15	1989	365	775.6	643.1	132.5	39.2	0.05	201.6	530.6	-4.2
Future	15	1990	365	920.9	765.1	155.8	77.9	0.08	291.2	547.4	-4.4
Future	15	1991	365	751.8	618.6	133.2	57.4	0.08	202.2	508.3	16.1
Future	15	1992	366	1064.9	934.7	130.2	78.7	0.07	433.6	544.3	-8.3
Future	15	1993	365	798.7	676.6	122.1	45.3	0.06	215.3	556.0	17.9
Future	15	1994	365	754.4	580.0	174.4	54.5	0.07	147.3	544.7	-8.0
Future	15	1995	365	925.3	784.8	140.5	77.2	0.08	292.3	544.9	-10.9
Future	15	1996	366	1033.9	908.7	125.2	71.9	0.07	382.8	571.1	-8.1
Future	15	1997	365	761.9	567.5	194.4	75.3	0.10	158.6	552.3	24.3
Future	15	1998	365	733.8	627.2	106.6	36.7	0.05	178.0	526.3	7.2
Future	15	1999	365	804.6	649.5	155.1	90.1	0.11	173.0	537.1	-4.4
Future	15	2000	366	984.2	803.3	180.9	69.4	0.07	248.5	594.7	-71.6
Future	16	1986	223	832.5	784.0	48.5	119.8	0.14	338.5	389.2	14.9
Future	16	1987	365	823.2	696.6	126.6	99.5	0.12	219.6	504.1	-0.1
Future	16	1988	366	676.4	569.5	106.9	49.8	0.07	174.5	444.5	-7.7
Future	16	1989	365	775.6	643.1	132.5	62.4	0.08	195.5	510.0	-7.7
Future	16	1990	365	920.9	765.1	155.8	115.4	0.13	283.4	524.6	2.4
Future	16	1991	365	751.8	618.6	133.2	85.2	0.11	200.6	475.8	9.8
Future	16	1992	366	1064.9	934.7	130.2	120.8	0.11	418.4	520.8	-4.9
Future	16	1993	365	798.7	676.6	122.1	72.0	0.09	210.3	531.6	15.2
Future	16	1994	365	754.4	580.0	174.4	81.4	0.11	148.8	517.2	-7.0
Future	16	1995	365	925.3	784.8	140.5	115.4	0.12	277.5	520.4	-12.0
Future	16	1996	366	1033.9	908.7	125.2	110.8	0.11	368.0	550.4	-4.7
Future	16	1997	365	761.9	567.5	194.4	106.8	0.14	154.5	520.3	19.8
Future	16	1998	365	733.8	627.2	106.6	58.2	0.08	183.4	490.2	-2.1

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	P-Q_{out} [mm/yr]
Future	16	1999	365	804.6	649.5	155.1	127.9	0.16	181.3	501.4	6.0
Future	16	2000	366	984.2	803.3	180.9	106.2	0.11	237.5	568.0	-72.6
Future	17	1986	223	832.5	784.0	48.5	131.6	0.16	322.3	378.7	0.1
Future	17	1987	365	823.2	696.6	126.6	108.1	0.13	215.9	499.2	0.1
Future	17	1988	366	676.4	569.5	106.9	54.8	0.08	169.7	444.8	-7.1
Future	17	1989	365	775.6	643.1	132.5	68.8	0.09	194.4	505.0	-7.4
Future	17	1990	365	920.9	765.1	155.8	125.7	0.14	277.6	519.5	1.9
Future	17	1991	365	751.8	618.6	133.2	92.5	0.12	194.5	474.8	10.1
Future	17	1992	366	1064.9	934.7	130.2	132.9	0.12	410.7	516.1	-5.2
Future	17	1993	365	798.7	676.6	122.1	79.7	0.10	210.2	524.2	15.3
Future	17	1994	365	754.4	580.0	174.4	88.3	0.12	146.4	512.9	-6.8
Future	17	1995	365	925.3	784.8	140.5	126.2	0.14	271.5	515.6	-12.0
Future	17	1996	366	1033.9	908.7	125.2	121.9	0.12	364.9	542.0	-5.1
Future	17	1997	365	761.9	567.5	194.4	114.4	0.15	150.0	517.8	20.3
Future	17	1998	365	733.8	627.2	106.6	64.1	0.09	177.8	490.4	-1.6
Future	17	1999	365	804.6	649.5	155.1	136.7	0.17	173.4	499.9	5.4
Future	17	2000	366	984.2	803.3	180.9	116.2	0.12	237.3	558.4	-72.3
Future	18	1986	223	832.5	784.0	48.5	155.1	0.19	287.5	370.4	-19.4
Future	18	1987	365	823.2	696.6	126.6	125.9	0.15	204.7	492.7	0.0
Future	18	1988	366	676.4	569.5	106.9	65.6	0.10	169.2	434.5	-7.1
Future	18	1989	365	775.6	643.1	132.5	82.1	0.11	185.6	498.8	-9.1
Future	18	1990	365	920.9	765.1	155.8	147.0	0.16	264.6	514.3	5.1
Future	18	1991	365	751.8	618.6	133.2	108.1	0.14	186.7	464.5	7.5
Future	18	1992	366	1064.9	934.7	130.2	158.7	0.15	390.8	511.3	-4.1
Future	18	1993	365	798.7	676.6	122.1	95.3	0.12	198.6	518.7	13.9
Future	18	1994	365	754.4	580.0	174.4	102.5	0.14	138.8	506.8	-6.3
Future	18	1995	365	925.3	784.8	140.5	149.0	0.16	255.4	508.4	-12.5
Future	18	1996	366	1033.9	908.7	125.2	144.7	0.14	345.9	539.9	-3.4
Future	18	1997	365	761.9	567.5	194.4	129.9	0.17	139.5	511.0	18.4
Future	18	1998	365	733.8	627.2	106.6	76.8	0.10	175.2	479.5	-2.2
Future	18	1999	365	804.6	649.5	155.1	156.3	0.19	164.7	489.9	6.3
Future	18	2000	366	984.2	803.3	180.9	136.7	0.14	217.4	557.5	-72.6
Future	19	1986	223	832.5	784.0	48.5	157.5	0.19	295.2	368.1	-11.7
Future	19	1987	365	823.2	696.6	126.6	130.4	0.16	205.5	487.6	0.3
Future	19	1988	366	676.4	569.5	106.9	71.1	0.11	166.0	432.1	-7.2
Future	19	1989	365	775.6	643.1	132.5	88.0	0.11	185.7	493.3	-8.7
Future	19	1990	365	920.9	765.1	155.8	151.8	0.16	265.1	508.4	4.4

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	$P-Q_{out}$ [mm/yr]
Future	19	1991	365	751.8	618.6	133.2	112.4	0.15	186.2	461.5	8.3
Future	19	1992	366	1064.9	934.7	130.2	163.5	0.15	391.9	505.2	-4.3
Future	19	1993	365	798.7	676.6	122.1	100.7	0.13	199.7	512.7	14.3
Future	19	1994	365	754.4	580.0	174.4	107.3	0.14	139.1	501.4	-6.5
Future	19	1995	365	925.3	784.8	140.5	152.8	0.17	257.1	503.2	-12.2
Future	19	1996	366	1033.9	908.7	125.2	150.6	0.15	347.6	532.2	-3.6
Future	19	1997	365	761.9	567.5	194.4	134.1	0.18	140.8	506.0	19.0
Future	19	1998	365	733.8	627.2	106.6	82.5	0.11	172.9	476.3	-2.1
Future	19	1999	365	804.6	649.5	155.1	159.6	0.20	165.1	486.1	6.1
Future	19	2000	366	984.2	803.3	180.9	141.4	0.14	221.8	548.6	-72.4
Future	20	1986	223	832.5	784.0	48.5	168.7	0.20	282.8	356.5	-24.6
Future	20	1987	365	823.2	696.6	126.6	137.4	0.17	205.1	480.8	0.1
Future	20	1988	366	676.4	569.5	106.9	73.8	0.11	171.0	424.7	-7.0
Future	20	1989	365	775.6	643.1	132.5	92.1	0.12	187.2	486.5	-9.8
Future	20	1990	365	920.9	765.1	155.8	160.5	0.17	264.1	502.4	6.1
Future	20	1991	365	751.8	618.6	133.2	118.2	0.16	186.9	453.7	6.9
Future	20	1992	366	1064.9	934.7	130.2	174.5	0.16	386.8	499.9	-3.6
Future	20	1993	365	798.7	676.6	122.1	106.2	0.13	201.5	504.3	13.4
Future	20	1994	365	754.4	580.0	174.4	112.1	0.15	141.0	495.0	-6.3
Future	20	1995	365	925.3	784.8	140.5	163.1	0.18	253.4	496.3	-12.5
Future	20	1996	366	1033.9	908.7	125.2	159.4	0.15	345.3	526.4	-2.8
Future	20	1997	365	761.9	567.5	194.4	139.7	0.18	139.1	501.1	18.0
Future	20	1998	365	733.8	627.2	106.6	86.1	0.12	175.8	469.4	-2.5
Future	20	1999	365	804.6	649.5	155.1	168.3	0.21	163.6	479.2	6.5
Future	20	2000	366	984.2	803.3	180.9	149.7	0.15	218.6	543.4	-72.5
Future	21	1986	223	832.5	784.0	48.5	361.2	0.43	179.0	257.8	-34.5
Future	21	1987	365	823.2	696.6	126.6	316.8	0.38	144.1	363.7	1.5
Future	21	1988	366	676.4	569.5	106.9	220.2	0.33	134.1	318.2	-3.8
Future	21	1989	365	775.6	643.1	132.5	261.5	0.34	134.6	365.5	-14.0
Future	21	1990	365	920.9	765.1	155.8	367.3	0.40	187.8	383.6	17.8
Future	21	1991	365	751.8	618.6	133.2	281.0	0.37	135.0	339.2	3.4
Future	21	1992	366	1064.9	934.7	130.2	420.0	0.39	257.3	389.7	2.1
Future	21	1993	365	798.7	676.6	122.1	284.2	0.36	141.1	382.3	8.9
Future	21	1994	365	754.4	580.0	174.4	270.0	0.36	105.3	375.4	-3.7
Future	21	1995	365	925.3	784.8	140.5	373.1	0.40	170.6	370.9	-10.8
Future	21	1996	366	1033.9	908.7	125.2	392.4	0.38	235.8	411.3	5.7
Future	21	1997	365	761.9	567.5	194.4	295.5	0.39	93.6	388.7	15.9

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	$P-Q_{out}$ [mm/yr]
Future	21	1998	365	733.8	627.2	106.6	250.1	0.34	130.6	353.5	0.4
Future	21	1999	365	804.6	649.5	155.1	345.4	0.43	113.2	353.0	7.0
Future	21	2000	366	984.2	803.3	180.9	351.3	0.36	137.0	424.9	-71.1
Future	21.1	1986	223	832.5	784.0	48.5	120.1	0.14	346.7	385.1	19.4
Future	21.1	1987	365	823.2	696.6	126.6	100.6	0.12	222.0	500.7	0.1
Future	21.1	1988	366	676.4	569.5	106.9	51.4	0.08	174.4	443.1	-7.5
Future	21.1	1989	365	775.6	643.1	132.5	64.2	0.08	198.0	506.2	-7.2
Future	21.1	1990	365	920.9	765.1	155.8	116.6	0.13	285.1	520.8	1.5
Future	21.1	1991	365	751.8	618.6	133.2	86.3	0.11	201.9	474.1	10.5
Future	21.1	1992	366	1064.9	934.7	130.2	122.0	0.11	420.4	517.4	-5.1
Future	21.1	1993	365	798.7	676.6	122.1	73.6	0.09	213.9	526.8	15.5
Future	21.1	1994	365	754.4	580.0	174.4	82.7	0.11	151.3	513.5	-6.9
Future	21.1	1995	365	925.3	784.8	140.5	116.3	0.13	280.1	516.9	-12.0
Future	21.1	1996	366	1033.9	908.7	125.2	112.4	0.11	371.3	545.1	-5.1
Future	21.1	1997	365	761.9	567.5	194.4	107.7	0.14	157.2	517.5	20.5
Future	21.1	1998	365	733.8	627.2	106.6	59.9	0.08	183.1	488.8	-2.0
Future	21.1	1999	365	804.6	649.5	155.1	128.4	0.16	182.7	499.3	5.9
Future	21.1	2000	366	984.2	803.3	180.9	107.4	0.11	242.4	562.0	-72.4
Future	22	1986	223	832.5	784.0	48.5	244.5	0.29	214.7	325.4	-48.0
Future	22	1987	365	823.2	696.6	126.6	199.6	0.24	168.6	454.7	-0.3
Future	22	1988	366	676.4	569.5	106.9	119.4	0.18	156.7	394.5	-5.8
Future	22	1989	365	775.6	643.1	132.5	146.2	0.19	155.9	460.5	-13.0
Future	22	1990	365	920.9	765.1	155.8	234.5	0.25	219.4	478.9	11.9
Future	22	1991	365	751.8	618.6	133.2	174.4	0.23	159.0	421.6	3.3
Future	22	1992	366	1064.9	934.7	130.2	268.0	0.25	315.5	479.4	-2.0
Future	22	1993	365	798.7	676.6	122.1	165.6	0.21	163.9	479.8	10.6
Future	22	1994	365	754.4	580.0	174.4	163.0	0.22	117.7	468.2	-5.4
Future	22	1995	365	925.3	784.8	140.5	242.2	0.26	203.0	467.2	-12.9
Future	22	1996	366	1033.9	908.7	125.2	242.2	0.23	282.5	509.9	0.7
Future	22	1997	365	761.9	567.5	194.4	190.6	0.25	110.1	476.5	15.4
Future	22	1998	365	733.8	627.2	106.6	139.1	0.19	155.4	437.6	-1.7
Future	22	1999	365	804.6	649.5	155.1	232.4	0.29	133.1	444.9	5.8
Future	22	2000	366	984.2	803.3	180.9	220.9	0.22	159.8	530.9	-72.6
Future	23	1986	223	832.5	784.0	48.5	366.2	0.44	176.0	263.3	-27.0
Future	23	1987	365	823.2	696.6	126.6	320.1	0.39	143.5	360.9	1.3
Future	23	1988	366	676.4	569.5	106.9	222.6	0.33	135.6	314.7	-3.5
Future	23	1989	365	775.6	643.1	132.5	264.6	0.34	133.7	362.5	-14.8

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	P-Q_{out} [mm/yr]
Future	23	1990	365	920.9	765.1	155.8	371.2	0.40	188.3	380.3	18.9
Future	23	1991	365	751.8	618.6	133.2	284.2	0.38	135.3	335.3	3.0
Future	23	1992	366	1064.9	934.7	130.2	425.4	0.40	251.1	390.7	2.3
Future	23	1993	365	798.7	676.6	122.1	287.2	0.36	138.5	381.5	8.4
Future	23	1994	365	754.4	580.0	174.4	272.6	0.36	105.6	372.6	-3.7
Future	23	1995	365	925.3	784.8	140.5	378.6	0.41	169.2	366.7	-10.8
Future	23	1996	366	1033.9	908.7	125.2	396.2	0.38	231.4	412.6	6.3
Future	23	1997	365	761.9	567.5	194.4	297.7	0.39	93.4	386.4	15.7
Future	23	1998	365	733.8	627.2	106.6	253.1	0.34	131.0	350.2	0.5
Future	23	1999	365	804.6	649.5	155.1	350.1	0.44	114.6	346.7	6.7
Future	23	2000	366	984.2	803.3	180.9	354.7	0.36	130.0	428.4	-71.1
Future	24	1986	223	832.5	784.0	48.5	268.8	0.32	221.1	305.8	-36.8
Future	24	1987	365	823.2	696.6	126.6	228.7	0.28	169.8	425.4	0.8
Future	24	1988	366	676.4	569.5	106.9	146.5	0.22	148.1	376.2	-5.7
Future	24	1989	365	775.6	643.1	132.5	176.9	0.23	157.6	430.0	-11.1
Future	24	1990	365	920.9	765.1	155.8	266.5	0.29	218.1	446.9	10.6
Future	24	1991	365	751.8	618.6	133.2	200.7	0.27	155.4	401.1	5.3
Future	24	1992	366	1064.9	934.7	130.2	300.4	0.28	316.3	446.8	-1.4
Future	24	1993	365	798.7	676.6	122.1	196.3	0.25	168.1	445.7	11.4
Future	24	1994	365	754.4	580.0	174.4	191.5	0.25	118.5	439.4	-5.0
Future	24	1995	365	925.3	784.8	140.5	270.4	0.29	205.5	437.6	-11.8
Future	24	1996	366	1033.9	908.7	125.2	278.9	0.27	285.6	469.8	0.4
Future	24	1997	365	761.9	567.5	194.4	218.7	0.29	112.8	447.6	17.2
Future	24	1998	365	733.8	627.2	106.6	167.7	0.23	149.0	415.6	-1.5
Future	24	1999	365	804.6	649.5	155.1	257.2	0.32	132.4	421.9	6.9
Future	24	2000	366	984.2	803.3	180.9	253.0	0.26	175.7	483.7	-71.8
Future	25	1986	223	832.5	784.0	48.5	338.2	0.41	203.9	267.6	-22.8
Future	25	1987	365	823.2	696.6	126.6	300.9	0.37	156.0	367.8	1.5
Future	25	1988	366	676.4	569.5	106.9	210.6	0.31	138.9	322.4	-4.6
Future	25	1989	365	775.6	643.1	132.5	248.8	0.32	144.5	369.2	-13.1
Future	25	1990	365	920.9	765.1	155.8	347.9	0.38	202.5	386.6	16.1
Future	25	1991	365	751.8	618.6	133.2	267.0	0.36	144.9	344.1	4.2
Future	25	1992	366	1064.9	934.7	130.2	392.7	0.37	285.0	388.7	1.4
Future	25	1993	365	798.7	676.6	122.1	269.5	0.34	154.4	384.4	9.6
Future	25	1994	365	754.4	580.0	174.4	258.5	0.34	112.8	379.1	-4.0
Future	25	1995	365	925.3	784.8	140.5	349.7	0.38	188.6	376.1	-10.9
Future	25	1996	366	1033.9	908.7	125.2	370.6	0.36	257.6	410.3	4.5

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	$P-Q_{out}$ [mm/yr]
Future	25	1997	365	761.9	567.5	194.4	284.7	0.37	104.0	389.8	16.5
Future	25	1998	365	733.8	627.2	106.6	237.7	0.32	139.4	356.7	-0.1
Future	25	1999	365	804.6	649.5	155.1	328.0	0.41	123.5	360.4	7.2
Future	25	2000	366	984.2	803.3	180.9	332.6	0.34	159.2	421.1	-71.3
Future	26	1986	223	832.5	784.0	48.5	433.1	0.52	144.8	229.5	-25.1
Future	26	1987	365	823.2	696.6	126.6	386.2	0.47	118.7	319.8	1.4
Future	26	1988	366	676.4	569.5	106.9	279.3	0.41	111.8	282.0	-3.3
Future	26	1989	365	775.6	643.1	132.5	329.3	0.42	111.0	320.7	-14.6
Future	26	1990	365	920.9	765.1	155.8	446.9	0.49	154.8	338.5	19.3
Future	26	1991	365	751.8	618.6	133.2	344.4	0.46	111.0	299.2	2.8
Future	26	1992	366	1064.9	934.7	130.2	513.1	0.48	207.8	346.9	2.9
Future	26	1993	365	798.7	676.6	122.1	354.3	0.44	115.3	336.5	7.4
Future	26	1994	365	754.4	580.0	174.4	332.2	0.44	87.1	331.5	-3.7
Future	26	1995	365	925.3	784.8	140.5	452.0	0.49	138.5	324.1	-10.7
Future	26	1996	366	1033.9	908.7	125.2	483.0	0.47	192.9	364.9	6.8
Future	26	1997	365	761.9	567.5	194.4	356.1	0.47	76.6	344.7	15.5
Future	26	1998	365	733.8	627.2	106.6	315.5	0.43	107.2	311.9	0.7
Future	26	1999	365	804.6	649.5	155.1	410.9	0.51	92.8	307.4	6.4
Future	26	2000	366	984.2	803.3	180.9	428.9	0.44	109.4	374.7	-71.2
Future	27	1986	223	832.5	784.0	48.5	320.2	0.38	212.8	285.4	-14.0
Future	27	1987	365	823.2	696.6	126.6	287.9	0.35	155.0	381.4	1.1
Future	27	1988	366	676.4	569.5	106.9	202.8	0.30	132.2	336.0	-5.4
Future	27	1989	365	775.6	643.1	132.5	239.0	0.31	142.7	381.7	-12.2
Future	27	1990	365	920.9	765.1	155.8	333.3	0.36	200.4	401.0	13.8
Future	27	1991	365	751.8	618.6	133.2	256.5	0.34	143.1	356.9	4.8
Future	27	1992	366	1064.9	934.7	130.2	373.7	0.35	289.7	401.8	0.3
Future	27	1993	365	798.7	676.6	122.1	257.7	0.32	150.8	400.1	9.8
Future	27	1994	365	754.4	580.0	174.4	247.9	0.33	106.0	395.9	-4.6
Future	27	1995	365	925.3	784.8	140.5	333.4	0.36	191.0	389.9	-11.0
Future	27	1996	366	1033.9	908.7	125.2	354.4	0.34	256.7	425.5	2.7
Future	27	1997	365	761.9	567.5	194.4	272.9	0.36	102.9	402.8	16.7
Future	27	1998	365	733.8	627.2	106.6	229.0	0.31	136.1	368.1	-0.6
Future	27	1999	365	804.6	649.5	155.1	312.7	0.39	123.6	375.2	6.9
Future	27	2000	366	984.2	803.3	180.9	315.8	0.32	155.8	441.1	-71.5
Future	28	1986	223	832.5	784.0	48.5	429.7	0.52	142.7	236.2	-23.9
Future	28	1987	365	823.2	696.6	126.6	391.3	0.48	109.2	323.3	0.5
Future	28	1988	366	676.4	569.5	106.9	288.4	0.43	96.0	287.1	-4.8

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	P-Q_{out} [mm/yr]
Future	28	1989	365	775.6	643.1	132.5	337.4	0.44	102.0	323.4	-12.7
Future	28	1990	365	920.9	765.1	155.8	452.4	0.49	139.5	342.2	13.3
Future	28	1991	365	751.8	618.6	133.2	350.6	0.47	101.2	303.9	3.9
Future	28	1992	366	1064.9	934.7	130.2	513.8	0.48	205.2	345.9	0.0
Future	28	1993	365	798.7	676.6	122.1	360.7	0.45	105.7	339.9	7.5
Future	28	1994	365	754.4	580.0	174.4	339.1	0.45	73.5	336.6	-5.3
Future	28	1995	365	925.3	784.8	140.5	451.9	0.49	134.0	327.6	-11.7
Future	28	1996	366	1033.9	908.7	125.2	489.6	0.47	181.5	365.0	2.3
Future	28	1997	365	761.9	567.5	194.4	363.2	0.48	71.9	343.0	16.1
Future	28	1998	365	733.8	627.2	106.6	324.0	0.44	96.6	312.3	-0.9
Future	28	1999	365	804.6	649.5	155.1	410.3	0.51	86.0	313.7	5.3
Future	28	2000	366	984.2	803.3	180.9	431.6	0.44	105.4	374.9	-72.3
Future + Nat Heritage	1	1986	223	832.5	784.0	48.5	180.3	0.22	260.9	360.3	-31.0
Future + Nat Heritage	1	1987	365	823.2	696.6	126.6	146.5	0.18	190.0	487.5	0.8
Future + Nat Heritage	1	1988	366	676.4	569.5	106.9	80.2	0.12	156.5	433.7	-6.0
Future + Nat Heritage	1	1989	365	775.6	643.1	132.5	99.5	0.13	174.2	493.7	-8.1
Future + Nat Heritage	1	1990	365	920.9	765.1	155.8	171.4	0.19	244.9	509.1	4.5
Future + Nat Heritage	1	1991	365	751.8	618.6	133.2	126.2	0.17	171.4	463.0	8.9
Future + Nat Heritage	1	1992	366	1064.9	934.7	130.2	188.6	0.18	365.6	506.9	-3.7
Future + Nat Heritage	1	1993	365	798.7	676.6	122.1	114.8	0.14	184.6	513.7	14.4
Future + Nat Heritage	1	1994	365	754.4	580.0	174.4	119.4	0.16	127.2	501.9	-5.9
Future + Nat Heritage	1	1995	365	925.3	784.8	140.5	174.2	0.19	237.1	502.5	-11.5
Future + Nat Heritage	1	1996	366	1033.9	908.7	125.2	172.4	0.17	324.7	533.1	-3.7
Future + Nat Heritage	1	1997	365	761.9	567.5	194.4	147.4	0.19	127.9	506.8	20.2
Future + Nat Heritage	1	1998	365	733.8	627.2	106.6	93.6	0.13	160.9	478.1	-1.2
Future + Nat Heritage	1	1999	365	804.6	649.5	155.1	175.4	0.22	148.7	486.4	5.9
Future + Nat Heritage	1	2000	366	984.2	803.3	180.9	160.6	0.16	202.4	549.7	-71.5
Future + Nat Heritage	2	1986	223	832.5	784.0	48.5	322.8	0.39	188.7	282.7	-38.3
Future + Nat Heritage	2	1987	365	823.2	696.6	126.6	279.0	0.34	148.3	397.0	1.1
Future + Nat Heritage	2	1988	366	676.4	569.5	106.9	187.9	0.28	135.1	348.7	-4.7
Future + Nat Heritage	2	1989	365	775.6	643.1	132.5	224.5	0.29	138.1	400.8	-12.2
Future + Nat Heritage	2	1990	365	920.9	765.1	155.8	324.7	0.35	191.6	418.5	13.9
Future + Nat Heritage	2	1991	365	751.8	618.6	133.2	246.6	0.33	137.8	371.6	4.3
Future + Nat Heritage	2	1992	366	1064.9	934.7	130.2	370.2	0.35	275.4	419.6	0.3
Future + Nat Heritage	2	1993	365	798.7	676.6	122.1	246.3	0.31	145.9	416.7	10.2
Future + Nat Heritage	2	1994	365	754.4	580.0	174.4	235.6	0.31	104.4	410.1	-4.4
Future + Nat Heritage	2	1995	365	925.3	784.8	140.5	329.4	0.36	177.7	407.0	-11.2

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	$P-Q_{out}$ [mm/yr]
Future + Nat Heritage	2	1996	366	1033.9	908.7	125.2	344.8	0.33	248.8	443.2	2.8
Future + Nat Heritage	2	1997	365	761.9	567.5	194.4	262.2	0.34	97.4	418.9	16.6
Future + Nat Heritage	2	1998	365	733.8	627.2	106.6	214.1	0.29	133.9	385.1	-0.7
Future + Nat Heritage	2	1999	365	804.6	649.5	155.1	306.4	0.38	115.7	389.5	7.0
Future + Nat Heritage	2	2000	366	984.2	803.3	180.9	309.6	0.31	146.7	456.5	-71.4
Future + Nat Heritage	3	1986	223	832.5	784.0	48.5	182.2	0.22	268.3	356.8	-25.2
Future + Nat Heritage	3	1987	365	823.2	696.6	126.6	150.6	0.18	193.0	479.8	0.3
Future + Nat Heritage	3	1988	366	676.4	569.5	106.9	85.3	0.13	158.6	425.8	-6.7
Future + Nat Heritage	3	1989	365	775.6	643.1	132.5	104.9	0.14	175.9	485.7	-9.0
Future + Nat Heritage	3	1990	365	920.9	765.1	155.8	175.8	0.19	249.3	501.1	5.4
Future + Nat Heritage	3	1991	365	751.8	618.6	133.2	130.4	0.17	174.7	454.4	7.6
Future + Nat Heritage	3	1992	366	1064.9	934.7	130.2	192.6	0.18	370.0	498.5	-3.8
Future + Nat Heritage	3	1993	365	798.7	676.6	122.1	119.7	0.15	187.7	504.9	13.6
Future + Nat Heritage	3	1994	365	754.4	580.0	174.4	124.1	0.16	130.1	494.1	-6.2
Future + Nat Heritage	3	1995	365	925.3	784.8	140.5	177.7	0.19	240.6	494.7	-12.2
Future + Nat Heritage	3	1996	366	1033.9	908.7	125.2	177.3	0.17	328.5	524.9	-3.3
Future + Nat Heritage	3	1997	365	761.9	567.5	194.4	151.5	0.20	130.4	498.9	18.9
Future + Nat Heritage	3	1998	365	733.8	627.2	106.6	98.8	0.13	163.9	469.2	-1.9
Future + Nat Heritage	3	1999	365	804.6	649.5	155.1	179.7	0.22	153.0	478.0	6.1
Future + Nat Heritage	3	2000	366	984.2	803.3	180.9	164.8	0.17	206.0	541.1	-72.3
Future + Nat Heritage	4	1986	223	832.5	784.0	48.5	192.9	0.23	246.1	352.0	-41.5
Future + Nat Heritage	4	1987	365	823.2	696.6	126.6	154.3	0.19	185.9	482.9	0.0
Future + Nat Heritage	4	1988	366	676.4	569.5	106.9	83.8	0.12	161.4	424.9	-6.4
Future + Nat Heritage	4	1989	365	775.6	643.1	132.5	104.6	0.13	171.7	489.5	-9.8
Future + Nat Heritage	4	1990	365	920.9	765.1	155.8	181.3	0.20	239.5	506.2	6.2
Future + Nat Heritage	4	1991	365	751.8	618.6	133.2	133.1	0.18	170.7	454.4	6.4
Future + Nat Heritage	4	1992	366	1064.9	934.7	130.2	202.4	0.19	353.9	505.0	-3.6
Future + Nat Heritage	4	1993	365	798.7	676.6	122.1	121.3	0.15	181.2	509.2	13.0
Future + Nat Heritage	4	1994	365	754.4	580.0	174.4	124.4	0.16	126.3	497.7	-6.0
Future + Nat Heritage	4	1995	365	925.3	784.8	140.5	186.4	0.20	229.0	497.4	-12.5
Future + Nat Heritage	4	1996	366	1033.9	908.7	125.2	182.9	0.18	314.8	533.3	-3.0
Future + Nat Heritage	4	1997	365	761.9	567.5	194.4	152.8	0.20	124.2	502.9	17.9
Future + Nat Heritage	4	1998	365	733.8	627.2	106.6	98.4	0.13	163.1	469.9	-2.4
Future + Nat Heritage	4	1999	365	804.6	649.5	155.1	185.1	0.23	147.0	478.8	6.2
Future + Nat Heritage	4	2000	366	984.2	803.3	180.9	169.9	0.17	190.3	551.8	-72.2
Future + Nat Heritage	5	1986	223	832.5	784.0	48.5	64.1	0.08	449.5	431.8	112.9
Future + Nat Heritage	5	1987	365	823.2	696.6	126.6	55.5	0.07	207.8	557.9	-1.9

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	$P-Q_{out}$ [mm/yr]
Future + Nat Heritage	5	1988	366	676.4	569.5	106.9	24.4	0.04	137.5	513.5	-1.1
Future + Nat Heritage	5	1989	365	775.6	643.1	132.5	31.3	0.04	183.1	558.1	-3.1
Future + Nat Heritage	5	1990	365	920.9	765.1	155.8	64.4	0.07	269.1	574.8	-12.6
Future + Nat Heritage	5	1991	365	751.8	618.6	133.2	47.3	0.06	198.0	544.3	37.9
Future + Nat Heritage	5	1992	366	1064.9	934.7	130.2	64.4	0.06	403.2	570.4	-27.0
Future + Nat Heritage	5	1993	365	798.7	676.6	122.1	36.4	0.05	195.3	588.7	21.7
Future + Nat Heritage	5	1994	365	754.4	580.0	174.4	44.9	0.06	129.4	572.2	-8.0
Future + Nat Heritage	5	1995	365	925.3	784.8	140.5	63.2	0.07	274.8	575.8	-11.5
Future + Nat Heritage	5	1996	366	1033.9	908.7	125.2	58.8	0.06	366.7	596.8	-11.7
Future + Nat Heritage	5	1997	365	761.9	567.5	194.4	63.9	0.08	156.9	582.7	41.6
Future + Nat Heritage	5	1998	365	733.8	627.2	106.6	29.5	0.04	168.6	562.9	27.3
Future + Nat Heritage	5	1999	365	804.6	649.5	155.1	74.1	0.09	122.6	572.0	-35.9
Future + Nat Heritage	5	2000	366	984.2	803.3	180.9	57.2	0.06	235.8	620.8	-70.4
Future + Nat Heritage	6	1986	223	832.5	784.0	48.5	164.7	0.20	237.2	393.2	-37.4
Future + Nat Heritage	6	1987	365	823.2	696.6	126.6	131.4	0.16	172.4	519.7	0.3
Future + Nat Heritage	6	1988	366	676.4	569.5	106.9	67.6	0.10	143.7	458.8	-6.2
Future + Nat Heritage	6	1989	365	775.6	643.1	132.5	84.3	0.11	157.0	525.7	-8.6
Future + Nat Heritage	6	1990	365	920.9	765.1	155.8	155.2	0.17	225.1	544.5	3.8
Future + Nat Heritage	6	1991	365	751.8	618.6	133.2	113.8	0.15	156.8	489.4	8.3
Future + Nat Heritage	6	1992	366	1064.9	934.7	130.2	172.2	0.16	343.3	544.7	-4.7
Future + Nat Heritage	6	1993	365	798.7	676.6	122.1	99.0	0.12	156.2	557.4	14.0
Future + Nat Heritage	6	1994	365	754.4	580.0	174.4	104.3	0.14	107.1	536.7	-6.2
Future + Nat Heritage	6	1995	365	925.3	784.8	140.5	160.0	0.17	219.9	533.5	-11.9
Future + Nat Heritage	6	1996	366	1033.9	908.7	125.2	153.9	0.15	294.3	581.0	-4.6
Future + Nat Heritage	6	1997	365	761.9	567.5	194.4	132.3	0.17	109.6	539.4	19.5
Future + Nat Heritage	6	1998	365	733.8	627.2	106.6	81.2	0.11	150.4	503.0	0.8
Future + Nat Heritage	6	1999	365	804.6	649.5	155.1	160.2	0.20	131.7	515.4	2.7
Future + Nat Heritage	6	2000	366	984.2	803.3	180.9	141.4	0.14	160.4	611.0	-71.3
Future + Nat Heritage	7	1986	223	832.5	784.0	48.5	109.4	0.13	322.8	411.9	11.6
Future + Nat Heritage	7	1987	365	823.2	696.6	126.6	90.0	0.11	200.9	532.2	-0.1
Future + Nat Heritage	7	1988	366	676.4	569.5	106.9	42.7	0.06	147.3	480.0	-6.4
Future + Nat Heritage	7	1989	365	775.6	643.1	132.5	54.2	0.07	179.5	536.1	-5.8
Future + Nat Heritage	7	1990	365	920.9	765.1	155.8	105.3	0.11	260.7	553.4	-1.5
Future + Nat Heritage	7	1991	365	751.8	618.6	133.2	77.0	0.10	179.1	509.9	14.1
Future + Nat Heritage	7	1992	366	1064.9	934.7	130.2	110.1	0.10	396.3	550.7	-7.8
Future + Nat Heritage	7	1993	365	798.7	676.6	122.1	63.5	0.08	186.1	565.5	16.4
Future + Nat Heritage	7	1994	365	754.4	580.0	174.4	72.6	0.10	125.7	548.9	-7.2

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	$P-Q_{out}$ [mm/yr]
Future + Nat Heritage	7	1995	365	925.3	784.8	140.5	105.8	0.11	259.6	548.8	-11.1
Future + Nat Heritage	7	1996	366	1033.9	908.7	125.2	100.1	0.10	345.2	581.5	-7.2
Future + Nat Heritage	7	1997	365	761.9	567.5	194.4	96.9	0.13	133.7	554.7	23.4
Future + Nat Heritage	7	1998	365	733.8	627.2	106.6	51.2	0.07	166.0	525.6	9.0
Future + Nat Heritage	7	1999	365	804.6	649.5	155.1	115.6	0.14	145.2	537.1	-6.6
Future + Nat Heritage	7	2000	366	984.2	803.3	180.9	94.8	0.10	211.3	606.8	-71.3
Future + Nat Heritage	8	1986	223	832.5	784.0	48.5	139.7	0.17	287.7	390.6	-14.5
Future + Nat Heritage	8	1987	365	823.2	696.6	126.6	113.3	0.14	199.6	510.3	0.0
Future + Nat Heritage	8	1988	366	676.4	569.5	106.9	56.8	0.08	160.1	452.3	-7.2
Future + Nat Heritage	8	1989	365	775.6	643.1	132.5	71.7	0.09	180.5	514.8	-8.6
Future + Nat Heritage	8	1990	365	920.9	765.1	155.8	133.2	0.14	258.4	533.5	4.2
Future + Nat Heritage	8	1991	365	751.8	618.6	133.2	97.6	0.13	181.0	481.2	8.0
Future + Nat Heritage	8	1992	366	1064.9	934.7	130.2	142.6	0.13	386.5	531.5	-4.3
Future + Nat Heritage	8	1993	365	798.7	676.6	122.1	83.5	0.10	188.1	541.3	14.2
Future + Nat Heritage	8	1994	365	754.4	580.0	174.4	91.2	0.12	128.7	528.0	-6.6
Future + Nat Heritage	8	1995	365	925.3	784.8	140.5	135.5	0.15	252.5	525.4	-11.9
Future + Nat Heritage	8	1996	366	1033.9	908.7	125.2	129.1	0.12	336.8	564.0	-4.0
Future + Nat Heritage	8	1997	365	761.9	567.5	194.4	117.4	0.15	131.4	531.8	18.7
Future + Nat Heritage	8	1998	365	733.8	627.2	106.6	67.8	0.09	168.2	496.2	-1.7
Future + Nat Heritage	8	1999	365	804.6	649.5	155.1	142.7	0.18	158.3	509.2	5.6
Future + Nat Heritage	8	2000	366	984.2	803.3	180.9	120.6	0.12	201.3	590.5	-71.9
Future + Nat Heritage	9	1986	223	832.5	784.0	48.5	180.1	0.22	235.4	373.3	-43.6
Future + Nat Heritage	9	1987	365	823.2	696.6	126.6	143.2	0.17	174.7	505.3	0.1
Future + Nat Heritage	9	1988	366	676.4	569.5	106.9	75.1	0.11	147.6	447.3	-6.3
Future + Nat Heritage	9	1989	365	775.6	643.1	132.5	94.4	0.12	161.1	510.7	-9.4
Future + Nat Heritage	9	1990	365	920.9	765.1	155.8	169.6	0.18	226.7	530.1	5.5
Future + Nat Heritage	9	1991	365	751.8	618.6	133.2	124.0	0.16	158.5	476.0	6.7
Future + Nat Heritage	9	1992	366	1064.9	934.7	130.2	189.5	0.18	341.6	529.8	-3.9
Future + Nat Heritage	9	1993	365	798.7	676.6	122.1	110.2	0.14	163.9	537.9	13.2
Future + Nat Heritage	9	1994	365	754.4	580.0	174.4	113.5	0.15	111.4	523.5	-6.0
Future + Nat Heritage	9	1995	365	925.3	784.8	140.5	175.3	0.19	218.7	519.1	-12.1
Future + Nat Heritage	9	1996	366	1033.9	908.7	125.2	169.7	0.16	297.9	562.6	-3.7
Future + Nat Heritage	9	1997	365	761.9	567.5	194.4	141.3	0.19	111.2	527.6	18.3
Future + Nat Heritage	9	1998	365	733.8	627.2	106.6	89.9	0.12	151.6	490.9	-1.4
Future + Nat Heritage	9	1999	365	804.6	649.5	155.1	172.5	0.21	134.5	502.7	5.1
Future + Nat Heritage	9	2000	366	984.2	803.3	180.9	154.9	0.16	167.5	590.3	-71.4
Future + Nat Heritage	10	1986	223	832.5	784.0	48.5	142.8	0.17	283.5	385.3	-20.8

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	$P-Q_{out}$ [mm/yr]
Future + Nat Heritage	10	1987	365	823.2	696.6	126.6	114.8	0.14	198.9	509.7	0.2
Future + Nat Heritage	10	1988	366	676.4	569.5	106.9	57.1	0.08	156.8	456.1	-6.4
Future + Nat Heritage	10	1989	365	775.6	643.1	132.5	72.5	0.09	182.3	513.7	-7.1
Future + Nat Heritage	10	1990	365	920.9	765.1	155.8	135.1	0.15	254.5	532.5	1.2
Future + Nat Heritage	10	1991	365	751.8	618.6	133.2	98.6	0.13	178.2	485.1	10.1
Future + Nat Heritage	10	1992	366	1064.9	934.7	130.2	145.3	0.14	382.6	531.8	-5.2
Future + Nat Heritage	10	1993	365	798.7	676.6	122.1	84.7	0.11	190.1	538.9	15.0
Future + Nat Heritage	10	1994	365	754.4	580.0	174.4	91.8	0.12	128.6	527.4	-6.5
Future + Nat Heritage	10	1995	365	925.3	784.8	140.5	137.8	0.15	251.3	524.7	-11.5
Future + Nat Heritage	10	1996	366	1033.9	908.7	125.2	131.3	0.13	335.8	560.6	-6.1
Future + Nat Heritage	10	1997	365	761.9	567.5	194.4	118.3	0.16	131.4	533.2	21.0
Future + Nat Heritage	10	1998	365	733.8	627.2	106.6	68.4	0.09	164.0	501.2	-0.2
Future + Nat Heritage	10	1999	365	804.6	649.5	155.1	143.3	0.18	152.9	512.2	3.8
Future + Nat Heritage	10	2000	366	984.2	803.3	180.9	122.2	0.12	205.1	585.7	-71.2
Future + Nat Heritage	11	1986	223	832.5	784.0	48.5	202.7	0.24	247.9	344.0	-37.9
Future + Nat Heritage	11	1987	365	823.2	696.6	126.6	165.3	0.20	186.3	471.8	0.2
Future + Nat Heritage	11	1988	366	676.4	569.5	106.9	93.7	0.14	160.2	416.2	-6.3
Future + Nat Heritage	11	1989	365	775.6	643.1	132.5	115.9	0.15	171.8	477.8	-10.0
Future + Nat Heritage	11	1990	365	920.9	765.1	155.8	193.6	0.21	239.9	494.3	6.9
Future + Nat Heritage	11	1991	365	751.8	618.6	133.2	143.1	0.19	170.4	444.6	6.3
Future + Nat Heritage	11	1992	366	1064.9	934.7	130.2	215.6	0.20	353.1	492.9	-3.3
Future + Nat Heritage	11	1993	365	798.7	676.6	122.1	132.7	0.17	182.6	496.2	12.8
Future + Nat Heritage	11	1994	365	754.4	580.0	174.4	134.9	0.18	127.4	486.3	-5.8
Future + Nat Heritage	11	1995	365	925.3	784.8	140.5	197.8	0.21	229.0	486.1	-12.4
Future + Nat Heritage	11	1996	366	1033.9	908.7	125.2	196.7	0.19	315.3	519.6	-2.4
Future + Nat Heritage	11	1997	365	761.9	567.5	194.4	162.9	0.21	124.7	492.2	17.9
Future + Nat Heritage	11	1998	365	733.8	627.2	106.6	109.1	0.15	162.4	460.0	-2.2
Future + Nat Heritage	11	1999	365	804.6	649.5	155.1	195.5	0.24	147.0	468.5	6.4
Future + Nat Heritage	11	2000	366	984.2	803.3	180.9	181.9	0.18	193.4	536.7	-72.2
Future + Nat Heritage	11.1	1986	223	832.5	784.0	48.5	221.6	0.27	218.9	340.1	-51.9
Future + Nat Heritage	11.1	1987	365	823.2	696.6	126.6	176.6	0.21	170.5	476.0	-0.1
Future + Nat Heritage	11.1	1988	366	676.4	569.5	106.9	99.2	0.15	153.9	417.3	-6.1
Future + Nat Heritage	11.1	1989	365	775.6	643.1	132.5	123.4	0.16	158.1	483.0	-11.1
Future + Nat Heritage	11.1	1990	365	920.9	765.1	155.8	208.4	0.23	220.4	500.5	8.4
Future + Nat Heritage	11.1	1991	365	751.8	618.6	133.2	153.2	0.20	157.5	445.9	4.8
Future + Nat Heritage	11.1	1992	366	1064.9	934.7	130.2	238.1	0.22	324.0	499.8	-3.0
Future + Nat Heritage	11.1	1993	365	798.7	676.6	122.1	142.5	0.18	165.3	502.8	11.8

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	P-Q_{out} [mm/yr]
Future + Nat Heritage	11.1	1994	365	754.4	580.0	174.4	141.7	0.19	115.7	491.3	-5.7
Future + Nat Heritage	11.1	1995	365	925.3	784.8	140.5	215.8	0.23	206.9	489.7	-12.9
Future + Nat Heritage	11.1	1996	366	1033.9	908.7	125.2	213.8	0.21	289.4	529.1	-1.6
Future + Nat Heritage	11.1	1997	365	761.9	567.5	194.4	169.9	0.22	111.7	497.0	16.7
Future + Nat Heritage	11.1	1998	365	733.8	627.2	106.6	116.6	0.16	153.3	461.6	-2.3
Future + Nat Heritage	11.1	1999	365	804.6	649.5	155.1	207.2	0.26	133.6	469.9	6.0
Future + Nat Heritage	11.1	2000	366	984.2	803.3	180.9	196.2	0.20	166.9	548.8	-72.4
Future + Nat Heritage	12	1986	223	832.5	784.0	48.5	287.3	0.35	229.5	294.5	-21.2
Future + Nat Heritage	12	1987	365	823.2	696.6	126.6	252.9	0.31	170.2	401.1	1.0
Future + Nat Heritage	12	1988	366	676.4	569.5	106.9	171.1	0.25	146.1	353.6	-5.6
Future + Nat Heritage	12	1989	365	775.6	643.1	132.5	203.4	0.26	156.5	404.1	-11.7
Future + Nat Heritage	12	1990	365	920.9	765.1	155.8	292.8	0.32	219.8	420.6	12.4
Future + Nat Heritage	12	1991	365	751.8	618.6	133.2	223.5	0.30	156.4	377.2	5.3
Future + Nat Heritage	12	1992	366	1064.9	934.7	130.2	327.7	0.31	316.5	420.3	-0.4
Future + Nat Heritage	12	1993	365	798.7	676.6	122.1	221.9	0.28	168.6	419.1	10.9
Future + Nat Heritage	12	1994	365	754.4	580.0	174.4	215.9	0.29	119.9	413.6	-4.9
Future + Nat Heritage	12	1995	365	925.3	784.8	140.5	293.9	0.32	208.0	412.0	-11.4
Future + Nat Heritage	12	1996	366	1033.9	908.7	125.2	308.7	0.30	284.4	442.6	1.9
Future + Nat Heritage	12	1997	365	761.9	567.5	194.4	242.4	0.32	114.9	421.6	17.1
Future + Nat Heritage	12	1998	365	733.8	627.2	106.6	193.6	0.26	149.0	390.1	-1.0
Future + Nat Heritage	12	1999	365	804.6	649.5	155.1	280.2	0.35	135.2	396.4	7.1
Future + Nat Heritage	12	2000	366	984.2	803.3	180.9	278.8	0.28	179.4	454.3	-71.8
Future + Nat Heritage	13	1986	223	832.5	784.0	48.5	151.6	0.18	291.4	376.0	-13.5
Future + Nat Heritage	13	1987	365	823.2	696.6	126.6	124.5	0.15	200.9	498.0	0.2
Future + Nat Heritage	13	1988	366	676.4	569.5	106.9	66.3	0.10	158.6	444.9	-6.6
Future + Nat Heritage	13	1989	365	775.6	643.1	132.5	82.5	0.11	181.5	504.2	-7.5
Future + Nat Heritage	13	1990	365	920.9	765.1	155.8	145.1	0.16	259.2	518.6	2.1
Future + Nat Heritage	13	1991	365	751.8	618.6	133.2	107.0	0.14	180.2	474.7	10.1
Future + Nat Heritage	13	1992	366	1064.9	934.7	130.2	156.2	0.15	388.2	515.5	-5.0
Future + Nat Heritage	13	1993	365	798.7	676.6	122.1	95.0	0.12	193.8	524.8	14.9
Future + Nat Heritage	13	1994	365	754.4	580.0	174.4	102.0	0.14	133.9	511.8	-6.7
Future + Nat Heritage	13	1995	365	925.3	784.8	140.5	146.0	0.16	253.4	513.9	-11.9
Future + Nat Heritage	13	1996	366	1033.9	908.7	125.2	143.6	0.14	343.5	541.7	-5.0
Future + Nat Heritage	13	1997	365	761.9	567.5	194.4	128.9	0.17	137.1	516.5	20.6
Future + Nat Heritage	13	1998	365	733.8	627.2	106.6	77.3	0.11	166.7	489.7	-0.1
Future + Nat Heritage	13	1999	365	804.6	649.5	155.1	152.6	0.19	157.5	498.4	3.8
Future + Nat Heritage	13	2000	366	984.2	803.3	180.9	135.1	0.14	219.1	557.9	-72.0

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	$P-Q_{out}$ [mm/yr]
Future + Nat Heritage	14	1986	223	832.5	784.0	48.5	168.5	0.20	277.6	365.7	-20.8
Future + Nat Heritage	14	1987	365	823.2	696.6	126.6	138.6	0.17	197.2	487.6	0.2
Future + Nat Heritage	14	1988	366	676.4	569.5	106.9	76.2	0.11	161.0	432.5	-6.7
Future + Nat Heritage	14	1989	365	775.6	643.1	132.5	94.2	0.12	179.1	493.7	-8.6
Future + Nat Heritage	14	1990	365	920.9	765.1	155.8	161.6	0.18	254.6	508.9	4.3
Future + Nat Heritage	14	1991	365	751.8	618.6	133.2	119.6	0.16	178.6	462.0	8.3
Future + Nat Heritage	14	1992	366	1064.9	934.7	130.2	175.8	0.17	378.6	506.3	-4.2
Future + Nat Heritage	14	1993	365	798.7	676.6	122.1	108.1	0.14	191.0	513.7	14.1
Future + Nat Heritage	14	1994	365	754.4	580.0	174.4	113.8	0.15	132.6	501.7	-6.4
Future + Nat Heritage	14	1995	365	925.3	784.8	140.5	163.3	0.18	247.0	502.8	-12.1
Future + Nat Heritage	14	1996	366	1033.9	908.7	125.2	161.5	0.16	335.2	533.3	-3.9
Future + Nat Heritage	14	1997	365	761.9	567.5	194.4	141.1	0.19	134.0	506.1	19.3
Future + Nat Heritage	14	1998	365	733.8	627.2	106.6	88.6	0.12	166.8	476.7	-1.7
Future + Nat Heritage	14	1999	365	804.6	649.5	155.1	167.7	0.21	156.9	485.8	5.8
Future + Nat Heritage	14	2000	366	984.2	803.3	180.9	151.0	0.15	211.0	549.9	-72.3
Future + Nat Heritage	15	1986	223	832.5	784.0	48.5	56.7	0.07	493.4	430.0	147.5
Future + Nat Heritage	15	1987	365	823.2	696.6	126.6	49.8	0.06	212.3	559.2	-2.0
Future + Nat Heritage	15	1988	366	676.4	569.5	106.9	21.7	0.03	135.7	517.5	-1.5
Future + Nat Heritage	15	1989	365	775.6	643.1	132.5	27.9	0.04	185.8	559.1	-2.8
Future + Nat Heritage	15	1990	365	920.9	765.1	155.8	57.6	0.06	275.7	575.1	-12.6
Future + Nat Heritage	15	1991	365	751.8	618.6	133.2	42.4	0.06	201.3	546.8	38.7
Future + Nat Heritage	15	1992	366	1064.9	934.7	130.2	57.1	0.05	410.3	569.7	-27.8
Future + Nat Heritage	15	1993	365	798.7	676.6	122.1	32.2	0.04	199.6	588.7	21.8
Future + Nat Heritage	15	1994	365	754.4	580.0	174.4	40.4	0.05	132.3	573.5	-8.2
Future + Nat Heritage	15	1995	365	925.3	784.8	140.5	56.3	0.06	280.2	577.6	-11.2
Future + Nat Heritage	15	1996	366	1033.9	908.7	125.2	52.2	0.05	375.1	594.9	-11.7
Future + Nat Heritage	15	1997	365	761.9	567.5	194.4	57.9	0.08	160.7	585.1	41.9
Future + Nat Heritage	15	1998	365	733.8	627.2	106.6	26.2	0.04	170.6	566.8	29.8
Future + Nat Heritage	15	1999	365	804.6	649.5	155.1	67.2	0.08	122.9	575.8	-38.7
Future + Nat Heritage	15	2000	366	984.2	803.3	180.9	51.1	0.05	243.8	618.3	-71.1
Future + Nat Heritage	16	1986	223	832.5	784.0	48.5	105.6	0.13	354.3	403.7	31.0
Future + Nat Heritage	16	1987	365	823.2	696.6	126.6	88.3	0.11	216.3	518.7	0.1
Future + Nat Heritage	16	1988	366	676.4	569.5	106.9	43.1	0.06	165.4	460.7	-7.2
Future + Nat Heritage	16	1989	365	775.6	643.1	132.5	54.1	0.07	190.5	524.8	-6.1
Future + Nat Heritage	16	1990	365	920.9	765.1	155.8	102.3	0.11	279.6	538.5	-0.5
Future + Nat Heritage	16	1991	365	751.8	618.6	133.2	75.5	0.10	195.8	493.0	12.5
Future + Nat Heritage	16	1992	366	1064.9	934.7	130.2	106.0	0.10	418.0	534.5	-6.4

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	P-Q_{out} [mm/yr]
Future + Nat Heritage	16	1993	365	798.7	676.6	122.1	62.6	0.08	202.8	549.7	16.3
Future + Nat Heritage	16	1994	365	754.4	580.0	174.4	72.3	0.10	143.6	531.1	-7.3
Future + Nat Heritage	16	1995	365	925.3	784.8	140.5	101.6	0.11	276.4	535.7	-11.6
Future + Nat Heritage	16	1996	366	1033.9	908.7	125.2	97.4	0.09	365.8	564.4	-6.4
Future + Nat Heritage	16	1997	365	761.9	567.5	194.4	96.6	0.13	152.9	534.3	21.9
Future + Nat Heritage	16	1998	365	733.8	627.2	106.6	50.5	0.07	177.9	507.0	1.6
Future + Nat Heritage	16	1999	365	804.6	649.5	155.1	114.7	0.14	174.4	517.4	2.0
Future + Nat Heritage	16	2000	366	984.2	803.3	180.9	93.9	0.10	236.5	581.5	-72.3
Future + Nat Heritage	17	1986	223	832.5	784.0	48.5	111.6	0.13	343.5	396.4	19.1
Future + Nat Heritage	17	1987	365	823.2	696.6	126.6	92.6	0.11	212.8	517.8	-0.1
Future + Nat Heritage	17	1988	366	676.4	569.5	106.9	45.3	0.07	158.6	466.3	-6.1
Future + Nat Heritage	17	1989	365	775.6	643.1	132.5	57.1	0.07	189.4	523.6	-5.5
Future + Nat Heritage	17	1990	365	920.9	765.1	155.8	107.3	0.12	274.4	536.8	-2.3
Future + Nat Heritage	17	1991	365	751.8	618.6	133.2	78.9	0.10	190.4	497.3	14.8
Future + Nat Heritage	17	1992	366	1064.9	934.7	130.2	111.9	0.11	412.2	533.0	-7.8
Future + Nat Heritage	17	1993	365	798.7	676.6	122.1	66.3	0.08	203.4	545.9	16.9
Future + Nat Heritage	17	1994	365	754.4	580.0	174.4	75.6	0.10	141.1	530.3	-7.5
Future + Nat Heritage	17	1995	365	925.3	784.8	140.5	106.8	0.12	272.1	535.0	-11.4
Future + Nat Heritage	17	1996	366	1033.9	908.7	125.2	102.9	0.10	365.2	558.4	-7.3
Future + Nat Heritage	17	1997	365	761.9	567.5	194.4	100.3	0.13	149.2	536.0	23.6
Future + Nat Heritage	17	1998	365	733.8	627.2	106.6	53.2	0.07	173.4	512.7	5.5
Future + Nat Heritage	17	1999	365	804.6	649.5	155.1	118.3	0.15	162.4	521.2	-2.7
Future + Nat Heritage	17	2000	366	984.2	803.3	180.9	98.8	0.10	239.2	574.4	-71.9
Future + Nat Heritage	18	1986	223	832.5	784.0	48.5	123.2	0.15	313.2	398.8	2.7
Future + Nat Heritage	18	1987	365	823.2	696.6	126.6	100.7	0.12	203.7	518.9	0.2
Future + Nat Heritage	18	1988	366	676.4	569.5	106.9	49.7	0.07	155.4	464.8	-6.5
Future + Nat Heritage	18	1989	365	775.6	643.1	132.5	62.4	0.08	181.6	525.3	-6.2
Future + Nat Heritage	18	1990	365	920.9	765.1	155.8	117.2	0.13	263.8	539.0	-0.9
Future + Nat Heritage	18	1991	365	751.8	618.6	133.2	86.0	0.11	182.5	496.5	13.2
Future + Nat Heritage	18	1992	366	1064.9	934.7	130.2	123.7	0.12	398.8	535.3	-7.1
Future + Nat Heritage	18	1993	365	798.7	676.6	122.1	73.0	0.09	192.3	549.6	16.2
Future + Nat Heritage	18	1994	365	754.4	580.0	174.4	82.0	0.11	133.6	531.8	-7.0
Future + Nat Heritage	18	1995	365	925.3	784.8	140.5	117.2	0.13	260.3	536.0	-11.8
Future + Nat Heritage	18	1996	366	1033.9	908.7	125.2	113.3	0.11	350.6	563.2	-6.8
Future + Nat Heritage	18	1997	365	761.9	567.5	194.4	107.9	0.14	140.4	536.4	22.8
Future + Nat Heritage	18	1998	365	733.8	627.2	106.6	58.5	0.08	169.2	511.0	4.9
Future + Nat Heritage	18	1999	365	804.6	649.5	155.1	127.5	0.16	155.2	520.1	-1.9

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	$P-Q_{out}$ [mm/yr]
Future + Nat Heritage	18	2000	366	984.2	803.3	180.9	108.3	0.11	224.1	579.9	-71.9
Future + Nat Heritage	19	1986	223	832.5	784.0	48.5	149.4	0.18	299.2	377.4	-6.4
Future + Nat Heritage	19	1987	365	823.2	696.6	126.6	124.0	0.15	203.8	495.7	0.3
Future + Nat Heritage	19	1988	366	676.4	569.5	106.9	67.1	0.10	162.0	440.5	-6.9
Future + Nat Heritage	19	1989	365	775.6	643.1	132.5	82.9	0.11	183.0	501.7	-8.0
Future + Nat Heritage	19	1990	365	920.9	765.1	155.8	144.2	0.16	263.4	516.3	3.0
Future + Nat Heritage	19	1991	365	751.8	618.6	133.2	106.8	0.14	184.0	470.5	9.5
Future + Nat Heritage	19	1992	366	1064.9	934.7	130.2	154.7	0.15	392.6	512.9	-4.7
Future + Nat Heritage	19	1993	365	798.7	676.6	122.1	94.9	0.12	195.6	522.9	14.7
Future + Nat Heritage	19	1994	365	754.4	580.0	174.4	102.1	0.14	136.3	509.3	-6.7
Future + Nat Heritage	19	1995	365	925.3	784.8	140.5	144.7	0.16	257.1	511.6	-11.9
Future + Nat Heritage	19	1996	366	1033.9	908.7	125.2	142.6	0.14	346.1	540.6	-4.6
Future + Nat Heritage	19	1997	365	761.9	567.5	194.4	128.6	0.17	140.0	513.3	20.0
Future + Nat Heritage	19	1998	365	733.8	627.2	106.6	77.8	0.11	170.0	484.9	-1.1
Future + Nat Heritage	19	1999	365	804.6	649.5	155.1	152.3	0.19	163.0	494.4	5.1
Future + Nat Heritage	19	2000	366	984.2	803.3	180.9	134.2	0.14	220.7	556.9	-72.4
Future + Nat Heritage	20	1986	223	832.5	784.0	48.5	165.9	0.20	280.9	362.4	-23.4
Future + Nat Heritage	20	1987	365	823.2	696.6	126.6	135.1	0.16	202.5	485.8	0.2
Future + Nat Heritage	20	1988	366	676.4	569.5	106.9	72.3	0.11	168.7	428.4	-7.0
Future + Nat Heritage	20	1989	365	775.6	643.1	132.5	90.1	0.12	184.3	491.6	-9.6
Future + Nat Heritage	20	1990	365	920.9	765.1	155.8	157.8	0.17	261.4	507.5	5.7
Future + Nat Heritage	20	1991	365	751.8	618.6	133.2	116.2	0.15	184.8	457.9	7.1
Future + Nat Heritage	20	1992	366	1064.9	934.7	130.2	171.4	0.16	384.9	504.7	-3.9
Future + Nat Heritage	20	1993	365	798.7	676.6	122.1	104.0	0.13	197.7	510.7	13.6
Future + Nat Heritage	20	1994	365	754.4	580.0	174.4	110.2	0.15	138.0	499.9	-6.3
Future + Nat Heritage	20	1995	365	925.3	784.8	140.5	160.2	0.17	251.5	501.2	-12.4
Future + Nat Heritage	20	1996	366	1033.9	908.7	125.2	156.6	0.15	341.9	532.4	-3.0
Future + Nat Heritage	20	1997	365	761.9	567.5	194.4	137.8	0.18	137.5	504.8	18.2
Future + Nat Heritage	20	1998	365	733.8	627.2	106.6	84.4	0.12	173.8	473.2	-2.4
Future + Nat Heritage	20	1999	365	804.6	649.5	155.1	165.7	0.21	162.2	483.2	6.5
Future + Nat Heritage	20	2000	366	984.2	803.3	180.9	147.1	0.15	214.7	549.8	-72.5
Future + Nat Heritage	21	1986	223	832.5	784.0	48.5	361.4	0.43	179.0	257.6	-34.5
Future + Nat Heritage	21	1987	365	823.2	696.6	126.6	316.9	0.38	144.2	363.6	1.5
Future + Nat Heritage	21	1988	366	676.4	569.5	106.9	220.3	0.33	134.2	318.1	-3.8
Future + Nat Heritage	21	1989	365	775.6	643.1	132.5	261.6	0.34	134.6	365.4	-14.0
Future + Nat Heritage	21	1990	365	920.9	765.1	155.8	367.4	0.40	187.9	383.5	17.9
Future + Nat Heritage	21	1991	365	751.8	618.6	133.2	281.0	0.37	135.0	339.1	3.4

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	$P-Q_{out}$ [mm/yr]
Future + Nat Heritage	21	1992	366	1064.9	934.7	130.2	420.1	0.39	257.3	389.5	2.1
Future + Nat Heritage	21	1993	365	798.7	676.6	122.1	284.3	0.36	141.1	382.1	8.9
Future + Nat Heritage	21	1994	365	754.4	580.0	174.4	270.1	0.36	105.4	375.3	-3.7
Future + Nat Heritage	21	1995	365	925.3	784.8	140.5	373.2	0.40	170.6	370.7	-10.8
Future + Nat Heritage	21	1996	366	1033.9	908.7	125.2	392.5	0.38	235.9	411.2	5.7
Future + Nat Heritage	21	1997	365	761.9	567.5	194.4	295.6	0.39	93.6	388.6	15.9
Future + Nat Heritage	21	1998	365	733.8	627.2	106.6	250.1	0.34	130.6	353.4	0.4
Future + Nat Heritage	21	1999	365	804.6	649.5	155.1	345.5	0.43	113.2	352.9	7.0
Future + Nat Heritage	21	2000	366	984.2	803.3	180.9	351.4	0.36	137.1	424.6	-71.1
Future + Nat Heritage	21.1	1986	223	832.5	784.0	48.5	120.7	0.14	337.9	392.3	18.3
Future + Nat Heritage	21.1	1987	365	823.2	696.6	126.6	100.9	0.12	216.7	505.6	0.0
Future + Nat Heritage	21.1	1988	366	676.4	569.5	106.9	51.7	0.08	171.4	446.0	-7.4
Future + Nat Heritage	21.1	1989	365	775.6	643.1	132.5	64.3	0.08	192.4	511.6	-7.3
Future + Nat Heritage	21.1	1990	365	920.9	765.1	155.8	117.0	0.13	279.5	526.0	1.7
Future + Nat Heritage	21.1	1991	365	751.8	618.6	133.2	86.7	0.12	197.8	477.8	10.5
Future + Nat Heritage	21.1	1992	366	1064.9	934.7	130.2	122.7	0.12	414.6	522.5	-5.1
Future + Nat Heritage	21.1	1993	365	798.7	676.6	122.1	73.8	0.09	205.9	534.5	15.5
Future + Nat Heritage	21.1	1994	365	754.4	580.0	174.4	82.9	0.11	146.1	518.4	-6.9
Future + Nat Heritage	21.1	1995	365	925.3	784.8	140.5	116.8	0.13	274.6	521.8	-12.1
Future + Nat Heritage	21.1	1996	366	1033.9	908.7	125.2	112.9	0.11	363.3	552.7	-5.0
Future + Nat Heritage	21.1	1997	365	761.9	567.5	194.4	108.1	0.14	153.0	521.2	20.4
Future + Nat Heritage	21.1	1998	365	733.8	627.2	106.6	60.2	0.08	180.6	491.6	-1.5
Future + Nat Heritage	21.1	1999	365	804.6	649.5	155.1	128.7	0.16	178.7	502.5	5.4
Future + Nat Heritage	21.1	2000	366	984.2	803.3	180.9	107.8	0.11	233.7	570.2	-72.5
Future + Nat Heritage	22	1986	223	832.5	784.0	48.5	241.6	0.29	215.9	327.5	-47.5
Future + Nat Heritage	22	1987	365	823.2	696.6	126.6	197.3	0.24	169.1	456.6	-0.3
Future + Nat Heritage	22	1988	366	676.4	569.5	106.9	117.7	0.17	156.8	396.1	-5.8
Future + Nat Heritage	22	1989	365	775.6	643.1	132.5	144.1	0.19	156.2	462.5	-12.8
Future + Nat Heritage	22	1990	365	920.9	765.1	155.8	231.8	0.25	220.0	480.7	11.6
Future + Nat Heritage	22	1991	365	751.8	618.6	133.2	172.4	0.23	159.4	423.3	3.3
Future + Nat Heritage	22	1992	366	1064.9	934.7	130.2	264.5	0.25	317.3	481.0	-2.0
Future + Nat Heritage	22	1993	365	798.7	676.6	122.1	163.4	0.20	164.1	482.0	10.7
Future + Nat Heritage	22	1994	365	754.4	580.0	174.4	161.1	0.21	117.7	470.2	-5.4
Future + Nat Heritage	22	1995	365	925.3	784.8	140.5	239.2	0.26	204.1	469.1	-12.9
Future + Nat Heritage	22	1996	366	1033.9	908.7	125.2	239.1	0.23	283.5	511.8	0.5
Future + Nat Heritage	22	1997	365	761.9	567.5	194.4	188.8	0.25	110.7	477.9	15.5
Future + Nat Heritage	22	1998	365	733.8	627.2	106.6	137.1	0.19	155.8	439.1	-1.7

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	$P-Q_{out}$ [mm/yr]
Future + Nat Heritage	22	1999	365	804.6	649.5	155.1	230.0	0.29	133.9	446.7	5.9
Future + Nat Heritage	22	2000	366	984.2	803.3	180.9	218.3	0.22	160.6	532.7	-72.6
Future + Nat Heritage	23	1986	223	832.5	784.0	48.5	366.3	0.44	176.1	263.1	-27.0
Future + Nat Heritage	23	1987	365	823.2	696.6	126.6	320.2	0.39	143.7	360.6	1.3
Future + Nat Heritage	23	1988	366	676.4	569.5	106.9	222.7	0.33	135.7	314.5	-3.5
Future + Nat Heritage	23	1989	365	775.6	643.1	132.5	264.7	0.34	133.9	362.3	-14.8
Future + Nat Heritage	23	1990	365	920.9	765.1	155.8	371.3	0.40	188.4	380.0	18.9
Future + Nat Heritage	23	1991	365	751.8	618.6	133.2	284.3	0.38	135.5	335.1	3.0
Future + Nat Heritage	23	1992	366	1064.9	934.7	130.2	425.5	0.40	251.2	390.5	2.3
Future + Nat Heritage	23	1993	365	798.7	676.6	122.1	287.3	0.36	138.6	381.2	8.4
Future + Nat Heritage	23	1994	365	754.4	580.0	174.4	272.6	0.36	105.7	372.4	-3.7
Future + Nat Heritage	23	1995	365	925.3	784.8	140.5	378.7	0.41	169.4	366.4	-10.8
Future + Nat Heritage	23	1996	366	1033.9	908.7	125.2	396.4	0.38	231.6	412.2	6.3
Future + Nat Heritage	23	1997	365	761.9	567.5	194.4	297.8	0.39	93.5	386.3	15.7
Future + Nat Heritage	23	1998	365	733.8	627.2	106.6	253.2	0.35	131.0	350.1	0.5
Future + Nat Heritage	23	1999	365	804.6	649.5	155.1	350.1	0.44	114.6	346.5	6.7
Future + Nat Heritage	23	2000	366	984.2	803.3	180.9	354.8	0.36	130.2	428.0	-71.1
Future + Nat Heritage	24	1986	223	832.5	784.0	48.5	267.1	0.32	221.9	307.1	-36.4
Future + Nat Heritage	24	1987	365	823.2	696.6	126.6	227.4	0.28	170.0	426.6	0.8
Future + Nat Heritage	24	1988	366	676.4	569.5	106.9	145.5	0.22	147.9	377.3	-5.7
Future + Nat Heritage	24	1989	365	775.6	643.1	132.5	175.7	0.23	157.8	431.3	-10.9
Future + Nat Heritage	24	1990	365	920.9	765.1	155.8	264.9	0.29	218.4	448.1	10.4
Future + Nat Heritage	24	1991	365	751.8	618.6	133.2	199.5	0.27	155.5	402.3	5.4
Future + Nat Heritage	24	1992	366	1064.9	934.7	130.2	298.4	0.28	317.2	447.9	-1.4
Future + Nat Heritage	24	1993	365	798.7	676.6	122.1	195.0	0.24	168.2	447.0	11.5
Future + Nat Heritage	24	1994	365	754.4	580.0	174.4	190.4	0.25	118.4	440.5	-5.1
Future + Nat Heritage	24	1995	365	925.3	784.8	140.5	268.6	0.29	206.0	438.9	-11.8
Future + Nat Heritage	24	1996	366	1033.9	908.7	125.2	277.1	0.27	286.2	471.0	0.4
Future + Nat Heritage	24	1997	365	761.9	567.5	194.4	217.6	0.29	113.0	448.6	17.3
Future + Nat Heritage	24	1998	365	733.8	627.2	106.6	166.5	0.23	149.0	416.7	-1.5
Future + Nat Heritage	24	1999	365	804.6	649.5	155.1	255.8	0.32	132.7	423.1	6.9
Future + Nat Heritage	24	2000	366	984.2	803.3	180.9	251.4	0.26	176.2	484.8	-71.8
Future + Nat Heritage	25	1986	223	832.5	784.0	48.5	338.3	0.41	204.6	266.9	-22.7
Future + Nat Heritage	25	1987	365	823.2	696.6	126.6	301.0	0.37	156.6	367.0	1.5
Future + Nat Heritage	25	1988	366	676.4	569.5	106.9	210.6	0.31	139.2	322.0	-4.6
Future + Nat Heritage	25	1989	365	775.6	643.1	132.5	248.9	0.32	145.1	368.5	-13.1
Future + Nat Heritage	25	1990	365	920.9	765.1	155.8	348.0	0.38	203.2	385.9	16.2

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	P-Q_{out} [mm/yr]
Future + Nat Heritage	25	1991	365	751.8	618.6	133.2	267.1	0.36	145.1	343.8	4.2
Future + Nat Heritage	25	1992	366	1064.9	934.7	130.2	392.7	0.37	285.5	388.0	1.4
Future + Nat Heritage	25	1993	365	798.7	676.6	122.1	269.6	0.34	155.2	383.5	9.5
Future + Nat Heritage	25	1994	365	754.4	580.0	174.4	258.6	0.34	113.4	378.4	-4.0
Future + Nat Heritage	25	1995	365	925.3	784.8	140.5	349.8	0.38	189.3	375.3	-10.9
Future + Nat Heritage	25	1996	366	1033.9	908.7	125.2	370.7	0.36	258.5	409.3	4.5
Future + Nat Heritage	25	1997	365	761.9	567.5	194.4	284.7	0.37	104.3	389.4	16.5
Future + Nat Heritage	25	1998	365	733.8	627.2	106.6	237.7	0.32	139.6	356.4	0.0
Future + Nat Heritage	25	1999	365	804.6	649.5	155.1	328.1	0.41	123.8	360.0	7.2
Future + Nat Heritage	25	2000	366	984.2	803.3	180.9	332.7	0.34	160.2	420.0	-71.3
Future + Nat Heritage	26	1986	223	832.5	784.0	48.5	433.0	0.52	144.5	230.0	-25.0
Future + Nat Heritage	26	1987	365	823.2	696.6	126.6	386.1	0.47	118.4	320.1	1.4
Future + Nat Heritage	26	1988	366	676.4	569.5	106.9	279.2	0.41	111.7	282.2	-3.3
Future + Nat Heritage	26	1989	365	775.6	643.1	132.5	329.2	0.42	110.7	321.1	-14.6
Future + Nat Heritage	26	1990	365	920.9	765.1	155.8	446.8	0.49	154.4	338.9	19.3
Future + Nat Heritage	26	1991	365	751.8	618.6	133.2	344.4	0.46	110.8	299.4	2.8
Future + Nat Heritage	26	1992	366	1064.9	934.7	130.2	513.0	0.48	207.5	347.3	2.9
Future + Nat Heritage	26	1993	365	798.7	676.6	122.1	354.2	0.44	115.0	336.9	7.4
Future + Nat Heritage	26	1994	365	754.4	580.0	174.4	332.1	0.44	86.8	331.8	-3.6
Future + Nat Heritage	26	1995	365	925.3	784.8	140.5	451.9	0.49	138.1	324.6	-10.7
Future + Nat Heritage	26	1996	366	1033.9	908.7	125.2	482.9	0.47	192.4	365.4	6.8
Future + Nat Heritage	26	1997	365	761.9	567.5	194.4	356.0	0.47	76.4	345.0	15.5
Future + Nat Heritage	26	1998	365	733.8	627.2	106.6	315.4	0.43	107.1	312.0	0.7
Future + Nat Heritage	26	1999	365	804.6	649.5	155.1	410.8	0.51	92.6	307.6	6.4
Future + Nat Heritage	26	2000	366	984.2	803.3	180.9	428.7	0.44	108.8	375.4	-71.2
Future + Nat Heritage	27	1986	223	832.5	784.0	48.5	319.9	0.38	212.5	286.2	-13.8
Future + Nat Heritage	27	1987	365	823.2	696.6	126.6	287.6	0.35	154.6	382.1	1.1
Future + Nat Heritage	27	1988	366	676.4	569.5	106.9	202.6	0.30	131.9	336.5	-5.4
Future + Nat Heritage	27	1989	365	775.6	643.1	132.5	238.8	0.31	142.3	382.4	-12.2
Future + Nat Heritage	27	1990	365	920.9	765.1	155.8	333.0	0.36	199.9	401.8	13.8
Future + Nat Heritage	27	1991	365	751.8	618.6	133.2	256.3	0.34	142.8	357.4	4.7
Future + Nat Heritage	27	1992	366	1064.9	934.7	130.2	373.3	0.35	289.4	402.4	0.3
Future + Nat Heritage	27	1993	365	798.7	676.6	122.1	257.4	0.32	150.2	400.9	9.8
Future + Nat Heritage	27	1994	365	754.4	580.0	174.4	247.6	0.33	105.5	396.6	-4.7
Future + Nat Heritage	27	1995	365	925.3	784.8	140.5	333.1	0.36	190.7	390.5	-11.0
Future + Nat Heritage	27	1996	366	1033.9	908.7	125.2	354.0	0.34	256.2	426.3	2.7
Future + Nat Heritage	27	1997	365	761.9	567.5	194.4	272.6	0.36	102.8	403.3	16.7

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	P-Q_{out} [mm/yr]
Future + Nat Heritage	27	1998	365	733.8	627.2	106.6	228.8	0.31	135.9	368.5	-0.6
Future + Nat Heritage	27	1999	365	804.6	649.5	155.1	312.4	0.39	123.4	375.7	6.9
Future + Nat Heritage	27	2000	366	984.2	803.3	180.9	315.4	0.32	155.3	442.0	-71.5
Future + Nat Heritage	28	1986	223	832.5	784.0	48.5	429.6	0.52	142.3	236.7	-23.9
Future + Nat Heritage	28	1987	365	823.2	696.6	126.6	391.2	0.48	108.8	323.7	0.5
Future + Nat Heritage	28	1988	366	676.4	569.5	106.9	288.4	0.43	95.8	287.4	-4.8
Future + Nat Heritage	28	1989	365	775.6	643.1	132.5	337.3	0.43	101.7	323.8	-12.7
Future + Nat Heritage	28	1990	365	920.9	765.1	155.8	452.4	0.49	139.2	342.6	13.3
Future + Nat Heritage	28	1991	365	751.8	618.6	133.2	350.6	0.47	100.9	304.2	3.9
Future + Nat Heritage	28	1992	366	1064.9	934.7	130.2	513.7	0.48	204.8	346.3	0.0
Future + Nat Heritage	28	1993	365	798.7	676.6	122.1	360.6	0.45	105.2	340.5	7.5
Future + Nat Heritage	28	1994	365	754.4	580.0	174.4	339.0	0.45	73.1	337.0	-5.3
Future + Nat Heritage	28	1995	365	925.3	784.8	140.5	451.8	0.49	133.7	328.0	-11.8
Future + Nat Heritage	28	1996	366	1033.9	908.7	125.2	489.6	0.47	181.0	365.6	2.3
Future + Nat Heritage	28	1997	365	761.9	567.5	194.4	363.1	0.48	71.6	343.2	16.1
Future + Nat Heritage	28	1998	365	733.8	627.2	106.6	323.9	0.44	96.4	312.6	-0.9
Future + Nat Heritage	28	1999	365	804.6	649.5	155.1	410.2	0.51	85.8	313.9	5.3
Future + Nat Heritage	28	2000	366	984.2	803.3	180.9	431.5	0.44	104.7	375.6	-72.3
Future + 50% Dev	1	1986	223	832.5	784.0	48.5	198.4	0.24	252.5	344.4	-37.2
Future + 50% Dev	1	1987	365	823.2	696.6	126.6	161.1	0.20	189.4	473.4	0.7
Future + 50% Dev	1	1988	366	676.4	569.5	106.9	90.0	0.13	161.1	419.1	-6.2
Future + 50% Dev	1	1989	365	775.6	643.1	132.5	111.9	0.14	174.9	479.4	-9.4
Future + 50% Dev	1	1990	365	920.9	765.1	155.8	188.8	0.21	243.7	495.6	7.2
Future + 50% Dev	1	1991	365	751.8	618.6	133.2	139.1	0.19	172.2	447.4	6.9
Future + 50% Dev	1	1992	366	1064.9	934.7	130.2	209.8	0.20	358.3	494.0	-2.8
Future + 50% Dev	1	1993	365	798.7	676.6	122.1	128.6	0.16	186.3	497.2	13.4
Future + 50% Dev	1	1994	365	754.4	580.0	174.4	131.2	0.17	129.6	488.1	-5.5
Future + 50% Dev	1	1995	365	925.3	784.8	140.5	192.9	0.21	232.4	488.1	-11.8
Future + 50% Dev	1	1996	366	1033.9	908.7	125.2	191.3	0.19	321.0	519.6	-2.0
Future + 50% Dev	1	1997	365	761.9	567.5	194.4	159.3	0.21	126.7	494.4	18.6
Future + 50% Dev	1	1998	365	733.8	627.2	106.6	105.0	0.14	163.7	463.1	-2.0
Future + 50% Dev	1	1999	365	804.6	649.5	155.1	191.4	0.24	148.5	471.6	7.0
Future + 50% Dev	1	2000	366	984.2	803.3	180.9	177.3	0.18	199.0	536.3	-71.6
Future + 50% Dev	2	1986	223	832.5	784.0	48.5	359.6	0.43	170.4	263.5	-39.0
Future + 50% Dev	2	1987	365	823.2	696.6	126.6	312.9	0.38	137.0	374.7	1.4
Future + 50% Dev	2	1988	366	676.4	569.5	106.9	215.7	0.32	127.4	329.2	-4.1
Future + 50% Dev	2	1989	365	775.6	643.1	132.5	256.9	0.33	128.1	377.7	-12.9

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	P-Q_{out} [mm/yr]
Future + 50% Dev	2	1990	365	920.9	765.1	155.8	363.9	0.40	177.5	395.8	16.3
Future + 50% Dev	2	1991	365	751.8	618.6	133.2	277.4	0.37	127.8	350.4	3.7
Future + 50% Dev	2	1992	366	1064.9	934.7	130.2	417.7	0.39	250.1	398.7	1.6
Future + 50% Dev	2	1993	365	798.7	676.6	122.1	280.3	0.35	134.7	393.2	9.4
Future + 50% Dev	2	1994	365	754.4	580.0	174.4	265.3	0.35	98.0	387.3	-3.9
Future + 50% Dev	2	1995	365	925.3	784.8	140.5	369.6	0.40	161.6	383.2	-10.8
Future + 50% Dev	2	1996	366	1033.9	908.7	125.2	389.3	0.38	228.4	420.8	4.7
Future + 50% Dev	2	1997	365	761.9	567.5	194.4	290.9	0.38	88.7	398.5	16.3
Future + 50% Dev	2	1998	365	733.8	627.2	106.6	245.6	0.33	124.3	364.0	0.0
Future + 50% Dev	2	1999	365	804.6	649.5	155.1	339.8	0.42	105.8	366.1	7.1
Future + 50% Dev	2	2000	366	984.2	803.3	180.9	347.8	0.35	131.9	433.5	-71.0
Future + 50% Dev	3	1986	223	832.5	784.0	48.5	200.2	0.24	259.9	342.0	-30.4
Future + 50% Dev	3	1987	365	823.2	696.6	126.6	166.0	0.20	191.4	466.0	0.2
Future + 50% Dev	3	1988	366	676.4	569.5	106.9	96.3	0.14	161.3	412.3	-6.6
Future + 50% Dev	3	1989	365	775.6	643.1	132.5	118.3	0.15	175.6	471.5	-10.2
Future + 50% Dev	3	1990	365	920.9	765.1	155.8	193.7	0.21	246.9	487.7	7.5
Future + 50% Dev	3	1991	365	751.8	618.6	133.2	144.0	0.19	174.2	439.9	6.3
Future + 50% Dev	3	1992	366	1064.9	934.7	130.2	214.0	0.20	362.3	485.5	-3.1
Future + 50% Dev	3	1993	365	798.7	676.6	122.1	134.3	0.17	188.1	489.0	12.7
Future + 50% Dev	3	1994	365	754.4	580.0	174.4	136.9	0.18	131.2	480.4	-5.9
Future + 50% Dev	3	1995	365	925.3	784.8	140.5	196.6	0.21	235.7	480.6	-12.4
Future + 50% Dev	3	1996	366	1033.9	908.7	125.2	196.9	0.19	324.0	511.1	-1.9
Future + 50% Dev	3	1997	365	761.9	567.5	194.4	164.5	0.22	128.6	486.5	17.7
Future + 50% Dev	3	1998	365	733.8	627.2	106.6	111.3	0.15	165.1	455.1	-2.3
Future + 50% Dev	3	1999	365	804.6	649.5	155.1	195.9	0.24	151.3	463.9	6.5
Future + 50% Dev	3	2000	366	984.2	803.3	180.9	182.2	0.19	202.6	527.1	-72.3
Future + 50% Dev	4	1986	223	832.5	784.0	48.5	469.5	0.56	118.3	224.2	-20.4
Future + 50% Dev	4	1987	365	823.2	696.6	126.6	416.8	0.51	99.8	310.0	3.4
Future + 50% Dev	4	1988	366	676.4	569.5	106.9	303.5	0.45	96.9	274.4	-1.6
Future + 50% Dev	4	1989	365	775.6	643.1	132.5	358.3	0.46	92.9	311.3	-13.1
Future + 50% Dev	4	1990	365	920.9	765.1	155.8	483.7	0.53	130.0	329.4	22.1
Future + 50% Dev	4	1991	365	751.8	618.6	133.2	372.6	0.50	93.5	290.0	4.3
Future + 50% Dev	4	1992	366	1064.9	934.7	130.2	559.9	0.53	173.0	338.1	6.2
Future + 50% Dev	4	1993	365	798.7	676.6	122.1	384.7	0.48	95.6	326.9	8.5
Future + 50% Dev	4	1994	365	754.4	580.0	174.4	357.8	0.47	72.6	322.1	-2.0
Future + 50% Dev	4	1995	365	925.3	784.8	140.5	490.2	0.53	113.1	313.9	-8.2
Future + 50% Dev	4	1996	366	1033.9	908.7	125.2	525.5	0.51	162.4	355.8	9.7

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	$P-Q_{out}$ [mm/yr]
Future + 50% Dev	4	1997	365	761.9	567.5	194.4	380.0	0.50	63.6	335.4	17.1
Future + 50% Dev	4	1998	365	733.8	627.2	106.6	343.7	0.47	90.4	302.2	2.4
Future + 50% Dev	4	1999	365	804.6	649.5	155.1	439.6	0.55	76.9	296.6	8.4
Future + 50% Dev	4	2000	366	984.2	803.3	180.9	463.3	0.47	86.5	365.5	-69.0
Future + 50% Dev	5	1986	223	832.5	784.0	48.5	75.4	0.09	424.2	412.7	79.8
Future + 50% Dev	5	1987	365	823.2	696.6	126.6	64.6	0.08	221.5	536.2	-0.9
Future + 50% Dev	5	1988	366	676.4	569.5	106.9	29.1	0.04	153.6	489.3	-4.4
Future + 50% Dev	5	1989	365	775.6	643.1	132.5	37.4	0.05	197.2	537.8	-3.2
Future + 50% Dev	5	1990	365	920.9	765.1	155.8	75.0	0.08	282.9	554.8	-8.2
Future + 50% Dev	5	1991	365	751.8	618.6	133.2	55.1	0.07	200.0	518.8	22.1
Future + 50% Dev	5	1992	366	1064.9	934.7	130.2	75.6	0.07	424.0	552.4	-12.9
Future + 50% Dev	5	1993	365	798.7	676.6	122.1	43.2	0.05	210.1	564.7	19.3
Future + 50% Dev	5	1994	365	754.4	580.0	174.4	52.3	0.07	142.2	551.9	-8.0
Future + 50% Dev	5	1995	365	925.3	784.8	140.5	74.2	0.08	287.6	552.8	-10.7
Future + 50% Dev	5	1996	366	1033.9	908.7	125.2	69.1	0.07	376.4	578.4	-10.1
Future + 50% Dev	5	1997	365	761.9	567.5	194.4	72.8	0.10	157.6	560.6	29.1
Future + 50% Dev	5	1998	365	733.8	627.2	106.6	35.1	0.05	175.7	537.1	14.0
Future + 50% Dev	5	1999	365	804.6	649.5	155.1	86.4	0.11	157.7	546.8	-13.7
Future + 50% Dev	5	2000	366	984.2	803.3	180.9	66.7	0.07	244.6	602.3	-70.6
Future + 50% Dev	6	1986	223	832.5	784.0	48.5	201.9	0.24	226.6	361.7	-42.3
Future + 50% Dev	6	1987	365	823.2	696.6	126.6	163.9	0.20	170.0	489.6	0.2
Future + 50% Dev	6	1988	366	676.4	569.5	106.9	92.5	0.14	147.6	430.0	-6.3
Future + 50% Dev	6	1989	365	775.6	643.1	132.5	114.2	0.15	156.7	494.6	-10.2
Future + 50% Dev	6	1990	365	920.9	765.1	155.8	193.5	0.21	220.4	514.4	7.4
Future + 50% Dev	6	1991	365	751.8	618.6	133.2	143.1	0.19	156.6	458.0	5.9
Future + 50% Dev	6	1992	366	1064.9	934.7	130.2	217.3	0.20	330.0	514.6	-3.1
Future + 50% Dev	6	1993	365	798.7	676.6	122.1	130.6	0.16	159.2	521.2	12.4
Future + 50% Dev	6	1994	365	754.4	580.0	174.4	131.9	0.17	109.7	507.1	-5.7
Future + 50% Dev	6	1995	365	925.3	784.8	140.5	199.3	0.22	211.9	502.1	-12.0
Future + 50% Dev	6	1996	366	1033.9	908.7	125.2	196.2	0.19	287.4	548.0	-2.3
Future + 50% Dev	6	1997	365	761.9	567.5	194.4	159.6	0.21	109.1	510.7	17.5
Future + 50% Dev	6	1998	365	733.8	627.2	106.6	109.1	0.15	150.5	472.3	-1.8
Future + 50% Dev	6	1999	365	804.6	649.5	155.1	193.6	0.24	133.3	483.8	6.0
Future + 50% Dev	6	2000	366	984.2	803.3	180.9	177.7	0.18	159.1	575.7	-71.6
Future + 50% Dev	7	1986	223	832.5	784.0	48.5	128.1	0.15	308.3	394.3	-1.8
Future + 50% Dev	7	1987	365	823.2	696.6	126.6	105.3	0.13	204.0	513.9	0.1
Future + 50% Dev	7	1988	366	676.4	569.5	106.9	52.8	0.08	156.4	460.2	-7.0

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	$P-Q_{out}$ [mm/yr]
Future + 50% Dev	7	1989	365	775.6	643.1	132.5	66.6	0.09	183.8	517.9	-7.3
Future + 50% Dev	7	1990	365	920.9	765.1	155.8	123.4	0.13	263.3	535.9	1.8
Future + 50% Dev	7	1991	365	751.8	618.6	133.2	90.6	0.12	182.4	488.9	10.1
Future + 50% Dev	7	1992	366	1064.9	934.7	130.2	130.7	0.12	395.3	533.7	-5.2
Future + 50% Dev	7	1993	365	798.7	676.6	122.1	77.2	0.10	192.5	544.1	15.1
Future + 50% Dev	7	1994	365	754.4	580.0	174.4	85.3	0.11	131.0	531.3	-6.8
Future + 50% Dev	7	1995	365	925.3	784.8	140.5	124.6	0.13	259.6	529.5	-11.6
Future + 50% Dev	7	1996	366	1033.9	908.7	125.2	119.2	0.12	345.4	563.9	-5.4
Future + 50% Dev	7	1997	365	761.9	567.5	194.4	110.5	0.15	135.3	536.5	20.4
Future + 50% Dev	7	1998	365	733.8	627.2	106.6	62.9	0.09	167.0	504.5	0.5
Future + 50% Dev	7	1999	365	804.6	649.5	155.1	133.0	0.17	158.4	516.4	3.3
Future + 50% Dev	7	2000	366	984.2	803.3	180.9	111.6	0.11	212.1	588.8	-71.7
Future + 50% Dev	8	1986	223	832.5	784.0	48.5	422.9	0.51	150.1	236.5	-22.9
Future + 50% Dev	8	1987	365	823.2	696.6	126.6	382.4	0.46	116.2	327.2	2.6
Future + 50% Dev	8	1988	366	676.4	569.5	106.9	279.0	0.41	106.6	287.6	-3.2
Future + 50% Dev	8	1989	365	775.6	643.1	132.5	327.2	0.42	109.0	326.1	-13.2
Future + 50% Dev	8	1990	365	920.9	765.1	155.8	442.7	0.48	151.7	345.9	19.5
Future + 50% Dev	8	1991	365	751.8	618.6	133.2	342.2	0.46	109.5	304.3	4.2
Future + 50% Dev	8	1992	366	1064.9	934.7	130.2	503.9	0.47	216.2	348.7	4.0
Future + 50% Dev	8	1993	365	798.7	676.6	122.1	350.9	0.44	113.2	343.0	8.4
Future + 50% Dev	8	1994	365	754.4	580.0	174.4	330.3	0.44	81.0	340.0	-3.0
Future + 50% Dev	8	1995	365	925.3	784.8	140.5	444.2	0.48	140.0	332.0	-9.1
Future + 50% Dev	8	1996	366	1033.9	908.7	125.2	477.7	0.46	193.4	369.9	7.2
Future + 50% Dev	8	1997	365	761.9	567.5	194.4	354.9	0.47	74.8	349.0	16.8
Future + 50% Dev	8	1998	365	733.8	627.2	106.6	314.4	0.43	106.4	314.2	1.2
Future + 50% Dev	8	1999	365	804.6	649.5	155.1	405.1	0.50	90.4	316.9	7.9
Future + 50% Dev	8	2000	366	984.2	803.3	180.9	422.0	0.43	109.8	382.4	-70.0
Future + 50% Dev	9	1986	223	832.5	784.0	48.5	434.5	0.52	125.6	240.2	-32.3
Future + 50% Dev	9	1987	365	823.2	696.6	126.6	385.4	0.47	101.7	338.7	2.7
Future + 50% Dev	9	1988	366	676.4	569.5	106.9	278.0	0.41	98.6	297.3	-2.5
Future + 50% Dev	9	1989	365	775.6	643.1	132.5	328.0	0.42	95.3	339.2	-13.1
Future + 50% Dev	9	1990	365	920.9	765.1	155.8	448.8	0.49	132.4	359.9	20.2
Future + 50% Dev	9	1991	365	751.8	618.6	133.2	345.3	0.46	96.7	313.7	3.9
Future + 50% Dev	9	1992	366	1064.9	934.7	130.2	518.2	0.49	187.6	363.8	4.7
Future + 50% Dev	9	1993	365	798.7	676.6	122.1	352.8	0.44	97.3	357.1	8.4
Future + 50% Dev	9	1994	365	754.4	580.0	174.4	328.9	0.44	70.4	352.4	-2.7
Future + 50% Dev	9	1995	365	925.3	784.8	140.5	454.4	0.49	118.8	343.3	-8.7

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	$P-Q_{out}$ [mm/yr]
Future + 50% Dev	9	1996	366	1033.9	908.7	125.2	485.4	0.47	169.8	386.5	7.8
Future + 50% Dev	9	1997	365	761.9	567.5	194.4	352.3	0.46	63.9	362.3	16.6
Future + 50% Dev	9	1998	365	733.8	627.2	106.6	315.8	0.43	94.7	324.9	1.6
Future + 50% Dev	9	1999	365	804.6	649.5	155.1	408.3	0.51	77.9	326.3	7.9
Future + 50% Dev	9	2000	366	984.2	803.3	180.9	425.4	0.43	86.6	402.7	-69.5
Future + 50% Dev	10	1986	223	832.5	784.0	48.5	414.6	0.50	156.6	240.6	-20.7
Future + 50% Dev	10	1987	365	823.2	696.6	126.6	376.0	0.46	119.3	330.6	2.6
Future + 50% Dev	10	1988	366	676.4	569.5	106.9	274.5	0.41	104.1	294.1	-3.7
Future + 50% Dev	10	1989	365	775.6	643.1	132.5	322.0	0.42	111.8	330.2	-11.7
Future + 50% Dev	10	1990	365	920.9	765.1	155.8	435.1	0.47	153.3	349.1	16.7
Future + 50% Dev	10	1991	365	751.8	618.6	133.2	336.3	0.45	109.7	311.1	5.3
Future + 50% Dev	10	1992	366	1064.9	934.7	130.2	493.4	0.46	223.1	351.4	3.0
Future + 50% Dev	10	1993	365	798.7	676.6	122.1	345.0	0.43	116.6	346.4	9.3
Future + 50% Dev	10	1994	365	754.4	580.0	174.4	325.3	0.43	81.3	344.4	-3.4
Future + 50% Dev	10	1995	365	925.3	784.8	140.5	435.0	0.47	145.0	336.0	-9.2
Future + 50% Dev	10	1996	366	1033.9	908.7	125.2	469.5	0.45	199.3	370.6	5.4
Future + 50% Dev	10	1997	365	761.9	567.5	194.4	349.9	0.46	78.0	351.7	17.7
Future + 50% Dev	10	1998	365	733.8	627.2	106.6	308.8	0.42	105.2	320.4	0.6
Future + 50% Dev	10	1999	365	804.6	649.5	155.1	396.9	0.49	92.7	323.1	8.1
Future + 50% Dev	10	2000	366	984.2	803.3	180.9	414.9	0.42	118.5	380.8	-70.0
Future + 50% Dev	11	1986	223	832.5	784.0	48.5	461.0	0.55	126.4	220.8	-24.2
Future + 50% Dev	11	1987	365	823.2	696.6	126.6	411.2	0.50	104.7	310.6	3.3
Future + 50% Dev	11	1988	366	676.4	569.5	106.9	299.6	0.44	100.0	274.8	-2.0
Future + 50% Dev	11	1989	365	775.6	643.1	132.5	353.0	0.46	98.0	311.6	-13.0
Future + 50% Dev	11	1990	365	920.9	765.1	155.8	476.6	0.52	136.2	329.6	21.5
Future + 50% Dev	11	1991	365	751.8	618.6	133.2	367.3	0.49	97.9	290.9	4.3
Future + 50% Dev	11	1992	366	1064.9	934.7	130.2	549.6	0.52	185.0	336.1	5.8
Future + 50% Dev	11	1993	365	798.7	676.6	122.1	379.4	0.48	101.6	326.2	8.6
Future + 50% Dev	11	1994	365	754.4	580.0	174.4	353.8	0.47	76.2	322.3	-2.1
Future + 50% Dev	11	1995	365	925.3	784.8	140.5	481.6	0.52	120.4	315.0	-8.3
Future + 50% Dev	11	1996	366	1033.9	908.7	125.2	517.3	0.50	172.0	353.8	9.3
Future + 50% Dev	11	1997	365	761.9	567.5	194.4	377.1	0.49	67.0	335.0	17.2
Future + 50% Dev	11	1998	365	733.8	627.2	106.6	338.5	0.46	94.9	302.6	2.2
Future + 50% Dev	11	1999	365	804.6	649.5	155.1	433.9	0.54	80.3	298.8	8.4
Future + 50% Dev	11	2000	366	984.2	803.3	180.9	457.4	0.46	95.3	362.3	-69.1
Future + 50% Dev	11.1	1986	223	832.5	784.0	48.5	595.5	0.72	49.4	190.2	2.6
Future + 50% Dev	11.1	1987	365	823.2	696.6	126.6	537.1	0.65	49.3	243.9	7.1

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	$P-Q_{out}$ [mm/yr]
Future + 50% Dev	11.1	1988	366	676.4	569.5	106.9	405.9	0.60	51.3	221.5	2.3
Future + 50% Dev	11.1	1989	365	775.6	643.1	132.5	476.9	0.61	44.8	243.1	-10.9
Future + 50% Dev	11.1	1990	365	920.9	765.1	155.8	625.1	0.68	63.3	261.7	29.2
Future + 50% Dev	11.1	1991	365	751.8	618.6	133.2	483.0	0.64	46.4	229.5	7.1
Future + 50% Dev	11.1	1992	366	1064.9	934.7	130.2	722.9	0.68	70.2	284.9	13.1
Future + 50% Dev	11.1	1993	365	798.7	676.6	122.1	501.4	0.63	42.1	264.0	8.8
Future + 50% Dev	11.1	1994	365	754.4	580.0	174.4	458.6	0.61	36.1	260.7	1.0
Future + 50% Dev	11.1	1995	365	925.3	784.8	140.5	632.0	0.68	48.7	241.1	-3.5
Future + 50% Dev	11.1	1996	366	1033.9	908.7	125.2	682.7	0.66	74.9	292.9	16.6
Future + 50% Dev	11.1	1997	365	761.9	567.5	194.4	475.1	0.62	34.3	272.0	19.5
Future + 50% Dev	11.1	1998	365	733.8	627.2	106.6	457.8	0.62	44.8	237.6	6.3
Future + 50% Dev	11.1	1999	365	804.6	649.5	155.1	550.9	0.68	39.0	225.7	11.0
Future + 50% Dev	11.1	2000	366	984.2	803.3	180.9	588.8	0.60	33.2	297.0	-65.2
Future + 50% Dev	12	1986	223	832.5	784.0	48.5	305.1	0.37	219.6	286.2	-21.6
Future + 50% Dev	12	1987	365	823.2	696.6	126.6	269.8	0.33	163.9	390.7	1.2
Future + 50% Dev	12	1988	366	676.4	569.5	106.9	185.1	0.27	141.8	344.1	-5.3
Future + 50% Dev	12	1989	365	775.6	643.1	132.5	219.5	0.28	151.0	393.2	-11.9
Future + 50% Dev	12	1990	365	920.9	765.1	155.8	312.3	0.34	211.9	410.0	13.3
Future + 50% Dev	12	1991	365	751.8	618.6	133.2	238.9	0.32	150.9	367.0	5.0
Future + 50% Dev	12	1992	366	1064.9	934.7	130.2	350.5	0.33	304.6	409.9	0.0
Future + 50% Dev	12	1993	365	798.7	676.6	122.1	238.7	0.30	162.3	408.2	10.6
Future + 50% Dev	12	1994	365	754.4	580.0	174.4	231.0	0.31	115.9	402.9	-4.6
Future + 50% Dev	12	1995	365	925.3	784.8	140.5	313.3	0.34	199.9	400.9	-11.2
Future + 50% Dev	12	1996	366	1033.9	908.7	125.2	330.7	0.32	273.8	432.0	2.6
Future + 50% Dev	12	1997	365	761.9	567.5	194.4	257.4	0.34	110.4	411.1	17.0
Future + 50% Dev	12	1998	365	733.8	627.2	106.6	209.2	0.29	144.3	379.5	-0.8
Future + 50% Dev	12	1999	365	804.6	649.5	155.1	296.6	0.37	130.0	385.2	7.2
Future + 50% Dev	12	2000	366	984.2	803.3	180.9	297.7	0.30	171.8	443.0	-71.7
Future + 50% Dev	13	1986	223	832.5	784.0	48.5	222.3	0.27	249.0	331.6	-29.6
Future + 50% Dev	13	1987	365	823.2	696.6	126.6	187.3	0.23	184.4	451.8	0.3
Future + 50% Dev	13	1988	366	676.4	569.5	106.9	114.2	0.17	158.0	397.8	-6.4
Future + 50% Dev	13	1989	365	775.6	643.1	132.5	138.7	0.18	169.3	456.8	-10.8
Future + 50% Dev	13	1990	365	920.9	765.1	155.8	218.2	0.24	238.6	473.2	9.1
Future + 50% Dev	13	1991	365	751.8	618.6	133.2	163.5	0.22	169.3	424.7	5.7
Future + 50% Dev	13	1992	366	1064.9	934.7	130.2	242.4	0.23	348.8	471.3	-2.4
Future + 50% Dev	13	1993	365	798.7	676.6	122.1	155.5	0.19	181.3	474.1	12.2
Future + 50% Dev	13	1994	365	754.4	580.0	174.4	156.0	0.21	127.1	465.6	-5.6

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	$P-Q_{out}$ [mm/yr]
Future + 50% Dev	13	1995	365	925.3	784.8	140.5	221.0	0.24	226.8	465.3	-12.2
Future + 50% Dev	13	1996	366	1033.9	908.7	125.2	224.4	0.22	311.3	497.4	-0.7
Future + 50% Dev	13	1997	365	761.9	567.5	194.4	183.5	0.24	123.9	471.8	17.2
Future + 50% Dev	13	1998	365	733.8	627.2	106.6	131.2	0.18	161.6	439.1	-1.8
Future + 50% Dev	13	1999	365	804.6	649.5	155.1	217.0	0.27	146.6	447.7	6.7
Future + 50% Dev	13	2000	366	984.2	803.3	180.9	205.9	0.21	193.0	512.9	-72.3
Future + 50% Dev	14	1986	223	832.5	784.0	48.5	339.3	0.41	191.8	272.4	-29.0
Future + 50% Dev	14	1987	365	823.2	696.6	126.6	299.5	0.36	147.4	377.8	1.5
Future + 50% Dev	14	1988	366	676.4	569.5	106.9	207.8	0.31	131.8	332.1	-4.7
Future + 50% Dev	14	1989	365	775.6	643.1	132.5	246.2	0.32	136.7	380.4	-12.4
Future + 50% Dev	14	1990	365	920.9	765.1	155.8	347.1	0.38	191.1	397.7	15.0
Future + 50% Dev	14	1991	365	751.8	618.6	133.2	265.6	0.35	136.9	353.8	4.6
Future + 50% Dev	14	1992	366	1064.9	934.7	130.2	393.2	0.37	274.4	398.3	1.0
Future + 50% Dev	14	1993	365	798.7	676.6	122.1	267.7	0.34	145.4	395.6	9.9
Future + 50% Dev	14	1994	365	754.4	580.0	174.4	256.1	0.34	104.2	390.1	-4.1
Future + 50% Dev	14	1995	365	925.3	784.8	140.5	349.4	0.38	178.1	386.9	-10.9
Future + 50% Dev	14	1996	366	1033.9	908.7	125.2	370.0	0.36	247.1	420.6	3.8
Future + 50% Dev	14	1997	365	761.9	567.5	194.4	282.4	0.37	97.7	398.6	16.8
Future + 50% Dev	14	1998	365	733.8	627.2	106.6	235.1	0.32	132.4	366.1	-0.2
Future + 50% Dev	14	1999	365	804.6	649.5	155.1	325.8	0.40	115.8	370.3	7.3
Future + 50% Dev	14	2000	366	984.2	803.3	180.9	331.7	0.34	149.6	431.7	-71.3
Future + 50% Dev	15	1986	223	832.5	784.0	48.5	78.2	0.09	425.3	405.1	76.1
Future + 50% Dev	15	1987	365	823.2	696.6	126.6	67.1	0.08	227.8	528.1	-0.2
Future + 50% Dev	15	1988	366	676.4	569.5	106.9	30.6	0.05	158.9	480.0	-6.9
Future + 50% Dev	15	1989	365	775.6	643.1	132.5	39.2	0.05	201.6	530.5	-4.2
Future + 50% Dev	15	1990	365	920.9	765.1	155.8	77.9	0.08	291.2	547.3	-4.4
Future + 50% Dev	15	1991	365	751.8	618.6	133.2	57.4	0.08	202.2	508.3	16.1
Future + 50% Dev	15	1992	366	1064.9	934.7	130.2	78.7	0.07	433.7	544.3	-8.3
Future + 50% Dev	15	1993	365	798.7	676.6	122.1	45.3	0.06	215.3	555.9	17.8
Future + 50% Dev	15	1994	365	754.4	580.0	174.4	54.5	0.07	147.2	544.7	-8.0
Future + 50% Dev	15	1995	365	925.3	784.8	140.5	77.2	0.08	292.5	544.9	-10.7
Future + 50% Dev	15	1996	366	1033.9	908.7	125.2	71.9	0.07	382.8	571.1	-8.1
Future + 50% Dev	15	1997	365	761.9	567.5	194.4	75.3	0.10	158.6	552.3	24.3
Future + 50% Dev	15	1998	365	733.8	627.2	106.6	36.7	0.05	178.0	526.3	7.2
Future + 50% Dev	15	1999	365	804.6	649.5	155.1	90.1	0.11	173.0	537.1	-4.4
Future + 50% Dev	15	2000	366	984.2	803.3	180.9	69.4	0.07	248.6	594.7	-71.5
Future + 50% Dev	16	1986	223	832.5	784.0	48.5	172.6	0.21	304.8	360.9	5.9

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	$P-Q_{out}$ [mm/yr]
Future + 50% Dev	16	1987	365	823.2	696.6	126.6	149.1	0.18	204.8	469.6	0.3
Future + 50% Dev	16	1988	366	676.4	569.5	106.9	89.9	0.13	166.6	412.7	-7.2
Future + 50% Dev	16	1989	365	775.6	643.1	132.5	108.7	0.14	183.4	474.4	-9.2
Future + 50% Dev	16	1990	365	920.9	765.1	155.8	172.5	0.19	264.4	489.7	5.8
Future + 50% Dev	16	1991	365	751.8	618.6	133.2	130.1	0.17	188.3	441.5	8.1
Future + 50% Dev	16	1992	366	1064.9	934.7	130.2	186.7	0.18	388.0	486.7	-3.5
Future + 50% Dev	16	1993	365	798.7	676.6	122.1	120.7	0.15	197.7	494.1	13.7
Future + 50% Dev	16	1994	365	754.4	580.0	174.4	125.5	0.17	140.3	482.3	-6.3
Future + 50% Dev	16	1995	365	925.3	784.8	140.5	172.3	0.19	257.0	484.0	-12.0
Future + 50% Dev	16	1996	366	1033.9	908.7	125.2	174.5	0.17	342.1	514.8	-2.5
Future + 50% Dev	16	1997	365	761.9	567.5	194.4	151.1	0.20	143.5	485.9	18.7
Future + 50% Dev	16	1998	365	733.8	627.2	106.6	102.7	0.14	174.1	454.9	-2.1
Future + 50% Dev	16	1999	365	804.6	649.5	155.1	176.9	0.22	169.5	465.0	6.7
Future + 50% Dev	16	2000	366	984.2	803.3	180.9	161.6	0.16	219.5	530.5	-72.5
Future + 50% Dev	17	1986	223	832.5	784.0	48.5	171.3	0.21	299.0	357.2	-4.9
Future + 50% Dev	17	1987	365	823.2	696.6	126.6	145.6	0.18	205.0	473.0	0.3
Future + 50% Dev	17	1988	366	676.4	569.5	106.9	85.2	0.13	163.8	420.5	-6.9
Future + 50% Dev	17	1989	365	775.6	643.1	132.5	103.9	0.13	185.2	478.0	-8.5
Future + 50% Dev	17	1990	365	920.9	765.1	155.8	168.9	0.18	263.6	493.0	4.6
Future + 50% Dev	17	1991	365	751.8	618.6	133.2	126.5	0.17	185.2	448.6	8.5
Future + 50% Dev	17	1992	366	1064.9	934.7	130.2	182.8	0.17	388.1	490.2	-3.8
Future + 50% Dev	17	1993	365	798.7	676.6	122.1	116.5	0.15	200.1	496.1	14.0
Future + 50% Dev	17	1994	365	754.4	580.0	174.4	121.6	0.16	139.9	486.5	-6.5
Future + 50% Dev	17	1995	365	925.3	784.8	140.5	169.2	0.18	256.3	487.9	-11.9
Future + 50% Dev	17	1996	366	1033.9	908.7	125.2	170.2	0.16	345.1	515.2	-3.5
Future + 50% Dev	17	1997	365	761.9	567.5	194.4	147.8	0.19	141.9	491.7	19.5
Future + 50% Dev	17	1998	365	733.8	627.2	106.6	97.8	0.13	170.7	463.3	-1.9
Future + 50% Dev	17	1999	365	804.6	649.5	155.1	173.6	0.22	165.2	472.2	6.3
Future + 50% Dev	17	2000	366	984.2	803.3	180.9	158.1	0.16	223.8	530.0	-72.4
Future + 50% Dev	18	1986	223	832.5	784.0	48.5	305.8	0.37	214.3	289.6	-22.8
Future + 50% Dev	18	1987	365	823.2	696.6	126.6	270.1	0.33	159.7	394.6	1.2
Future + 50% Dev	18	1988	366	676.4	569.5	106.9	185.3	0.27	138.7	347.1	-5.4
Future + 50% Dev	18	1989	365	775.6	643.1	132.5	219.5	0.28	147.0	397.4	-11.7
Future + 50% Dev	18	1990	365	920.9	765.1	155.8	312.8	0.34	206.8	414.2	13.0
Future + 50% Dev	18	1991	365	751.8	618.6	133.2	239.3	0.32	147.5	370.1	5.1
Future + 50% Dev	18	1992	366	1064.9	934.7	130.2	351.4	0.33	299.8	413.6	0.0
Future + 50% Dev	18	1993	365	798.7	676.6	122.1	238.9	0.30	157.2	413.2	10.7

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	P-Q_{out} [mm/yr]
Future + 50% Dev	18	1994	365	754.4	580.0	174.4	231.1	0.31	111.7	406.9	-4.7
Future + 50% Dev	18	1995	365	925.3	784.8	140.5	313.9	0.34	195.4	404.8	-11.2
Future + 50% Dev	18	1996	366	1033.9	908.7	125.2	331.4	0.32	268.1	436.8	2.3
Future + 50% Dev	18	1997	365	761.9	567.5	194.4	257.6	0.34	107.6	413.8	17.1
Future + 50% Dev	18	1998	365	733.8	627.2	106.6	209.4	0.29	141.4	382.2	-0.8
Future + 50% Dev	18	1999	365	804.6	649.5	155.1	296.6	0.37	127.3	387.9	7.2
Future + 50% Dev	18	2000	366	984.2	803.3	180.9	298.2	0.30	166.1	448.1	-71.7
Future + 50% Dev	19	1986	223	832.5	784.0	48.5	370.3	0.44	185.5	254.7	-21.9
Future + 50% Dev	19	1987	365	823.2	696.6	126.6	332.3	0.40	141.2	351.5	1.8
Future + 50% Dev	19	1988	366	676.4	569.5	106.9	237.2	0.35	125.2	309.6	-4.3
Future + 50% Dev	19	1989	365	775.6	643.1	132.5	279.2	0.36	130.9	352.8	-12.7
Future + 50% Dev	19	1990	365	920.9	765.1	155.8	384.1	0.42	183.3	369.9	16.4
Future + 50% Dev	19	1991	365	751.8	618.6	133.2	295.8	0.39	130.8	329.7	4.5
Future + 50% Dev	19	1992	366	1064.9	934.7	130.2	434.5	0.41	261.4	371.0	2.0
Future + 50% Dev	19	1993	365	798.7	676.6	122.1	301.2	0.38	140.0	366.9	9.5
Future + 50% Dev	19	1994	365	754.4	580.0	174.4	286.8	0.38	100.9	362.9	-3.8
Future + 50% Dev	19	1995	365	925.3	784.8	140.5	384.8	0.42	170.9	359.1	-10.4
Future + 50% Dev	19	1996	366	1033.9	908.7	125.2	411.9	0.40	235.8	391.2	5.0
Future + 50% Dev	19	1997	365	761.9	567.5	194.4	312.6	0.41	94.3	372.0	16.9
Future + 50% Dev	19	1998	365	733.8	627.2	106.6	267.1	0.36	126.1	340.8	0.1
Future + 50% Dev	19	1999	365	804.6	649.5	155.1	357.0	0.44	111.2	344.0	7.5
Future + 50% Dev	19	2000	366	984.2	803.3	180.9	367.9	0.37	145.6	399.7	-71.0
Future + 50% Dev	20	1986	223	832.5	784.0	48.5	460.0	0.55	135.3	213.9	-23.3
Future + 50% Dev	20	1987	365	823.2	696.6	126.6	414.2	0.50	110.2	302.1	3.3
Future + 50% Dev	20	1988	366	676.4	569.5	106.9	303.6	0.45	103.3	267.3	-2.1
Future + 50% Dev	20	1989	365	775.6	643.1	132.5	356.7	0.46	103.4	302.1	-13.3
Future + 50% Dev	20	1990	365	920.9	765.1	155.8	478.9	0.52	143.8	319.9	21.7
Future + 50% Dev	20	1991	365	751.8	618.6	133.2	370.1	0.49	102.8	283.3	4.3
Future + 50% Dev	20	1992	366	1064.9	934.7	130.2	549.1	0.52	195.2	326.2	5.6
Future + 50% Dev	20	1993	365	798.7	676.6	122.1	382.7	0.48	107.7	316.6	8.4
Future + 50% Dev	20	1994	365	754.4	580.0	174.4	358.1	0.47	80.8	313.3	-2.2
Future + 50% Dev	20	1995	365	925.3	784.8	140.5	482.2	0.52	128.7	306.0	-8.5
Future + 50% Dev	20	1996	366	1033.9	908.7	125.2	519.4	0.50	180.7	343.1	9.3
Future + 50% Dev	20	1997	365	761.9	567.5	194.4	382.1	0.50	71.2	325.8	17.2
Future + 50% Dev	20	1998	365	733.8	627.2	106.6	341.9	0.47	99.5	294.5	2.1
Future + 50% Dev	20	1999	365	804.6	649.5	155.1	437.0	0.54	85.3	290.7	8.4
Future + 50% Dev	20	2000	366	984.2	803.3	180.9	460.4	0.47	104.3	350.2	-69.3

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	P-Q_{out} [mm/yr]
Future + 50% Dev	21	1986	223	832.5	784.0	48.5	394.4	0.47	163.5	247.3	-27.4
Future + 50% Dev	21	1987	365	823.2	696.6	126.6	347.3	0.42	133.5	344.3	1.9
Future + 50% Dev	21	1988	366	676.4	569.5	106.9	245.5	0.36	125.5	302.3	-3.1
Future + 50% Dev	21	1989	365	775.6	643.1	132.5	291.0	0.38	124.8	345.7	-14.1
Future + 50% Dev	21	1990	365	920.9	765.1	155.8	402.5	0.44	174.2	363.6	19.5
Future + 50% Dev	21	1991	365	751.8	618.6	133.2	308.8	0.41	124.9	321.5	3.4
Future + 50% Dev	21	1992	366	1064.9	934.7	130.2	462.0	0.43	234.0	372.1	3.2
Future + 50% Dev	21	1993	365	798.7	676.6	122.1	314.8	0.39	129.8	362.7	8.6
Future + 50% Dev	21	1994	365	754.4	580.0	174.4	296.9	0.39	98.0	356.3	-3.3
Future + 50% Dev	21	1995	365	925.3	784.8	140.5	409.0	0.44	156.3	350.0	-10.1
Future + 50% Dev	21	1996	366	1033.9	908.7	125.2	432.3	0.42	216.8	391.8	7.0
Future + 50% Dev	21	1997	365	761.9	567.5	194.4	321.6	0.42	86.4	370.1	16.1
Future + 50% Dev	21	1998	365	733.8	627.2	106.6	278.4	0.38	120.6	335.7	0.9
Future + 50% Dev	21	1999	365	804.6	649.5	155.1	374.9	0.47	104.7	332.2	7.2
Future + 50% Dev	21	2000	366	984.2	803.3	180.9	385.6	0.39	123.6	404.4	-70.6
Future + 50% Dev	21.1	1986	223	832.5	784.0	48.5	267.9	0.32	252.8	307.5	-4.4
Future + 50% Dev	21.1	1987	365	823.2	696.6	126.6	239.2	0.29	178.9	406.1	0.9
Future + 50% Dev	21.1	1988	366	676.4	569.5	106.9	163.6	0.24	150.3	356.4	-6.2
Future + 50% Dev	21.1	1989	365	775.6	643.1	132.5	193.5	0.25	162.5	408.7	-10.9
Future + 50% Dev	21.1	1990	365	920.9	765.1	155.8	276.1	0.30	230.6	425.0	10.8
Future + 50% Dev	21.1	1991	365	751.8	618.6	133.2	211.9	0.28	165.3	380.9	6.2
Future + 50% Dev	21.1	1992	366	1064.9	934.7	130.2	306.7	0.29	333.2	424.0	-1.0
Future + 50% Dev	21.1	1993	365	798.7	676.6	122.1	209.7	0.26	175.5	424.9	11.4
Future + 50% Dev	21.1	1994	365	754.4	580.0	174.4	205.6	0.27	125.9	417.7	-5.2
Future + 50% Dev	21.1	1995	365	925.3	784.8	140.5	275.4	0.30	221.5	416.9	-11.5
Future + 50% Dev	21.1	1996	366	1033.9	908.7	125.2	290.6	0.28	296.4	447.8	0.9
Future + 50% Dev	21.1	1997	365	761.9	567.5	194.4	231.3	0.30	124.3	423.9	17.6
Future + 50% Dev	21.1	1998	365	733.8	627.2	106.6	184.4	0.25	155.1	393.0	-1.3
Future + 50% Dev	21.1	1999	365	804.6	649.5	155.1	265.3	0.33	146.6	400.0	7.3
Future + 50% Dev	21.1	2000	366	984.2	803.3	180.9	262.4	0.27	190.2	459.4	-72.2
Future + 50% Dev	22	1986	223	832.5	784.0	48.5	561.3	0.67	66.1	204.7	-0.4
Future + 50% Dev	22	1987	365	823.2	696.6	126.6	502.4	0.61	64.1	262.2	5.6
Future + 50% Dev	22	1988	366	676.4	569.5	106.9	375.3	0.55	65.7	236.4	1.1
Future + 50% Dev	22	1989	365	775.6	643.1	132.5	442.9	0.57	58.6	262.0	-12.1
Future + 50% Dev	22	1990	365	920.9	765.1	155.8	585.2	0.64	82.8	280.1	27.2
Future + 50% Dev	22	1991	365	751.8	618.6	133.2	451.6	0.60	60.2	245.9	5.8
Future + 50% Dev	22	1992	366	1064.9	934.7	130.2	677.8	0.64	93.5	304.4	10.7

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	P-Q_{out} [mm/yr]
Future + 50% Dev	22	1993	365	798.7	676.6	122.1	467.4	0.59	55.4	284.1	8.2
Future + 50% Dev	22	1994	365	754.4	580.0	174.4	428.2	0.57	47.4	278.7	-0.1
Future + 50% Dev	22	1995	365	925.3	784.8	140.5	594.7	0.64	65.2	260.2	-5.3
Future + 50% Dev	22	1996	366	1033.9	908.7	125.2	637.1	0.62	97.7	313.6	14.5
Future + 50% Dev	22	1997	365	761.9	567.5	194.4	445.9	0.59	43.9	290.5	18.4
Future + 50% Dev	22	1998	365	733.8	627.2	106.6	425.4	0.58	58.5	254.9	5.0
Future + 50% Dev	22	1999	365	804.6	649.5	155.1	520.0	0.65	50.5	243.8	9.7
Future + 50% Dev	22	2000	366	984.2	803.3	180.9	552.9	0.56	44.2	320.5	-66.6
Future + 50% Dev	23	1986	223	832.5	784.0	48.5	402.7	0.48	158.0	251.5	-20.4
Future + 50% Dev	23	1987	365	823.2	696.6	126.6	353.8	0.43	132.0	339.4	1.9
Future + 50% Dev	23	1988	366	676.4	569.5	106.9	250.4	0.37	125.6	297.7	-2.8
Future + 50% Dev	23	1989	365	775.6	643.1	132.5	297.2	0.38	122.7	340.9	-14.7
Future + 50% Dev	23	1990	365	920.9	765.1	155.8	410.2	0.45	172.9	358.3	20.5
Future + 50% Dev	23	1991	365	751.8	618.6	133.2	314.9	0.42	124.0	316.1	3.2
Future + 50% Dev	23	1992	366	1064.9	934.7	130.2	471.8	0.44	224.7	371.9	3.6
Future + 50% Dev	23	1993	365	798.7	676.6	122.1	320.9	0.40	125.7	360.3	8.2
Future + 50% Dev	23	1994	365	754.4	580.0	174.4	302.0	0.40	97.2	352.0	-3.2
Future + 50% Dev	23	1995	365	925.3	784.8	140.5	418.5	0.45	153.1	343.7	-10.0
Future + 50% Dev	23	1996	366	1033.9	908.7	125.2	440.4	0.43	210.3	391.0	7.7
Future + 50% Dev	23	1997	365	761.9	567.5	194.4	326.2	0.43	86.1	365.6	15.9
Future + 50% Dev	23	1998	365	733.8	627.2	106.6	284.5	0.39	120.3	330.2	1.2
Future + 50% Dev	23	1999	365	804.6	649.5	155.1	382.5	0.48	104.9	324.2	7.0
Future + 50% Dev	23	2000	366	984.2	803.3	180.9	392.5	0.40	115.6	405.6	-70.5
Future + 50% Dev	24	1986	223	832.5	784.0	48.5	440.9	0.53	138.4	222.2	-30.9
Future + 50% Dev	24	1987	365	823.2	696.6	126.6	393.5	0.48	113.5	319.2	3.0
Future + 50% Dev	24	1988	366	676.4	569.5	106.9	284.7	0.42	106.2	282.9	-2.5
Future + 50% Dev	24	1989	365	775.6	643.1	132.5	335.9	0.43	106.5	320.4	-12.8
Future + 50% Dev	24	1990	365	920.9	765.1	155.8	455.9	0.50	147.2	338.1	20.3
Future + 50% Dev	24	1991	365	751.8	618.6	133.2	350.8	0.47	105.4	300.0	4.4
Future + 50% Dev	24	1992	366	1064.9	934.7	130.2	524.0	0.49	202.8	343.1	4.9
Future + 50% Dev	24	1993	365	798.7	676.6	122.1	361.8	0.45	111.6	334.2	8.9
Future + 50% Dev	24	1994	365	754.4	580.0	174.4	338.3	0.45	82.5	331.1	-2.5
Future + 50% Dev	24	1995	365	925.3	784.8	140.5	460.0	0.50	132.0	324.5	-8.8
Future + 50% Dev	24	1996	366	1033.9	908.7	125.2	493.7	0.48	187.8	360.6	8.2
Future + 50% Dev	24	1997	365	761.9	567.5	194.4	362.5	0.48	73.0	343.5	17.1
Future + 50% Dev	24	1998	365	733.8	627.2	106.6	321.6	0.44	102.1	311.7	1.7
Future + 50% Dev	24	1999	365	804.6	649.5	155.1	416.5	0.52	86.7	309.7	8.3

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	P-Q_{out} [mm/yr]
Future + 50% Dev	24	2000	366	984.2	803.3	180.9	437.8	0.44	108.6	368.3	-69.5
Future + 50% Dev	25	1986	223	832.5	784.0	48.5	338.2	0.41	203.9	267.6	-22.8
Future + 50% Dev	25	1987	365	823.2	696.6	126.6	300.9	0.37	156.0	367.8	1.5
Future + 50% Dev	25	1988	366	676.4	569.5	106.9	210.6	0.31	138.9	322.4	-4.6
Future + 50% Dev	25	1989	365	775.6	643.1	132.5	248.8	0.32	144.5	369.2	-13.1
Future + 50% Dev	25	1990	365	920.9	765.1	155.8	347.9	0.38	202.5	386.6	16.1
Future + 50% Dev	25	1991	365	751.8	618.6	133.2	267.0	0.36	144.9	344.1	4.2
Future + 50% Dev	25	1992	366	1064.9	934.7	130.2	392.7	0.37	285.0	388.7	1.4
Future + 50% Dev	25	1993	365	798.7	676.6	122.1	269.5	0.34	154.4	384.4	9.5
Future + 50% Dev	25	1994	365	754.4	580.0	174.4	258.5	0.34	112.8	379.1	-4.0
Future + 50% Dev	25	1995	365	925.3	784.8	140.5	349.7	0.38	188.6	376.1	-10.9
Future + 50% Dev	25	1996	366	1033.9	908.7	125.2	370.6	0.36	257.6	410.3	4.5
Future + 50% Dev	25	1997	365	761.9	567.5	194.4	284.7	0.37	104.0	389.8	16.5
Future + 50% Dev	25	1998	365	733.8	627.2	106.6	237.7	0.32	139.4	356.7	-0.1
Future + 50% Dev	25	1999	365	804.6	649.5	155.1	328.0	0.41	123.5	360.4	7.2
Future + 50% Dev	25	2000	366	984.2	803.3	180.9	332.6	0.34	159.2	421.1	-71.3
Future + 50% Dev	26	1986	223	832.5	784.0	48.5	433.1	0.52	144.8	229.5	-25.1
Future + 50% Dev	26	1987	365	823.2	696.6	126.6	386.2	0.47	118.7	319.8	1.4
Future + 50% Dev	26	1988	366	676.4	569.5	106.9	279.3	0.41	111.8	282.0	-3.3
Future + 50% Dev	26	1989	365	775.6	643.1	132.5	329.3	0.42	111.0	320.7	-14.6
Future + 50% Dev	26	1990	365	920.9	765.1	155.8	446.9	0.49	154.8	338.5	19.3
Future + 50% Dev	26	1991	365	751.8	618.6	133.2	344.4	0.46	111.0	299.2	2.8
Future + 50% Dev	26	1992	366	1064.9	934.7	130.2	513.1	0.48	207.8	346.9	2.9
Future + 50% Dev	26	1993	365	798.7	676.6	122.1	354.3	0.44	115.3	336.5	7.4
Future + 50% Dev	26	1994	365	754.4	580.0	174.4	332.2	0.44	87.1	331.5	-3.7
Future + 50% Dev	26	1995	365	925.3	784.8	140.5	452.0	0.49	138.5	324.1	-10.7
Future + 50% Dev	26	1996	366	1033.9	908.7	125.2	483.0	0.47	192.8	364.9	6.8
Future + 50% Dev	26	1997	365	761.9	567.5	194.4	356.1	0.47	76.6	344.7	15.5
Future + 50% Dev	26	1998	365	733.8	627.2	106.6	315.5	0.43	107.2	311.9	0.7
Future + 50% Dev	26	1999	365	804.6	649.5	155.1	410.9	0.51	92.8	307.4	6.4
Future + 50% Dev	26	2000	366	984.2	803.3	180.9	428.9	0.44	109.4	374.7	-71.2
Future + 50% Dev	27	1986	223	832.5	784.0	48.5	414.5	0.50	165.3	235.3	-17.3
Future + 50% Dev	27	1987	365	823.2	696.6	126.6	377.3	0.46	126.0	322.0	2.1
Future + 50% Dev	27	1988	366	676.4	569.5	106.9	276.4	0.41	111.9	284.3	-3.7
Future + 50% Dev	27	1989	365	775.6	643.1	132.5	323.8	0.42	117.9	320.5	-13.4
Future + 50% Dev	27	1990	365	920.9	765.1	155.8	436.0	0.47	163.5	339.9	18.5
Future + 50% Dev	27	1991	365	751.8	618.6	133.2	337.6	0.45	117.0	301.3	4.1

Annual Water Balance Table

Scenario	Basin	YEAR	DAYS /YR	PRECIP [mm/yr]	RAIN [mm/yr]	SNOW [mm/yr]	RO [mm/yr]	C	GWI [mm/yr]	E [mm/yr]	$P-Q_{out}$ [mm/yr]
Future + 50% Dev	27	1992	366	1064.9	934.7	130.2	494.0	0.46	230.7	343.3	3.1
Future + 50% Dev	27	1993	365	798.7	676.6	122.1	346.5	0.43	123.7	336.7	8.2
Future + 50% Dev	27	1994	365	754.4	580.0	174.4	327.2	0.43	88.8	334.9	-3.5
Future + 50% Dev	27	1995	365	925.3	784.8	140.5	436.1	0.47	152.7	326.8	-9.7
Future + 50% Dev	27	1996	366	1033.9	908.7	125.2	470.2	0.45	207.4	362.7	6.4
Future + 50% Dev	27	1997	365	761.9	567.5	194.4	351.6	0.46	82.1	344.8	16.6
Future + 50% Dev	27	1998	365	733.8	627.2	106.6	310.8	0.42	112.6	311.1	0.8
Future + 50% Dev	27	1999	365	804.6	649.5	155.1	399.7	0.50	98.4	313.9	7.4
Future + 50% Dev	27	2000	366	984.2	803.3	180.9	416.1	0.42	124.1	373.4	-70.6
Future + 50% Dev	28	1986	223	832.5	784.0	48.5	429.7	0.52	142.7	236.2	-23.9
Future + 50% Dev	28	1987	365	823.2	696.6	126.6	391.3	0.48	109.2	323.3	0.6
Future + 50% Dev	28	1988	366	676.4	569.5	106.9	288.4	0.43	96.0	287.1	-4.8
Future + 50% Dev	28	1989	365	775.6	643.1	132.5	337.4	0.44	102.0	323.4	-12.7
Future + 50% Dev	28	1990	365	920.9	765.1	155.8	452.4	0.49	139.5	342.2	13.3
Future + 50% Dev	28	1991	365	751.8	618.6	133.2	350.6	0.47	101.2	303.9	3.9
Future + 50% Dev	28	1992	366	1064.9	934.7	130.2	513.8	0.48	205.2	345.9	0.0
Future + 50% Dev	28	1993	365	798.7	676.6	122.1	360.7	0.45	105.7	339.9	7.5
Future + 50% Dev	28	1994	365	754.4	580.0	174.4	339.1	0.45	73.5	336.6	-5.2
Future + 50% Dev	28	1995	365	925.3	784.8	140.5	451.9	0.49	134.0	327.6	-11.7
Future + 50% Dev	28	1996	366	1033.9	908.7	125.2	489.6	0.47	181.5	365.0	2.3
Future + 50% Dev	28	1997	365	761.9	567.5	194.4	363.2	0.48	71.9	343.0	16.1
Future + 50% Dev	28	1998	365	733.8	627.2	106.6	324.0	0.44	96.6	312.3	-0.9
Future + 50% Dev	28	1999	365	804.6	649.5	155.1	410.3	0.51	86.0	313.7	5.3
Future + 50% Dev	28	2000	366	984.2	803.3	180.9	431.6	0.44	105.4	374.9	-72.3

Appendix G: Average Monthly Water Balance Results

Scenario	Basin	Precipitation [mm]											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Existing	1	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Existing	2	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Existing	3	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Existing	4	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Existing	5	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Existing	6	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Existing	7	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Existing	8	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Existing	9	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Existing	10	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Existing	11	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Existing	11.1	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Existing	12	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Existing	13	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Existing	14	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Existing	15	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Existing	16	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Existing	17	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Existing	18	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Existing	19	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Existing	20	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Existing	21	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Existing	21.1	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Existing	22	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Existing	23	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Existing	24	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Existing	25	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Existing	26	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Existing	27	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6

Scenario	Basin	Precipitation [mm]											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Existing	28	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future	1	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future	2	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future	3	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future	4	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future	5	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future	6	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future	7	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future	8	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future	9	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future	10	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future	11	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future	11.1	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future	12	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future	13	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future	14	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future	15	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future	16	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future	17	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future	18	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future	19	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future	20	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future	21	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future	21.1	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future	22	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future	23	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future	24	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future	25	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6

Scenario	Basin	Precipitation [mm]											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Future	26	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future	27	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future	28	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future + Nat Heritage	1	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future + Nat Heritage	2	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future + Nat Heritage	3	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future + Nat Heritage	4	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future + Nat Heritage	5	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future + Nat Heritage	6	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future + Nat Heritage	7	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future + Nat Heritage	8	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future + Nat Heritage	9	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future + Nat Heritage	10	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future + Nat Heritage	11	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future + Nat Heritage	11.1	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future + Nat Heritage	12	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future + Nat Heritage	13	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future + Nat Heritage	14	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future + Nat Heritage	15	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future + Nat Heritage	16	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future + Nat Heritage	17	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future + Nat Heritage	18	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future + Nat Heritage	19	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future + Nat Heritage	20	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future + Nat Heritage	21	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future + Nat Heritage	21.1	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future + Nat Heritage	22	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future + Nat Heritage	23	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6

Scenario	Basin	Precipitation [mm]											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Future + Nat Heritage	24	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future + Nat Heritage	25	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future + Nat Heritage	26	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future + Nat Heritage	27	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6
Future + Nat Heritage	28	66.1	46.2	53.3	72.6	77.2	84.5	85.5	84.6	84.5	68	78.5	62.6

Scenario	Basin	Runoff											
		Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Existing	1	17.6	21.5	17.3	9.15	10.5	10.2	9.72	14	13.3	8.52	15.1	15.9
Existing	2	21.7	25.3	21.7	14.5	16.3	16.5	16.2	20.7	19.8	14	21.4	20.1
Existing	3	16.4	20.4	16.4	8.55	9.89	9.66	9.17	13.2	12.5	7.88	13.8	14.8
Existing	4	17.7	21.6	17.2	8.54	9.85	9.31	8.81	13.3	12.6	7.97	14.8	15.8
Existing	5	7.97	11	7.87	2.81	3.44	3.17	2.81	4.84	4.72	2.38	4.99	7.03
Existing	6	17.3	20.8	15.9	7.72	8.92	8.05	7.46	12	11.6	7.14	14.1	15.5
Existing	7	12.2	15.8	11.7	4.82	5.79	5.33	4.78	8	7.69	4.24	8.67	10.8
Existing	8	13.7	17.4	13	5.65	6.72	6.2	5.62	9.25	8.87	5.11	10.2	12.2
Existing	9	17.4	20.9	16	7.81	9.03	8.15	7.56	12.1	11.7	7.21	14.2	15.6
Existing	10	13.8	17.4	13.1	5.68	6.76	6.22	5.64	9.32	8.94	5.09	10.3	12.3
Existing	11	17.5	21.4	17.1	8.56	9.9	9.43	8.94	13.4	12.7	8	14.7	15.7
Existing	11.1	20.3	24.1	19.4	10.5	11.9	11.2	10.8	15.9	15.1	10.2	18.3	18.4
Existing	12	15.4	19.2	15.8	8.99	10.3	10.4	9.92	13.3	12.8	8.21	13.3	14
Existing	13	16.2	20.2	16.2	8.18	9.5	9.22	8.72	12.7	12.1	7.56	13.5	14.6
Existing	14	16.2	20.2	16.2	8.42	9.74	9.5	9.01	12.9	12.3	7.74	13.6	14.6
Existing	15	8.26	11.3	8.13	2.93	3.6	3.33	2.97	5.08	4.93	2.53	5.23	7.27
Existing	16	11.6	15.5	11.8	4.85	5.81	5.53	5.05	8.04	7.67	4.26	8.29	10.3
Existing	17	12.5	16.4	12.7	5.41	6.45	6.17	5.65	8.88	8.43	4.77	9.2	11.1
Existing	18	14.5	18.5	14.5	6.52	7.69	7.31	6.77	10.5	9.98	5.88	11.2	12.9
Existing	19	14.3	18.2	14.5	7.17	8.36	8.16	7.66	11.1	10.6	6.45	11.5	12.9
Existing	20	15.5	19.4	15.4	7.36	8.65	8.35	7.84	11.8	11.1	6.8	12.4	13.8
Existing	21	23	26.5	23.3	16.9	18.9	19.7	19.4	23.6	22.8	16.4	23.7	21.5
Existing	21.1	11.2	15	11.4	4.61	5.54	5.29	4.82	7.71	7.36	4.04	7.89	9.9
Existing	22	20	23.8	19.2	10.3	11.7	11.2	10.8	15.8	15	10.1	17.9	18.1
Existing	23	15.8	19.8	15.7	7.61	8.89	8.63	8.14	12.1	11.5	7.14	12.8	14.1
Existing	24	16.6	20.6	16.3	7.83	9.14	8.66	8.15	12.4	11.8	7.24	13.6	14.8
Existing	25	13.6	17.5	13.9	6.79	7.94	7.83	7.34	10.6	10.1	6.14	10.8	12.2
Existing	26	31	33.7	32.3	29.9	32.7	35.3	35.3	39	38.2	29.1	37.4	30.2

Scenario	Basin	Runoff											
		Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Existing	27	21.8	24.9	22.6	19	20.9	22.2	21.9	25	24.5	17.8	23.7	20.9
Existing	28	21.8	24.8	22.6	19.3	21.2	22.5	22.3	25.3	24.9	18	24	21.1
Future	1	17.6	21.5	17.3	9.15	10.5	10.2	9.72	14	13.3	8.52	15.1	15.9
Future	2	25.8	29.1	26.2	20.6	22.8	23.8	23.7	28	27.1	20.1	28.2	24.5
Future	3	17	21	17.1	9.35	10.7	10.6	10.1	14.1	13.5	8.67	14.7	15.4
Future	4	17.7	21.6	17.2	8.54	9.85	9.31	8.81	13.3	12.6	7.97	14.8	15.8
Future	5	7.97	11	7.87	2.81	3.44	3.17	2.81	4.84	4.72	2.38	4.99	7.03
Future	6	17.3	20.8	15.9	7.72	8.92	8.05	7.46	12	11.6	7.14	14.1	15.5
Future	7	12.2	15.8	11.7	4.82	5.79	5.33	4.78	8	7.69	4.24	8.67	10.8
Future	8	13.7	17.4	13	5.65	6.72	6.2	5.62	9.25	8.87	5.11	10.2	12.2
Future	9	17.4	20.9	16	7.81	9.03	8.15	7.56	12.1	11.7	7.21	14.2	15.6
Future	10	13.8	17.4	13.1	5.68	6.76	6.22	5.64	9.32	8.94	5.09	10.3	12.3
Future	11	18.1	22	17.9	9.74	11.2	10.9	10.4	14.8	14.1	9.15	15.9	16.4
Future	11.1	20.3	24.1	19.4	10.5	11.9	11.2	10.8	15.9	15.1	10.2	18.3	18.4
Future	12	21.8	25.3	22.9	18	20	21.1	20.8	24.3	23.6	17	23.2	20.7
Future	13	16.2	20.2	16.2	8.18	9.5	9.22	8.72	12.7	12.1	7.56	13.5	14.6
Future	14	16.2	20.2	16.2	8.42	9.74	9.5	9.01	12.9	12.3	7.74	13.6	14.6
Future	15	8.26	11.3	8.13	2.93	3.6	3.33	2.97	5.08	4.93	2.53	5.23	7.27
Future	16	11.6	15.5	11.8	4.85	5.81	5.53	5.05	8.04	7.67	4.26	8.29	10.3
Future	17	12.5	16.4	12.7	5.41	6.45	6.17	5.65	8.88	8.43	4.77	9.2	11.1
Future	18	14.5	18.5	14.5	6.52	7.69	7.31	6.77	10.5	9.98	5.88	11.2	12.9
Future	19	14.3	18.2	14.5	7.17	8.36	8.16	7.66	11.1	10.6	6.45	11.5	12.9
Future	20	15.4	19.4	15.4	7.36	8.64	8.35	7.84	11.8	11.1	6.8	12.4	13.8
Future	21	26.8	30	27.6	23	25.4	27	26.9	30.9	30.1	22.4	30.2	25.6
Future	21.1	11.5	15.3	11.8	5.05	6.01	5.81	5.34	8.23	7.87	4.46	8.36	10.2
Future	22	21.2	24.9	20.5	12.1	13.6	13.4	13	17.9	17.1	11.9	19.8	19.3
Future	23	27.2	30.4	27.9	23.1	25.5	27.3	27.1	31.3	30.4	22.7	30.6	26
Future	24	21.5	25.1	21.8	15.3	17.1	17.6	17.3	21.4	20.6	14.5	21.6	20.1

Scenario	Basin	Runoff											
		Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Future	25	24.8	28.1	26.2	22.2	24.5	26.1	26	29.5	28.7	21.1	27.8	23.8
Future	26	30.6	33.4	32	29.5	32.3	34.9	34.9	38.6	37.7	28.7	36.8	29.8
Future	27	23.5	26.5	24.6	21.6	23.7	25.3	25.1	28.2	27.7	20.3	26.5	22.8
Future	28	29.7	32.2	31.6	31.2	33.8	36.4	36.5	39.4	38.8	29.4	36.7	29.5
Future + Nat Heritage	1	16.2	20.1	16.1	8.2	9.45	9.06	8.54	12.5	11.9	7.34	13.4	14.6
Future + Nat Heritage	2	24.7	28.1	25.2	19.8	21.8	22.7	22.6	26.7	25.9	19	26.7	23.5
Future + Nat Heritage	3	16.1	20	16.2	8.74	10	9.84	9.35	13.1	12.6	7.92	13.7	14.6
Future + Nat Heritage	4	17.6	21.5	17.1	8.48	9.78	9.23	8.74	13.2	12.5	7.89	14.7	15.7
Future + Nat Heritage	5	6.89	9.68	6.89	2.37	2.89	2.65	2.33	4.05	3.98	1.93	4.14	6.08
Future + Nat Heritage	6	16	19.6	14.9	6.92	7.97	7.03	6.42	10.6	10.3	5.97	12.5	14.3
Future + Nat Heritage	7	11.1	14.5	10.7	4.23	5.08	4.63	4.12	6.99	6.76	3.57	7.54	9.78
Future + Nat Heritage	8	13.7	17.3	13	5.61	6.68	6.15	5.57	9.19	8.81	5.06	10.1	12.2
Future + Nat Heritage	9	17.2	20.6	15.8	7.65	8.83	7.93	7.34	11.8	11.4	6.96	13.9	15.4
Future + Nat Heritage	10	13.9	17.4	13.1	5.68	6.77	6.23	5.65	9.33	8.95	5.1	10.3	12.4
Future + Nat Heritage	11	17.9	21.8	17.7	9.57	11	10.7	10.2	14.5	13.8	8.93	15.6	16.2
Future + Nat Heritage	11.1	19.9	23.6	19.1	10.2	11.5	10.8	10.3	15.3	14.6	9.69	17.7	17.9
Future + Nat Heritage	12	21.8	25.3	22.9	18	20	21.1	20.9	24.3	23.6	17	23.2	20.7
Future + Nat Heritage	13	14	17.8	14.1	6.74	7.86	7.56	7.04	10.5	10	5.9	10.9	12.5
Future + Nat Heritage	14	15.2	19.1	15.3	7.76	8.98	8.72	8.21	11.9	11.4	6.96	12.4	13.7
Future + Nat Heritage	15	6.17	8.79	6.21	2.09	2.56	2.35	2.07	3.6	3.54	1.71	3.64	5.44
Future + Nat Heritage	16	10.5	14.1	10.7	4.22	5.05	4.76	4.31	6.97	6.69	3.56	7.17	9.21
Future + Nat Heritage	17	10.9	14.6	11.1	4.5	5.38	5.08	4.6	7.36	7.06	3.78	7.59	9.6
Future + Nat Heritage	18	11.9	15.8	12.1	4.98	5.91	5.52	4.99	8.04	7.7	4.15	8.49	10.5
Future + Nat Heritage	19	13.7	17.6	13.9	6.79	7.9	7.68	7.18	10.5	10	6	10.8	12.3
Future + Nat Heritage	20	15.3	19.2	15.2	7.23	8.47	8.14	7.62	11.5	10.9	6.61	12.2	13.6
Future + Nat Heritage	21	26.8	30	27.6	23	25.4	27	26.9	31	30.1	22.4	30.2	25.6
Future + Nat Heritage	21.1	11.6	15.4	11.8	5.08	6.03	5.8	5.33	8.23	7.88	4.45	8.41	10.3
Future + Nat Heritage	22	21	24.7	20.3	11.9	13.4	13.2	12.8	17.7	16.9	11.7	19.5	19.1

Scenario	Basin	Runoff											
		Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Future + Nat Heritage	23	27.2	30.4	27.9	23.1	25.6	27.4	27.1	31.3	30.4	22.7	30.6	26
Future + Nat Heritage	24	21.4	25	21.7	15.2	17	17.5	17.2	21.3	20.5	14.4	21.4	20
Future + Nat Heritage	25	24.8	28.1	26.2	22.2	24.5	26.2	26	29.5	28.7	21.1	27.8	23.8
Future + Nat Heritage	26	30.6	33.4	32	29.5	32.3	34.9	34.9	38.5	37.7	28.7	36.8	29.8
Future + Nat Heritage	27	23.4	26.5	24.5	21.5	23.7	25.3	25.1	28.2	27.6	20.3	26.5	22.7
Future + Nat Heritage	28	29.7	32.2	31.6	31.2	33.8	36.4	36.5	39.4	38.8	29.4	36.7	29.5

Scenario	Basin	GWI											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Existing	1	28.3	19.4	17.3	15.7	7.27	4.2	5.45	8.39	11.1	23.3	35.4	33.8
Existing	2	24	16.1	14	13.5	6.06	3.78	4.93	7.4	9.66	22.6	32.4	29.7
Existing	3	29.5	20.5	18.3	16.4	7.72	4.6	5.78	9.02	11.7	23.9	36.4	34.8
Existing	4	28.2	19.2	17	15.4	6.82	3.77	4.95	7.75	10.7	23	35.3	33.9
Existing	5	36.9	28.1	26.5	19.8	14.3	6.13	5.65	9.24	14.2	18.5	34.1	38.7
Existing	6	28.2	18.8	16.4	14.5	6.01	2.77	3.64	6.29	10.3	20.3	33.3	33.1
Existing	7	33.4	23.6	21.1	17.4	8.42	4.5	4.9	8.62	12.8	20.5	35.9	36.7
Existing	8	31.8	22.1	19.4	16.6	7.56	4.09	4.73	8.33	12.3	22.1	36.3	36.2
Existing	9	28.1	18.7	16.3	14.5	6.14	2.9	3.82	6.43	10.3	20.2	33	32.8
Existing	10	31.9	22.2	19.9	16.6	7.91	4.05	5.02	8.23	12.1	20.9	35.1	35.8
Existing	11	28.4	19.4	17.2	15.6	7.05	4.04	5.26	8.16	11	23.6	35.7	34.1
Existing	11.1	25.3	16.7	14.6	13.8	5.77	3.32	4.36	6.72	9.54	22.5	33.4	31.2
Existing	12	30.6	21.8	19.6	17	8.18	5.1	5.87	9.36	12.3	23.4	36.5	35.5
Existing	13	29.6	20.6	18.3	16.5	7.67	4.61	5.72	9.02	11.8	24.3	36.9	35.1
Existing	14	29.7	20.6	18.5	16.4	7.64	4.5	5.61	8.86	11.7	23.8	36.5	35
Existing	15	37	27.8	25.5	19.5	14.2	6.31	5.89	10	14.6	20.4	36.7	39.4
Existing	16	34.4	25	22.7	18.7	9.61	5.53	5.8	9.79	13.5	23.8	39.1	38.9
Existing	17	33.5	24.1	22	18.4	9.19	5.55	6.13	9.88	13.2	23.4	38.2	38
Existing	18	31.4	22.1	19.8	17.3	7.94	4.65	5.58	9.08	12.3	23.9	37.7	36.6
Existing	19	31.6	22.5	20.3	17.4	8.21	4.93	5.68	9.27	12.4	23.3	37.3	36.4
Existing	20	30.4	21.2	18.9	17	8.08	5.04	6.18	9.6	12.3	25.2	37.8	36
Existing	21	22.4	15.2	12.9	13.1	6.05	4.24	5.28	7.9	9.97	24	32.7	28.2
Existing	21.1	34.9	25.5	23.3	19	10.3	5.89	6.14	10.1	13.7	23.9	39.2	39.3
Existing	22	25.3	16.9	14.5	14.1	5.85	3.55	4.5	7.11	10	24.3	35	31.6
Existing	23	29.8	20.9	18.2	16.7	7.42	4.69	5.53	9.05	12.2	26.6	38.9	35.9
Existing	24	29.4	20.2	18.1	16.1	7.5	4.26	5.56	8.56	11.4	23.5	36.1	34.8
Existing	25	32.4	23.2	20.9	17.9	8.83	5.64	6.21	9.97	13	24.7	38.4	37.4
Existing	26	14.4	9.51	7.86	8.79	4.22	3.37	3.91	5.66	7.08	17.8	22.9	18.8

Scenario	Basin	GWI											
		Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Existing	27	23.9	16.5	14.2	13.1	6.17	3.96	4.56	7.45	10.1	20.9	30.4	28.4
Existing	28	24.4	16.8	15.2	12.6	6.25	3.23	4.2	6.47	9.18	16.7	27	27.7
Future	1	28.3	19.4	17.3	15.7	7.27	4.2	5.45	8.38	11.1	23.4	35.4	33.8
Future	2	19.7	13	11.1	11.4	5.09	3.43	4.43	6.53	8.34	20.8	28.6	25
Future	3	28.8	20	17.8	16.1	7.55	4.56	5.73	8.9	11.6	23.9	36	34.2
Future	4	28.2	19.2	17	15.4	6.82	3.77	4.95	7.75	10.7	23	35.3	33.9
Future	5	36.9	28.1	26.5	19.8	14.3	6.14	5.65	9.24	14.1	18.5	34.1	38.7
Future	6	28.2	18.8	16.4	14.5	6.01	2.77	3.64	6.29	10.3	20.3	33.3	33.1
Future	7	33.3	23.6	21.1	17.4	8.42	4.5	4.9	8.62	12.8	20.5	35.9	36.7
Future	8	31.8	22.1	19.4	16.6	7.56	4.09	4.73	8.33	12.3	22.1	36.3	36.1
Future	9	28.1	18.7	16.3	14.5	6.14	2.9	3.82	6.42	10.3	20.2	33	32.8
Future	10	31.9	22.2	19.9	16.6	7.91	4.05	5.02	8.23	12.1	20.9	35.1	35.8
Future	11	27.7	18.9	16.8	15.3	7.04	4.14	5.39	8.25	10.9	23.5	35.2	33.4
Future	11.1	25.3	16.7	14.6	13.8	5.77	3.33	4.36	6.72	9.54	22.5	33.4	31.2
Future	12	24	16.7	14.7	13.9	6.7	4.52	5.55	8.38	10.3	22.4	31.9	29.1
Future	13	29.6	20.6	18.3	16.5	7.67	4.61	5.72	9.02	11.8	24.3	36.9	35.1
Future	14	29.7	20.7	18.5	16.4	7.63	4.5	5.61	8.86	11.7	23.8	36.5	35
Future	15	37	27.8	25.5	19.5	14.2	6.31	5.89	10	14.5	20.5	36.7	39.4
Future	16	34.4	25	22.7	18.7	9.61	5.53	5.8	9.79	13.5	23.8	39.1	38.9
Future	17	33.6	24.1	22	18.4	9.19	5.55	6.13	9.88	13.2	23.4	38.2	38
Future	18	31.4	22.1	19.8	17.3	7.94	4.65	5.58	9.07	12.3	23.9	37.7	36.5
Future	19	31.7	22.5	20.3	17.4	8.21	4.93	5.68	9.27	12.4	23.3	37.3	36.4
Future	20	30.4	21.2	18.9	17	8.08	5.04	6.18	9.6	12.3	25.2	37.8	36
Future	21	18.6	12.4	10.5	11.3	5.43	4.11	5.03	7.29	8.88	21.6	28.4	23.7
Future	21.1	34.6	25.2	23.1	18.8	10.1	5.88	6.13	10.1	13.6	23.9	39	39
Future	22	24.1	16.1	13.7	13.5	5.65	3.52	4.45	6.95	9.69	23.9	34	30.3
Future	23	17.9	12	9.96	11.1	5.4	4.33	4.95	7.23	9.06	22.2	28.3	23.1
Future	24	24.3	16.5	14.5	13.8	6.49	4.08	5.34	7.91	9.95	22.4	32.2	29.8

Scenario	Basin	GWI											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Future	25	20.9	14.4	12.4	12.6	6.18	4.5	5.57	8.14	9.65	22	29.9	25.9
Future	26	14.8	9.81	8.18	9.13	4.48	3.58	4.23	6.03	7.34	18.2	23.4	19.2
Future	27	22.2	15.2	13.1	12.4	6.03	4.04	4.76	7.5	9.7	20.5	29.1	26.7
Future	28	16.3	10.8	9.42	8.62	3.95	2.21	2.94	4.56	6.43	14.2	20.7	19.8
Future + Nat Heritage	1	29.9	20.8	18.9	16.3	7.43	3.79	4.94	7.92	11.2	21	34.8	34.4
Future + Nat Heritage	2	20.9	14	12.1	11.9	5.32	3.4	4.42	6.6	8.6	20.6	29.2	26.2
Future + Nat Heritage	3	29.9	20.9	18.8	16.4	7.53	4.18	5.2	8.4	11.5	22.1	35.5	34.6
Future + Nat Heritage	4	28.3	19.3	17.1	15.4	6.83	3.73	4.92	7.72	10.7	22.9	35.3	33.9
Future + Nat Heritage	5	36.2	28.4	28.1	20.4	16	5.83	4.8	7.81	13.6	15.3	28.7	36.8
Future + Nat Heritage	6	29.5	20	17.7	14.9	5.92	2.11	2.94	5.43	10.2	16.9	31.8	32.9
Future + Nat Heritage	7	34	24.8	22.6	17.8	8.96	4.09	4.38	7.87	12.7	17.4	33.6	36.3
Future + Nat Heritage	8	31.9	22.2	19.5	16.6	7.55	4.05	4.66	8.26	12.2	21.8	36.2	36.1
Future + Nat Heritage	9	28.4	18.9	16.6	14.6	6.09	2.73	3.63	6.22	10.3	19.4	32.8	32.8
Future + Nat Heritage	10	31.9	22.2	19.9	16.6	7.9	4.05	5.02	8.23	12.1	20.9	35.1	35.8
Future + Nat Heritage	11	28	19.1	17	15.4	7.02	4.01	5.22	8.08	10.9	23.1	35.1	33.6
Future + Nat Heritage	11.1	25.8	17.2	15	14	5.79	3.19	4.21	6.58	9.57	22	33.4	31.6
Future + Nat Heritage	12	24	16.7	14.7	13.9	6.75	4.58	5.64	8.47	10.4	22.5	32	29.1
Future + Nat Heritage	13	32.1	22.9	21	17.5	8.17	4.37	5.22	8.59	12.2	20.7	35.8	36
Future + Nat Heritage	14	30.8	21.7	19.6	16.8	7.74	4.26	5.21	8.51	11.8	22	36	35.4
Future + Nat Heritage	15	36.6	28.9	28.8	20.8	18.5	6.25	5.01	8.21	14.2	15.5	28.9	37.3
Future + Nat Heritage	16	35.5	26.3	24.2	19.1	10.4	5.02	5.13	9.06	13.4	20.2	37.4	38.6
Future + Nat Heritage	17	34.9	25.9	24.2	19.1	10.2	5.14	5.44	9.05	13.3	19.3	35.9	37.8
Future + Nat Heritage	18	33.8	24.8	23	18.4	8.8	4.24	4.79	8.25	12.6	18.4	35.1	36.8
Future + Nat Heritage	19	32.3	23.2	21.1	17.6	8.25	4.63	5.24	8.83	12.4	21.5	36.6	36.4
Future + Nat Heritage	20	30.6	21.4	19.1	16.9	7.85	4.7	5.7	9.13	12.1	24.3	37.5	35.9
Future + Nat Heritage	21	18.5	12.4	10.5	11.3	5.44	4.12	5.04	7.31	8.89	21.6	28.4	23.7
Future + Nat Heritage	21.1	34.5	25.2	22.9	18.6	9.65	5.23	5.47	9.4	13.3	22.6	38.3	38.6
Future + Nat Heritage	22	24.4	16.3	13.9	13.6	5.65	3.46	4.39	6.92	9.7	23.8	34	30.5

Scenario	Basin	GWI											
		Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Future + Nat Heritage	23	17.9	12	9.96	11.1	5.41	4.36	4.99	7.27	9.08	22.2	28.3	23.1
Future + Nat Heritage	24	24.5	16.6	14.6	13.8	6.51	4.05	5.29	7.88	9.96	22.3	32.2	29.9
Future + Nat Heritage	25	20.9	14.4	12.4	12.6	6.25	4.58	5.67	8.26	9.7	22.1	29.9	25.9
Future + Nat Heritage	26	14.8	9.82	8.18	9.11	4.44	3.54	4.17	5.96	7.3	18.1	23.4	19.2
Future + Nat Heritage	27	22.2	15.2	13.1	12.4	5.98	3.99	4.69	7.42	9.66	20.4	29	26.7
Future + Nat Heritage	28	16.3	10.8	9.42	8.61	3.92	2.18	2.89	4.49	6.4	14.1	20.6	19.8

Scenario	Basin	E											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Existing	1	9.29	14	33.8	55.6	73.5	68.6	72.9	69.9	44.8	22.5	14.3	7.42
Existing	2	9.01	13.5	32.1	51.8	65.6	61	65.8	63.4	41.4	21.5	13.9	7.26
Existing	3	9.28	14	33.7	55.6	74	69.2	73.5	70.3	44.9	22.5	14.3	7.42
Existing	4	9.38	14.1	34.4	56.9	75.3	69.8	74.3	71.2	45.4	22.8	14.4	7.47
Existing	5	10.1	15.8	36.8	59.5	85.7	83.4	86.8	80	48.7	24	15.1	7.74
Existing	6	10.1	15.8	36.7	58.7	79.2	74	78.2	73.3	46.3	23.9	15.1	7.74
Existing	7	10.1	15.8	36.7	58.8	82.1	78.5	82.1	76.2	47.5	23.9	15.1	7.74
Existing	8	10.1	15.8	36.7	58.6	80.3	76.1	80	74.6	46.9	23.9	15.1	7.74
Existing	9	10.1	15.8	36.7	58.4	78.7	73.9	78.1	73.2	46.5	23.9	15.1	7.74
Existing	10	10.1	15.8	36.7	58.5	79.9	76.3	80.2	74.9	47.4	24	15.1	7.74
Existing	11	9.36	14.1	34.2	56.5	74.5	69.2	73.8	70.8	45.2	22.8	14.4	7.46
Existing	11.1	9.38	14.1	34.3	56.4	72.7	67	72	69.4	44.7	22.8	14.4	7.47
Existing	12	9.16	13.8	33.1	54.6	73.9	69.4	73.2	69.7	44.1	22	14.1	7.35
Existing	13	9.31	14	33.9	56	74.5	69.5	73.8	70.6	45	22.6	14.3	7.43
Existing	14	9.28	14	33.8	55.8	74.6	69.7	73.9	70.6	44.8	22.5	14.3	7.42
Existing	15	10.1	15.8	36.7	58.9	83.8	81.2	84.8	78.5	48.4	24	15.1	7.74
Existing	16	9.38	14.1	34.4	57.9	80.8	75.8	79.3	74.9	46.3	22.8	14.4	7.47
Existing	17	9.37	14.1	34.3	57.3	79.3	74.8	78.4	74.3	46.4	22.8	14.4	7.47
Existing	18	9.38	14.1	34.4	57.3	77.9	72.7	76.7	73	45.8	22.8	14.4	7.47
Existing	19	9.29	14	33.9	56.4	77.1	72.4	76.1	72.2	45.3	22.5	14.3	7.42
Existing	20	9.35	14.1	34.1	56.3	74.7	69.9	74.3	71.1	45.4	22.7	14.4	7.45
Existing	21	8.84	13.2	31	49.4	60.2	56.2	61.7	59.5	38.9	20.8	13.7	7.16
Existing	21.1	9.38	14.1	34.5	57.8	80.6	75.8	79.3	75	46.5	22.9	14.4	7.47
Existing	22	9.38	14.1	34.3	56.5	71.8	65.9	71.6	69	44.1	22.8	14.4	7.47
Existing	23	9.34	14.1	34.2	56.8	74.8	69	73.9	70.9	44.6	22.7	14.4	7.45
Existing	24	9.38	14.1	34.3	56.7	75.3	70.3	74.7	71.5	45.7	22.8	14.4	7.47
Existing	25	9.29	14	33.8	56.2	76.4	71.8	75.6	71.9	45.2	22.5	14.3	7.42
Existing	26	8.02	11.7	25.9	39.1	44	42.1	46.9	44.6	30.5	17.8	12.7	6.68

Scenario	Basin	E											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Existing	27	9	13.7	30.5	46.7	60.5	57.5	61.2	57.6	37.5	20.3	13.8	7.14
Existing	28	9	13.7	30.6	47.1	62.2	59.4	62.7	58.7	38.3	20.3	13.8	7.14
Future	1	9.29	14	33.8	55.6	73.5	68.6	72.9	69.9	44.8	22.5	14.3	7.42
Future	2	8.65	12.8	29.8	47	57	53.2	58.2	56.1	37.3	20.1	13.5	7.05
Future	3	9.24	13.9	33.5	55	72.8	68.1	72.3	69.2	44.3	22.3	14.2	7.39
Future	4	9.38	14.1	34.4	56.9	75.3	69.8	74.3	71.2	45.4	22.8	14.4	7.47
Future	5	10.1	15.8	36.8	59.5	85.7	83.4	86.8	80	48.7	24	15.1	7.74
Future	6	10.1	15.8	36.7	58.7	79.2	74	78.2	73.3	46.3	23.9	15.1	7.74
Future	7	10.1	15.8	36.7	58.8	82.1	78.5	82.1	76.2	47.5	23.9	15.1	7.74
Future	8	10.1	15.8	36.7	58.6	80.3	76.1	80	74.6	46.9	23.9	15.1	7.74
Future	9	10.1	15.8	36.7	58.4	78.7	73.9	78.1	73.2	46.5	23.9	15.1	7.74
Future	10	10.1	15.8	36.7	58.5	79.9	76.3	80.2	74.9	47.4	24	15.1	7.74
Future	11	9.28	14	33.7	55.3	72.4	67.4	72	69.1	44.4	22.5	14.3	7.41
Future	11.1	9.38	14.1	34.3	56.4	72.7	67	72	69.4	44.7	22.8	14.4	7.47
Future	12	8.61	12.7	29.6	47.2	60.4	56.7	60.6	58.2	38.1	20	13.4	7.02
Future	13	9.31	14	33.9	56	74.5	69.5	73.8	70.7	45	22.6	14.3	7.43
Future	14	9.28	14	33.8	55.8	74.6	69.7	73.9	70.6	44.8	22.5	14.3	7.42
Future	15	10.1	15.8	36.7	58.9	83.8	81.2	84.8	78.5	48.4	24	15.1	7.74
Future	16	9.38	14.1	34.4	57.9	80.8	75.8	79.3	74.9	46.3	22.8	14.4	7.47
Future	17	9.37	14.1	34.3	57.3	79.3	74.8	78.4	74.3	46.4	22.8	14.4	7.47
Future	18	9.38	14.1	34.4	57.3	77.9	72.7	76.7	73	45.8	22.8	14.4	7.47
Future	19	9.29	14	33.9	56.4	77.1	72.4	76.1	72.3	45.3	22.5	14.3	7.42
Future	20	9.35	14.1	34.1	56.3	74.7	69.9	74.3	71.1	45.4	22.7	14.4	7.45
Future	21	8.45	12.5	28.5	44.3	51.7	48.9	54.2	52	34.9	19.4	13.2	6.93
Future	21.1	9.35	14.1	34.3	57.5	79.9	75.2	78.7	74.5	46.2	22.7	14.4	7.45
Future	22	9.26	13.9	33.6	55	69.1	63.5	69.2	66.8	42.9	22.4	14.3	7.41
Future	23	8.49	12.5	28.7	44.4	50.7	48.4	54.2	51.6	34.4	19.5	13.3	6.95
Future	24	8.9	13.3	31.4	50.4	64.2	60.1	64.5	62	40.7	21.1	13.8	7.19

Scenario	Basin	E											
		Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Future	25	8.35	12.3	28	43.8	53.6	50.4	54.8	52.7	35	19	13.1	6.87
Future	26	8.02	11.7	25.9	39	44.2	42.3	46.9	44.7	30.7	17.8	12.7	6.68
Future	27	8.8	13.4	29.4	44.3	56.2	53.6	57.3	54	35.8	19.6	13.5	7.03
Future	28	8.12	12.1	25.5	37.7	46.9	44.5	47.5	44.6	30.2	17.3	12.7	6.65
Future + Nat Heritage	1	9.29	14	33.9	56.5	77.3	72.3	76.1	72.2	45.3	22.5	14.3	7.42
Future + Nat Heritage	2	8.65	12.8	29.8	47.5	59.1	55	59.6	57.4	37.8	20.1	13.5	7.05
Future + Nat Heritage	3	9.24	13.9	33.5	55.7	75.7	70.8	74.6	70.9	44.7	22.3	14.2	7.39
Future + Nat Heritage	4	9.38	14.1	34.4	57	75.6	70	74.5	71.4	45.4	22.8	14.4	7.47
Future + Nat Heritage	5	10.1	15.8	36.9	60.5	90.7	89.5	92.4	83.6	49.4	24	15.1	7.74
Future + Nat Heritage	6	10.1	15.8	36.8	59.9	84.6	78.9	82.1	75.8	46.7	23.9	15.1	7.74
Future + Nat Heritage	7	10.1	15.8	36.8	59.6	85.9	82.7	85.7	78.7	47.9	23.9	15.1	7.74
Future + Nat Heritage	8	10.1	15.8	36.7	58.6	80.6	76.4	80.2	74.8	46.9	23.9	15.1	7.74
Future + Nat Heritage	9	10.1	15.8	36.7	58.7	79.8	74.9	78.9	73.8	46.5	23.9	15.1	7.74
Future + Nat Heritage	10	10.1	15.8	36.7	58.5	79.9	76.3	80.2	74.9	47.4	24	15.1	7.74
Future + Nat Heritage	11	9.28	14	33.7	55.6	73.3	68.2	72.6	69.6	44.5	22.5	14.3	7.41
Future + Nat Heritage	11.1	9.38	14.1	34.3	56.8	74.1	68.1	73	70.1	44.8	22.8	14.4	7.47
Future + Nat Heritage	12	8.61	12.7	29.6	47.2	60.2	56.5	60.5	58.1	38.1	20	13.4	7.02
Future + Nat Heritage	13	9.31	14	34	57.1	79.7	75.1	78.5	74	45.9	22.6	14.3	7.43
Future + Nat Heritage	14	9.28	14	33.8	56.4	77.4	72.5	76.2	72.2	45.2	22.5	14.3	7.42
Future + Nat Heritage	15	10.1	15.8	36.8	60.3	90.5	89.8	92.9	84.1	49.5	24	15.1	7.74
Future + Nat Heritage	16	9.38	14.1	34.5	58.7	84.8	80.1	82.9	77.1	46.7	22.8	14.4	7.47
Future + Nat Heritage	17	9.37	14.1	34.4	58.3	84	80.1	83	77.3	47	22.8	14.4	7.47
Future + Nat Heritage	18	9.38	14.1	34.5	58.7	84.8	80.4	83.2	77.3	46.8	22.8	14.4	7.47
Future + Nat Heritage	19	9.29	14	33.9	56.9	79.4	74.7	78	73.5	45.5	22.5	14.3	7.42
Future + Nat Heritage	20	9.35	14.1	34.2	56.7	76.2	71.2	75.3	71.9	45.5	22.7	14.4	7.45
Future + Nat Heritage	21	8.45	12.5	28.5	44.2	51.6	48.9	54.2	52	34.9	19.4	13.2	6.93
Future + Nat Heritage	21.1	9.35	14.1	34.3	57.9	81.6	76.6	79.8	75.1	46.1	22.7	14.4	7.45
Future + Nat Heritage	22	9.26	13.9	33.6	55.1	69.6	63.9	69.6	67.1	43	22.4	14.3	7.41

Scenario	Basin	E											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Future + Nat Heritage	23	8.49	12.5	28.7	44.4	50.6	48.4	54.2	51.5	34.4	19.5	13.3	6.95
Future + Nat Heritage	24	8.9	13.3	31.4	50.5	64.5	60.3	64.7	62.2	40.7	21.1	13.8	7.19
Future + Nat Heritage	25	8.35	12.3	28	43.7	53.4	50.3	54.7	52.5	35	19	13.1	6.87
Future + Nat Heritage	26	8.02	11.7	25.9	39.1	44.3	42.3	47	44.8	30.7	17.8	12.7	6.68
Future + Nat Heritage	27	8.8	13.4	29.4	44.4	56.4	53.8	57.5	54.1	35.8	19.6	13.5	7.03
Future + Nat Heritage	28	8.12	12.1	25.5	37.7	47	44.5	47.5	44.7	30.2	17.3	12.7	6.65

Appendix H: Precipitation Input Data for Calibration

1997 - 2000

This table shows daily precipitation values considered during calibration of the Duffins Creek Water Balance Analysis System model. The last column, 'Infill Data' was ultimately used as input precipitation.

Date	Climate Station		
	Buttonville	Cherrywood	Infill Data
	[mm]	[mm]	[mm]
01-Jan-97	3.6	2.0	3.6
02-Jan-97	1.2	0	1.2
03-Jan-97	0	0.6	0
04-Jan-97	2.4	0	2.4
05-Jan-97	4.6	6.0	4.6
06-Jan-97	0	0	0
07-Jan-97	1	0	1.0
08-Jan-97	0	0	0
09-Jan-97	18	0	18.0
10-Jan-97	1.9	0	1.9
11-Jan-97	0.4	13.2	0.4
12-Jan-97	0	0	0
13-Jan-97	0	0	0
14-Jan-97	0.8	0	0.8
15-Jan-97	3.3	0	3.3
16-Jan-97	2.6	8.2	2.6
17-Jan-97	0.6	0	0.6
18-Jan-97	0	0	0
19-Jan-97	0	0	0
20-Jan-97	1	0	1.0
21-Jan-97	4	0	4.0
22-Jan-97	1.2	6.0	1.2
23-Jan-97	0	0	0
24-Jan-97	6	5.4	6.0
25-Jan-97	2.6	9.0	2.6
26-Jan-97	0	0	0
27-Jan-97	7.9	0	7.9
28-Jan-97	0.8	2.0	0.8
29-Jan-97	0.4	0	0.4
30-Jan-97	1.9	0	1.9
31-Jan-97	5.3	3.2	5.3
01-Feb-97	0	0.6	0
02-Feb-97	0	0	0
03-Feb-97	0	0.8	0
04-Feb-97	12.4	0	12.4
05-Feb-97	8	0	8.0
06-Feb-97	0	0	0
07-Feb-97	0.6	0	0.6

Date	Climate Station		
	Buttonville	Cherrywood	Infill Data
	[mm]	[mm]	[mm]
08-Feb-97	0	0	0
09-Feb-97	0	0	0
10-Feb-97	0	1.6	0
11-Feb-97	0	9.8	0
12-Feb-97	0.6	0	0.6
13-Feb-97	1.4	0.4	1.4
14-Feb-97	6.3	2.6	6.3
15-Feb-97	1.5	0.2	1.5
16-Feb-97	6.2	0.4	6.2
17-Feb-97	0.6	0	0.6
18-Feb-97	0	0	0
19-Feb-97	0	0	0
20-Feb-97	1.8	1.2	1.8
21-Feb-97	29.4	24.2	29.4
22-Feb-97	4.8	15.8	4.8
23-Feb-97	0.6	0	0.6
24-Feb-97	0	0.2	0
25-Feb-97	0	0	0
26-Feb-97	3.4	0.4	3.4
27-Feb-97	6.6	17.2	6.6
28-Feb-97	0	0	0
01-Mar-97	0.6	0.2	0.6
02-Mar-97	0.6	0	0.6
03-Mar-97	0	0	0
04-Mar-97	0.2	0	0.2
05-Mar-97	6.4	4.6	6.4
06-Mar-97	3	1.8	3.0
07-Mar-97	2	0.6	2.0
08-Mar-97	5.2	0	5.2
09-Mar-97	2.6	0	2.6
10-Mar-97	4.4	0	4.4
11-Mar-97	3.2	1.0	3.2
12-Mar-97	0	0	0
13-Mar-97	0	0	0
14-Mar-97	20.6	19.8	20.6
15-Mar-97	0.2	19.0	0.2
16-Mar-97	0	0	0
17-Mar-97	0	0	0
18-Mar-97	0	0	0
19-Mar-97	0	0	0
20-Mar-97	0	0	0
21-Mar-97	4.8	3.6	4.8
22-Mar-97	0	0.2	0
23-Mar-97	0	0	0

Date	Climate Station		
	Buttonville	Cherrywood	Infill Data
	[mm]	[mm]	[mm]
24-Mar-97	0	0	0
25-Mar-97	15.4	17.2	15.4
26-Mar-97	0	0	0
27-Mar-97	0	0	0
28-Mar-97	1.2	0	1.2
29-Mar-97	4.4	2.8	4.4
30-Mar-97	3.6	1.4	3.6
31-Mar-97	1	0.6	1.0
01-Apr-97	0	0.4	0
02-Apr-97	0	5.2	0
03-Apr-97	0	0	0
04-Apr-97	0	0	0
05-Apr-97	2	0.2	2.0
06-Apr-97	2.4	0	2.4
07-Apr-97	0.2	0.2	0.2
08-Apr-97	1.2	0	1.2
09-Apr-97	0	0.2	0
10-Apr-97	0	0	0
11-Apr-97	0	1.2	0
12-Apr-97	8	7.6	8.0
13-Apr-97	2.6	0.6	2.6
14-Apr-97	0	0	0
15-Apr-97	0	0	0
16-Apr-97	1.6	0.8	1.6
17-Apr-97	0	0	0
18-Apr-97	0	0	0
19-Apr-97	3.4	1.8	3.4
20-Apr-97	0	0	0
21-Apr-97	0	0	0
22-Apr-97	0	0	0
23-Apr-97	0	0	0
24-Apr-97	0	0	0
25-Apr-97	0	0	0
26-Apr-97	0	0	0
27-Apr-97	3.8	0	3.8
28-Apr-97	7.2	12.6	7.2
29-Apr-97	0	0	0
30-Apr-97	0	0	0
01-May-97	0.4	7.6	0.4
02-May-97	1.2	12.2	1.2
03-May-97	27.2	0.2	27.2
04-May-97	0.5	1.6	0.5
05-May-97	15	0.6	15.0
06-May-97	0	0	0

Date	Climate Station		
	Buttonville	Cherrywood	Infill Data
	[mm]	[mm]	[mm]
07-May-97	0	0	0
08-May-97	0.4	0	0.4
09-May-97	4.6	0	4.6
10-May-97	1.8	0	1.8
11-May-97	6.2	0	6.2
12-May-97	4.4	0	4.4
13-May-97	0	0	0
14-May-97	0.2	0.8	0.2
15-May-97	6.1	4.6	6.1
16-May-97	0.6	2.0	0.6
17-May-97	1.8	1.6	1.8
18-May-97	2.2	0	2.2
19-May-97	0.8	1.4	0.8
20-May-97	0	0	0
21-May-97	0	0	0
22-May-97	0	0	0
23-May-97	0	0	0
24-May-97	0	0	0
25-May-97	0	0.2	0
26-May-97	0	0	0
27-May-97	0	0	0
28-May-97	0	0	0
29-May-97	0.6	0	0.6
30-May-97	1	1.2	1.0
31-May-97	0	1.2	0
01-Jun-97	0	0.2	0
02-Jun-97	0	0	0
03-Jun-97	0	3.0	0
04-Jun-97	0	0.4	0
05-Jun-97	0	2.0	0
06-Jun-97	0	0	0
07-Jun-97	1	0	1.0
08-Jun-97	9.4	0	9.4
09-Jun-97	0	2.0	0
10-Jun-97	0	0	0
11-Jun-97	0	0	0
12-Jun-97	2.5	0.6	2.5
13-Jun-97	4.2	0.6	4.2
14-Jun-97	0	0.2	0
15-Jun-97	0	0	0
16-Jun-97	8.4	0.6	8.4
17-Jun-97	1.4	1.4	1.4
18-Jun-97	5.8	2.6	5.8
19-Jun-97	0	10.2	0

Date	Climate Station		
	Buttonville	Cherrywood	Infill Data
	[mm]	[mm]	[mm]
20-Jun-97	7.8	0.6	7.8
21-Jun-97	23.2	10.2	23.2
22-Jun-97	0	10.2	0
23-Jun-97	3.2	0	3.2
24-Jun-97	11.8	0.2	11.8
25-Jun-97	0	0	0
26-Jun-97	0	0	0
27-Jun-97	0	0	0
28-Jun-97	0	0	0
29-Jun-97	0	0	0
30-Jun-97	0	0	0
01-Jul-97	0	0	0
02-Jul-97	0	0	0
03-Jul-97	1.7	0.4	1.7
04-Jul-97	0.8	3.8	0.8
05-Jul-97	0	0	0
06-Jul-97	5	1.0	5.0
07-Jul-97	0	1.2	0
08-Jul-97	16.4	0	16.4
09-Jul-97	0.6	0	0.6
10-Jul-97	0	0	0
11-Jul-97	0	0	0
12-Jul-97	0	0	0
13-Jul-97	0	0	0
14-Jul-97	0	0	0
15-Jul-97	8.4	0	8.4
16-Jul-97	0	0	0
17-Jul-97	3.8	0.4	3.8
18-Jul-97	11.5	0	11.5
19-Jul-97	0	0	0
20-Jul-97	0	0	0
21-Jul-97	8.8	1.0	8.8
22-Jul-97	0	0	0
23-Jul-97	0	0	0
24-Jul-97	0	0	0
25-Jul-97	0	0	0
26-Jul-97	0	0	0
27-Jul-97	13.2	0	13.2
28-Jul-97	1.6	1.2	1.6
29-Jul-97	0	0	0
30-Jul-97	0	0	0
31-Jul-97	0	0	0
01-Aug-97	0	0	0
02-Aug-97	0	0	0

Date	Climate Station		
	Buttonville	Cherrywood	Infill Data
	[mm]	[mm]	[mm]
03-Aug-97	0	1.2	0
04-Aug-97	0	4.2	0
05-Aug-97	0	0	0
06-Aug-97	0	0.6	0
07-Aug-97	0	0	0
08-Aug-97	0	0	0
09-Aug-97	0	0	0
10-Aug-97	0	0	0
11-Aug-97	0	0	0
12-Aug-97	5.5	0	5.5
13-Aug-97	3	0	3.0
14-Aug-97	0	0	0
15-Aug-97	17.4	2.6	17.4
16-Aug-97	7	2.4	7.0
17-Aug-97	0	0	0
18-Aug-97	0	0	0
19-Aug-97	0	0	0
20-Aug-97	15.7	0	15.7
21-Aug-97	16.4	0.2	16.4
22-Aug-97	5.6	0	5.6
23-Aug-97	0.2	0	0.2
24-Aug-97	1.6	0	1.6
25-Aug-97	0	0.8	0
26-Aug-97	0	0	0
27-Aug-97	1.2	1.0	1.2
28-Aug-97	0	1.8	0
29-Aug-97	0	0	0
30-Aug-97	0	0	0
31-Aug-97	0.8	0	0.8
01-Sep-97	0	6.4	0
02-Sep-97	0	0	0
03-Sep-97	0	0.2	0
04-Sep-97	0	0	0
05-Sep-97	1.6	3.8	1.6
06-Sep-97	14	0.2	14.0
07-Sep-97	0	0.2	0
08-Sep-97	0	0	0
09-Sep-97	0	0	0
10-Sep-97	16.8	0	16.8
11-Sep-97	0.8	0	0.8
12-Sep-97	0.2	0	0.2
13-Sep-97	0	0	0
14-Sep-97	0	0	0
15-Sep-97	0	0	0

Date	Climate Station		
	Buttonville	**Cherrywood**	**Infill Data**
	[mm]	[mm]	[mm]
16-Sep-97	0	0	0
17-Sep-97	5	1.0	5.0
18-Sep-97	0	0.2	0
19-Sep-97	4.4	0.6	4.4
20-Sep-97	1	0.6	1.0
21-Sep-97	0	0	0
22-Sep-97	0	0	0
23-Sep-97	0.4	0	0.4
24-Sep-97	0	0	0
25-Sep-97	6	1.2	6.0
26-Sep-97	0	0	0
27-Sep-97	0	0	0
28-Sep-97	0.6	0	0.6
29-Sep-97	13	3.2	13.0
30-Sep-97	3	0	3.0
01-Oct-97	0	1.8	0
02-Oct-97	1.8	0	1.8
03-Oct-97	1.8	2.8	1.8
04-Oct-97	0	0	0
05-Oct-97	0	0.2	0
06-Oct-97	0	0	0
07-Oct-97	0	0	0
08-Oct-97	0	0	0
09-Oct-97	1.2	17.8	1.2
10-Oct-97	0		0
11-Oct-97	0	0	0
12-Oct-97	0	0	0
13-Oct-97	0		0
14-Oct-97	0.4		0.4
15-Oct-97	0	0	0
16-Oct-97	0	0	0
17-Oct-97	0	0	0
18-Oct-97	0	0	0
19-Oct-97	0	0	0
20-Oct-97	0	0	0
21-Oct-97	0.8	0.8	0.8
22-Oct-97	0	0.2	0
23-Oct-97	0.4	0	0.4
24-Oct-97	0	0	0
25-Oct-97	0	0	0
26-Oct-97	16	0.4	16.0
27-Oct-97	9.4	19.6	9.4
28-Oct-97	0	0	0
29-Oct-97	1.8	2.0	1.8

Date	Climate Station		
	Buttonville	Cherrywood	Infill Data
	[mm]	[mm]	[mm]
30-Oct-97	0	0	0
31-Oct-97	3.4	0.8	3.4
01-Nov-97	24.2	0	24.2
02-Nov-97	2.2	0	2.2
03-Nov-97	0.8	7.4	0.8
04-Nov-97	1	0	1.0
05-Nov-97	0	0.4	0
06-Nov-97	0	0	0
07-Nov-97	0	0	0
08-Nov-97	0	0	0
09-Nov-97	0	5.2	0
10-Nov-97	0.8		0.8
11-Nov-97	0	0.4	0
12-Nov-97	1	0	1.0
13-Nov-97	0	0	0
14-Nov-97	13.4	3.6	13.4
15-Nov-97	1.8	0	1.8
16-Nov-97	0	0.2	0
17-Nov-97	0	0	0
18-Nov-97	0	0	0
19-Nov-97	0.2	0	0.2
20-Nov-97	0.8	0	0.8
21-Nov-97	1.8	3.2	1.8
22-Nov-97	2.9	0.6	2.9
23-Nov-97	0.2	0.4	0.2
24-Nov-97	0	0	0
25-Nov-97	0	0	0
26-Nov-97	1.2	2.2	1.2
27-Nov-97	0	0	0
28-Nov-97	2	1.8	2.0
29-Nov-97	0	0	0
30-Nov-97	3.8	2.0	3.8
01-Dec-97	0	0	0
02-Dec-97	0	0.8	0
03-Dec-97	9.4	0	9.4
04-Dec-97	0.8	6.4	0.8
05-Dec-97	1.8	3.6	1.8
06-Dec-97	2.6	4.0	2.6
07-Dec-97	0	0	0
08-Dec-97	0	0	0
09-Dec-97	0	0	0
10-Dec-97	0		0
11-Dec-97	0	0.2	0
12-Dec-97	0.7	0	0.7

Date	Climate Station		
	Buttonville	Cherrywood	Infill Data
	[mm]	[mm]	[mm]
13-Dec-97	1.2	0.8	1.2
14-Dec-97	0	0.2	0
15-Dec-97	0	0	0
16-Dec-97	0	0	0
17-Dec-97	0	0	0
18-Dec-97	0	0	0
19-Dec-97	0	0	0
20-Dec-97	0	0	0
21-Dec-97	0	0	0
22-Dec-97	3	0	3.0
23-Dec-97	6.2	8.8	6.2
24-Dec-97	0.2	0	0.2
25-Dec-97	2.7	7.2	2.7
26-Dec-97	2.2	1.0	2.2
27-Dec-97	0	0	0
28-Dec-97	0	0	0
29-Dec-97	0	0	0
30-Dec-97	1.8	0	1.8
31-Dec-97	0	0	0
01-Jan-98	1	0	1.0
02-Jan-98	0	0	0
03-Jan-98	1.8	2.2	1.8
04-Jan-98	2.6	1.2	2.6
05-Jan-98	9.4	6.2	9.4
06-Jan-98	6.6	12.2	6.6
07-Jan-98	14.1	6.8	14.1
08-Jan-98	12.2	15.4	12.2
09-Jan-98	4.2	5.2	4.2
10-Jan-98	0	0	0
11-Jan-98	0	0	0
12-Jan-98	2.4	0	2.4
13-Jan-98	0	6.8	0
14-Jan-98	0	0	0
15-Jan-98	6.6	2.8	6.6
16-Jan-98	0	0	0
17-Jan-98	0.6	0	0.6
18-Jan-98	5.5	0.4	5.5
19-Jan-98	3.2	0.2	3.2
20-Jan-98	0	0.2	0
21-Jan-98	0	0	0
22-Jan-98	0	0	0
23-Jan-98	12.2	11.2	12.2
24-Jan-98	0	0	0
25-Jan-98	0	0	0

Date	Climate Station		
	Buttonville	Cherrywood	Infill Data
	[mm]	[mm]	[mm]
26-Jan-98	0	0	0
27-Jan-98	1	0	1.0
28-Jan-98	0	0	0
29-Jan-98	8.4	3.0	8.4
30-Jan-98	0.8	1.4	0.8
31-Jan-98	0	0	0
01-Feb-98	0	0	0
02-Feb-98	0	0	0
03-Feb-98	0	0	0
04-Feb-98	0	0	0
05-Feb-98	0	0	0
06-Feb-98	0	0	0
07-Feb-98	0	0	0
08-Feb-98	0	0	0
09-Feb-98	0	0	0
10-Feb-98	0	0	0
11-Feb-98	0.2	0	0.2
12-Feb-98	4	2.4	4.0
13-Feb-98	0	0	0
14-Feb-98	0	0	0
15-Feb-98	0	0	0
16-Feb-98	0	0	0
17-Feb-98	32.8	5.8	32.8
18-Feb-98	12.6	16.8	12.6
19-Feb-98	2.6	0.8	2.6
20-Feb-98	0.2	0	0.2
21-Feb-98	0	0	0
22-Feb-98	0	0	0
23-Feb-98	0	0	0
24-Feb-98	0	0	0
25-Feb-98	0	0	0
26-Feb-98	0	0	0
27-Feb-98	0	0.8	0
28-Feb-98	1.6	0	1.6
01-Mar-98	7.2	14.4	7.2
02-Mar-98	0.2	0	0.2
03-Mar-98	3.2	0	3.2
04-Mar-98	0	0	0
05-Mar-98	0	0	0
06-Mar-98	0	0	0
07-Mar-98	0	0	0
08-Mar-98	12.6	18.0	12.6
09-Mar-98	10	18.8	10.0
10-Mar-98	2.6	0	2.6

Date	Climate Station		
	Buttonville	Cherrywood	Infill Data
	[mm]	[mm]	[mm]
11-Mar-98	2.4	0	2.4
12-Mar-98	2.6	0	2.6
13-Mar-98	2.8	0	2.8
14-Mar-98	6.4	6.4	6.4
15-Mar-98	0	0	0
16-Mar-98	0	0	0
17-Mar-98	0	0	0
18-Mar-98	15.1	1.4	15.1
19-Mar-98	8.6	13.8	8.6
20-Mar-98	0	0.4	0
21-Mar-98	13.8	4.4	13.8
22-Mar-98	5.2	2.0	5.2
23-Mar-98	0	0	0
24-Mar-98	0	0	0
25-Mar-98	0	0	0
26-Mar-98	0	0.2	0
27-Mar-98	0	0	0
28-Mar-98	8.2	8.0	8.2
29-Mar-98	0	0	0
30-Mar-98	0	0	0
31-Mar-98	0	0	0
01-Apr-98	7.4	6.0	7.4
02-Apr-98	5.4	6.4	5.4
03-Apr-98	0	1.0	0
04-Apr-98	0	0	0
05-Apr-98	0	0	0
06-Apr-98	0	0	0
07-Apr-98	0	0	0
08-Apr-98	4.2	5.0	4.2
09-Apr-98	0	0	0
10-Apr-98	0	0	0
11-Apr-98	0	0	0
12-Apr-98	0	0	0
13-Apr-98	0	0	0
14-Apr-98	2	0	2.0
15-Apr-98	0.2	2.4	0.2
16-Apr-98	19.4	21.4	19.4
17-Apr-98	15	2.0	15.0
18-Apr-98	0	0	0
19-Apr-98	6.4	0.6	6.4
20-Apr-98	4.6	4.0	4.6
21-Apr-98	0	0	0
22-Apr-98	0	0	0
23-Apr-98	0	0	0

Date	Climate Station		
	Buttonville	Cherrywood	Infill Data
	[mm]	[mm]	[mm]
24-Apr-98	0	0	0
25-Apr-98	0	0	0
26-Apr-98	0	0	0
27-Apr-98	0	0	0
28-Apr-98	0	0	0
29-Apr-98	0	0	0
30-Apr-98	0	0	0
01-May-98	1.4	0	1.4
02-May-98	4.4	12.2	4.4
03-May-98	0	4.0	0
04-May-98	0.4	0.2	0.4
05-May-98	0	0	0
06-May-98	0	0	0
07-May-98	0	0	0
08-May-98	0	0	0
09-May-98	0	0.2	0
10-May-98	15.4	2.6	15.4
11-May-98	18.1	28.6	18.1
12-May-98	0	0.6	0
13-May-98	0	0	0
14-May-98	0	0	0
15-May-98	0	0	0
16-May-98	0	0.2	0
17-May-98	0	0.2	0
18-May-98	0	0.2	0
19-May-98	3.6	2.6	3.6
20-May-98	0	0	0
21-May-98	0	0	0
22-May-98	0	0	0
23-May-98	0	0	0
24-May-98	0	0	0
25-May-98	0	0	0
26-May-98	0	0	0
27-May-98	0	0	0
28-May-98	0	0	0
29-May-98	2.8	8.6	2.8
30-May-98	0	0	0
31-May-98	1.8	1.8	1.8
01-Jun-98	0	0	0
02-Jun-98	9.6	9.2	9.6
03-Jun-98	0	0	0
04-Jun-98	0	0.2	0
05-Jun-98	0	0	0
06-Jun-98	0	0	0

Date	Climate Station		
	Buttonville	Cherrywood	Infill Data
	[mm]	[mm]	[mm]
07-Jun-98	1	0	1.0
08-Jun-98	0	0	0
09-Jun-98	0	0	0
10-Jun-98	1	1.4	1.0
11-Jun-98	4.3	0	4.3
12-Jun-98	12	27.0	12.0
13-Jun-98	0	1.6	0
14-Jun-98	0	0	0
15-Jun-98	0	0	0
16-Jun-98	1.5	0.8	1.5
17-Jun-98	1	0.2	1.0
18-Jun-98	0	0	0
19-Jun-98	0	0	0
20-Jun-98	0	0	0
21-Jun-98	0	0	0
22-Jun-98	0	0	0
23-Jun-98	3.4	3.0	3.4
24-Jun-98	0	0	0
25-Jun-98	2	0.4	2.0
26-Jun-98	13.4	23.6	13.4
27-Jun-98	0	0	0
28-Jun-98	0	0	0
29-Jun-98	0	0	0
30-Jun-98	11.6	10.4	11.6
01-Jul-98	0	0.8	0
02-Jul-98	0	0	0
03-Jul-98	0	0	0
04-Jul-98	7.2	2.8	7.2
05-Jul-98	0	0	0
06-Jul-98	2.5	0.2	2.5
07-Jul-98	28	28.4	28.0
08-Jul-98	1.5	1.6	1.5
09-Jul-98	4	26.6	4.0
10-Jul-98	0	0.4	0
11-Jul-98	0	0	0
12-Jul-98	0	0	0
13-Jul-98	0	0	0
14-Jul-98	0	0.2	0
15-Jul-98	0	0	0
16-Jul-98	2.2	27.0	2.2
17-Jul-98	0	0.4	0
18-Jul-98	0	0	0
19-Jul-98	1.6	0	1.6
20-Jul-98	0	1.0	0

Date	Climate Station		
	Buttonville	Cherrywood	Infill Data
	[mm]	[mm]	[mm]
21-Jul-98	0	0.2	0
22-Jul-98	0	0	0
23-Jul-98	0	0.4	0
24-Jul-98	0	0	0
25-Jul-98	0	0	0
26-Jul-98	0	0	0
27-Jul-98	4.2	0	4.2
28-Jul-98	0.4	0.2	0.4
29-Jul-98	0	2.4	0
30-Jul-98	0	0	0
31-Jul-98	0	0.2	0
01-Aug-98	0	0	0
02-Aug-98	0	0	0
03-Aug-98	0	0	0
04-Aug-98	0	0	0
05-Aug-98	0	0	0
06-Aug-98	18.6	13.4	18.6
07-Aug-98	19.4	18.8	19.4
08-Aug-98	0	0	0
09-Aug-98	12.8	6.4	12.8
10-Aug-98	1	1.8	1.0
11-Aug-98	0	0.4	0
12-Aug-98	0	0	0
13-Aug-98	0	0	0
14-Aug-98	0	0	0
15-Aug-98	0.8	0	0.8
16-Aug-98	0	0	0
17-Aug-98	0.5	0	0.5
18-Aug-98	0	0	0
19-Aug-98	0	0	0
20-Aug-98	0	0	0
21-Aug-98	0	0	0
22-Aug-98	0	0	0
23-Aug-98	5.2	6.4	5.2
24-Aug-98	11.4	17.8	11.4
25-Aug-98	10	9.4	10.0
26-Aug-98	0	0	0
27-Aug-98	0	0	0
28-Aug-98	2	0	2.0
29-Aug-98	2.6	1.4	2.6
30-Aug-98	0	0	0
31-Aug-98	0	0	0
01-Sep-98	0	0	0
02-Sep-98	3.6	5.8	3.6

Date	Climate Station		
	Buttonville	Cherrywood	Infill Data
	[mm]	[mm]	[mm]
03-Sep-98	0.6	0.2	0.6
04-Sep-98	0	0	0
05-Sep-98	0	0	0
06-Sep-98	4.2	0	4.2
07-Sep-98	0	2.0	0
08-Sep-98	2	2.6	2.0
09-Sep-98	0	0.2	0
10-Sep-98	0	0	0
11-Sep-98	0	0	0
12-Sep-98	0	2.0	0
13-Sep-98	0	0	0
14-Sep-98	3	0	3.0
15-Sep-98	13.4	10.6	13.4
16-Sep-98	0	4.0	0
17-Sep-98	0	0.2	0
18-Sep-98	0	0	0
19-Sep-98	0	0	0
20-Sep-98	0	0.2	0
21-Sep-98	0	0.6	0
22-Sep-98	1.2	0.4	1.2
23-Sep-98	0	0	0
24-Sep-98	0	0	0
25-Sep-98	0	0	0
26-Sep-98	2.8	1.4	2.8
27-Sep-98	1.8	1.4	1.8
28-Sep-98	0	0	0
29-Sep-98	0.2	0	0.2
30-Sep-98	10	0.2	10.0
01-Oct-98	0.4	8.2	0.4
02-Oct-98	0	0	0
03-Oct-98	0	0	0
04-Oct-98	0	0	0
05-Oct-98	0	0	0
06-Oct-98	0	0	0
07-Oct-98	18.8	11.0	18.8
08-Oct-98	1.2	3.4	1.2
09-Oct-98	0	0	0
10-Oct-98	0	0	0
11-Oct-98	0	0	0
12-Oct-98	0	0	0
13-Oct-98	0	0	0
14-Oct-98	3.2	3.0	3.2
15-Oct-98	0	0	0
16-Oct-98	0	0	0

Date	Climate Station		
	Buttonville	Cherrywood	Infill Data
	[mm]	[mm]	[mm]
17-Oct-98	0	0	0
18-Oct-98	0	0	0
19-Oct-98	0	0.2	0
20-Oct-98	0	0	0
21-Oct-98	0	0	0
22-Oct-98	0	0	0
23-Oct-98	0	0	0
24-Oct-98	0	0	0
25-Oct-98	0	0	0
26-Oct-98	0	0	0
27-Oct-98	0.2	0	0.2
28-Oct-98	0.6	0.8	0.6
29-Oct-98	0	0	0
30-Oct-98	0	0	0
31-Oct-98	0	0	0
01-Nov-98	0	0	0
02-Nov-98	0	0	0
03-Nov-98	0	0	0
04-Nov-98	0	0	0
05-Nov-98	0	0	0
06-Nov-98	0	0	0
07-Nov-98	0	0	0
08-Nov-98	0	0	0
09-Nov-98	0.3	0	0.3
10-Nov-98	17	11.6	17.0
11-Nov-98	0.2	4.4	0.2
12-Nov-98	1	0.2	1.0
13-Nov-98	0	0.2	0
14-Nov-98	0.4	0.2	0.4
15-Nov-98	0	0.4	0
16-Nov-98	12.6	3.6	12.6
17-Nov-98	3.2	1.2	3.2
18-Nov-98	0	0	0
19-Nov-98	0	0	0
20-Nov-98	0.4	0	0.4
21-Nov-98	0.5	0	0.5
22-Nov-98	0	0	0
23-Nov-98	1.2	0	1.2
24-Nov-98	0	1.6	0
25-Nov-98	2.2	0	2.2
26-Nov-98	5.2	7.8	5.2
27-Nov-98	0	0	0
28-Nov-98	0	0	0
29-Nov-98	0.2	0.2	0.2

Date	Climate Station		
	Buttonville	Cherrywood	Infill Data
	[mm]	[mm]	[mm]
30-Nov-98	1.8	0	1.8
01-Dec-98	0	2.2	0
02-Dec-98	0	0	0
03-Dec-98	0	0	0
04-Dec-98	0	0	0
05-Dec-98	3.8	0.8	3.8
06-Dec-98	28.6	0.6	28.6
07-Dec-98	8	31.4	8.0
08-Dec-98	0	0	0
09-Dec-98	0	0	0
10-Dec-98	0	0	0
11-Dec-98	0	0	0
12-Dec-98	0	0	0
13-Dec-98	0	0	0
14-Dec-98	0	0	0
15-Dec-98	0	0	0
16-Dec-98	0.4	0	0.4
17-Dec-98	4	1.8	4.0
18-Dec-98	0	0	0
19-Dec-98	1.5	0.8	1.5
20-Dec-98	0	0	0
21-Dec-98	7.7	2.6	7.7
22-Dec-98	6	7.4	6.0
23-Dec-98	0	0	0
24-Dec-98	0	0	0
25-Dec-98	0	0	0
26-Dec-98	0	0	0
27-Dec-98	0	0	0
28-Dec-98	0	0	0
29-Dec-98	3.3	1.4	3.3
30-Dec-98	0.4	0.2	0.4
31-Dec-98	0	0	0
01-Jan-99	0	0	0
02-Jan-99	23	0	23.0
03-Jan-99	37	0	37.0
04-Jan-99	1.2	0	1.2
05-Jan-99	0	0	0
06-Jan-99	4.4	17.2	4.4
07-Jan-99	0	5.2	0
08-Jan-99	5.4	0.2	5.4
09-Jan-99	3	0	3.0
10-Jan-99	0	0	0
11-Jan-99	4	0	4.0
12-Jan-99	10	0	10.0

Date	Climate Station		
	Buttonville	Cherrywood	Infill Data
	[mm]	[mm]	[mm]
13-Jan-99	4.6	3.8	4.6
14-Jan-99	6	0	6.0
15-Jan-99	10.8	2.4	10.8
16-Jan-99	0	0	0
17-Jan-99	0	0	0
18-Jan-99	8.4	7.2	8.4
19-Jan-99	0	0.2	0
20-Jan-99	0	0	0
21-Jan-99	0	0	0
22-Jan-99	6.6	4.8	6.6
23-Jan-99	11.8	5.6	11.8
24-Jan-99	0.6	0.4	0.6
25-Jan-99	0.8	0	0.8
26-Jan-99	0	0	0
27-Jan-99	0.4	0.2	0.4
28-Jan-99	2.2	0	2.2
29-Jan-99	1	0.2	1.0
30-Jan-99	0	0	0
31-Jan-99	0	0	0
01-Feb-99	0.8	0	0.8
02-Feb-99	4.6	4.4	4.6
03-Feb-99	0	0	0
04-Feb-99	1.6	0	1.6
05-Feb-99	0	0	0
06-Feb-99	1.2	7.0	1.2
07-Feb-99	0	0.2	0
08-Feb-99	0	0	0
09-Feb-99	0	0	0
10-Feb-99	0	2.8	0
11-Feb-99	0	8.4	0
12-Feb-99	7.6	0	7.6
13-Feb-99	0	0	0
14-Feb-99	0	0	0
15-Feb-99	0	0	0
16-Feb-99	1	0	1.0
17-Feb-99	0.6	0.4	0.6
18-Feb-99	0	0	0
19-Feb-99	0	0	0
20-Feb-99	0	0	0
21-Feb-99	0	0	0
22-Feb-99	0	0	0
23-Feb-99	0	0	0
24-Feb-99	0	0	0
25-Feb-99	0	0	0

Date	**Climate Station**		
	Buttonville	**Cherrywood**	**Infill Data**
	[mm]	[mm]	[mm]
26-Feb-99	0	0	0
27-Feb-99	0.8	0	0.8
28-Feb-99	15.4	13.8	15.4
01-Mar-99	0	24.4	0
02-Mar-99	0.3	0.2	0.3
03-Mar-99	10	6.4	10.0
04-Mar-99	0	0	0
05-Mar-99	0	0	0
06-Mar-99	21.4	0.2	21.4
07-Mar-99	0	0.4	0
08-Mar-99	0	0	0
09-Mar-99	0	0	0
10-Mar-99	0	1.4	0
11-Mar-99	0	3.4	0
12-Mar-99	0	0	0
13-Mar-99	0	0	0
14-Mar-99	0	0	0
15-Mar-99	0	0	0
16-Mar-99	0	0	0
17-Mar-99	0	0	0
18-Mar-99	0	0.4	0
19-Mar-99	0	0	0
20-Mar-99	0	0	0
21-Mar-99	0	0	0
22-Mar-99	0.6	0.2	0.6
23-Mar-99	0	0	0
24-Mar-99	0	0	0
25-Mar-99	0	0	0
26-Mar-99	0	0	0
27-Mar-99	0	0	0
28-Mar-99	0	0	0
29-Mar-99	0	0	0
30-Mar-99	0	0	0
31-Mar-99	0	0	0
01-Apr-99	0	0	0
02-Apr-99	0	0.4	0
03-Apr-99	12.2	0.2	12.2
04-Apr-99	5.6	1.6	5.6
05-Apr-99	0	0	0
06-Apr-99	6.4	0	6.4
07-Apr-99	3.8	14.8	3.8
08-Apr-99	0.5	16.2	0.5
09-Apr-99	0	0	0
10-Apr-99	0	6.2	0

Date	Climate Station		
	Buttonville	**Cherrywood**	**Infill Data**
	[mm]	[mm]	[mm]
11-Apr-99	0.4	12.4	0.4
12-Apr-99	0	1.6	0
13-Apr-99	0	0	0
14-Apr-99	0	0	0
15-Apr-99	0	0	0
16-Apr-99	6.6	5.0	6.6
17-Apr-99	0.4	0.2	0.4
18-Apr-99	0.2	1.8	0.2
19-Apr-99	0	1.4	0
20-Apr-99	0	0.4	0
21-Apr-99	0	0	0
22-Apr-99	17.8	3.2	17.8
23-Apr-99	0	11.2	0
24-Apr-99	0	0	0
25-Apr-99	0	0	0
26-Apr-99	0	0	0
27-Apr-99	0	0	0
28-Apr-99	0	0	0
29-Apr-99	0	0	0
30-Apr-99	0	0	0
01-May-99	0	0	0
02-May-99	0	0	0
03-May-99	0	0	0
04-May-99	0	0	0
05-May-99	0	0	0
06-May-99	0.8	0	0.8
07-May-99	0	0	0
08-May-99	9.4	0.2	9.4
09-May-99	0.6	0	0.6
10-May-99	0	0	0
11-May-99	0	0	0
12-May-99	0	6.2	0
13-May-99	0	0	0
14-May-99	0	0	0
15-May-99	0	0	0
16-May-99	0	0	0
17-May-99	0	0.6	0
18-May-99	5.4	2.2	5.4
19-May-99	5.2	11.8	5.2
20-May-99	0	0	0
21-May-99	0	0	0
22-May-99	0	0	0
23-May-99	0	0	0
24-May-99	12.6	14.2	12.6

Date	Climate Station		
	Buttonville	Cherrywood	Infill Data
	[mm]	[mm]	[mm]
25-May-99	12.2	7.4	12.2
26-May-99	0.8	3.6	0.8
27-May-99	0	0	0
28-May-99	0	0	0
29-May-99	0	0	0
30-May-99	0	0	0
31-May-99	1	0	1.0
01-Jun-99	23.4	0	23.4
02-Jun-99	15.4	0.4	15.4
03-Jun-99	0	3.4	0
04-Jun-99	0	4.6	0
05-Jun-99	0	0	0
06-Jun-99	0	0	0
07-Jun-99	1	0	1.0
08-Jun-99	0	0	0
09-Jun-99	0	0.2	0
10-Jun-99	0	0.2	0
11-Jun-99	0	0	0
12-Jun-99	0	6.6	0
13-Jun-99	0	0	0
14-Jun-99	6.4	8.8	6.4
15-Jun-99	0	0	0
16-Jun-99	0	0	0
17-Jun-99	0	0	0
18-Jun-99	0	0	0
19-Jun-99	0	0	0
20-Jun-99	0	0	0
21-Jun-99	0	0	0
22-Jun-99	0	0	0
23-Jun-99	0	0	0
24-Jun-99	1.6	0	1.6
25-Jun-99	22.2	38.4	22.2
26-Jun-99	0	0	0
27-Jun-99	16	4.2	16.0
28-Jun-99	0	0.8	0
29-Jun-99	3.2	1.4	3.2
30-Jun-99	0	0	0
01-Jul-99	2.2	0	2.2
02-Jul-99	0	0	0
03-Jul-99	1.2	0	1.2
04-Jul-99	7.8	0.2	7.8
05-Jul-99	0	0.4	0
06-Jul-99	0	13.6	0
07-Jul-99	0	0.2	0

Date	Climate Station		
	Buttonville	Cherrywood	Infill Data
	[mm]	[mm]	[mm]
08-Jul-99	0	0	0
09-Jul-99	6.8	12.8	6.8
10-Jul-99	0	0	0
11-Jul-99	0	0	0
12-Jul-99	0	0	0
13-Jul-99	0	0	0
14-Jul-99	0	0	0
15-Jul-99	0	0	0
16-Jul-99	0	0	0
17-Jul-99	25.2	17.8	25.2
18-Jul-99	0	0	0
19-Jul-99	0.6	0.2	0.6
20-Jul-99	0	0	0
21-Jul-99	0	0	0
22-Jul-99	0	0.4	0
23-Jul-99	0	0	0
24-Jul-99	0	0	0
25-Jul-99	0	0	0
26-Jul-99	0	0	0
27-Jul-99	0	0	0
28-Jul-99	0.2	0	0.2
29-Jul-99	0	0	0
30-Jul-99	0	0.4	0
31-Jul-99	16.4	6.8	16.4
01-Aug-99	0	0.2	0
02-Aug-99	0	0	0
03-Aug-99	0.4	0	0.4
04-Aug-99	34.5	2.2	34.5
05-Aug-99	0	9.4	0
06-Aug-99	6.4	0	6.4
07-Aug-99	5.8	0.2	5.8
08-Aug-99	3.4	0	3.4
09-Aug-99	0	0	0
10-Aug-99	7.6	1.0	7.6
11-Aug-99	0	0	0
12-Aug-99	0	0	0
13-Aug-99	3	0.6	3.0
14-Aug-99	0	1.0	0
15-Aug-99	0	0	0
16-Aug-99	0	0	0
17-Aug-99	0	0	0
18-Aug-99	0	1.2	0
19-Aug-99	0	0	0
20-Aug-99	8	3.8	8.0

Date	Climate Station		
	Buttonville	Cherrywood	Infill Data
	[mm]	[mm]	[mm]
21-Aug-99	0	0.6	0
22-Aug-99	0	0.2	0
23-Aug-99	0	0	0
24-Aug-99	0	0	0
25-Aug-99	0.6	0	0.6
26-Aug-99	0	0.2	0
27-Aug-99	0	0.4	0
28-Aug-99	0	0	0
29-Aug-99	0	0	0
30-Aug-99	0	0	0
31-Aug-99	0	0	0
01-Sep-99	0	0.6	0
02-Sep-99	0	0	0
03-Sep-99	0	0	0
04-Sep-99	0	0	0
05-Sep-99	0	2.6	0
06-Sep-99	3.4	0	3.4
07-Sep-99	0.2	6.0	0.2
08-Sep-99	1.6	0	1.6
09-Sep-99	5	7.0	5.0
10-Sep-99	0	3.2	0
11-Sep-99	0	0	0
12-Sep-99	0	0	0
13-Sep-99	8.6	6.4	8.6
14-Sep-99	0	0.4	0
15-Sep-99	0	0	0
16-Sep-99	0	0	0
17-Sep-99	0	0	0
18-Sep-99	0	0	0
19-Sep-99	0	0	0
20-Sep-99	3	0.2	3.0
21-Sep-99	0	0	0
22-Sep-99	0	0	0
23-Sep-99	0	0	0
24-Sep-99	3.6	1.6	3.6
25-Sep-99	0	0	0
26-Sep-99	0	0	0
27-Sep-99	0	0	0
28-Sep-99	0	0	0
29-Sep-99	55.8	15.6	55.8
30-Sep-99	2.2	4.6	2.2
01-Oct-99	0	0	0
02-Oct-99	10	0	10.0
03-Oct-99	1.2	0	1.2

Date	Climate Station		
	Buttonville	Cherrywood	Infill Data
	[mm]	[mm]	[mm]
04-Oct-99	9.5	0	9.5
05-Oct-99	0	0	0
06-Oct-99	0.4	0	0.4
07-Oct-99	0	3.2	0
08-Oct-99	6	4.8	6.0
09-Oct-99	0	0	0
10-Oct-99	0	0	0
11-Oct-99	0	7.2	0
12-Oct-99	0.2	3.6	0.2
13-Oct-99	42.2	0.2	42.2
14-Oct-99	0	0	0
15-Oct-99	0	0	0
16-Oct-99	0	0	0
17-Oct-99	0.2	0	0.2
18-Oct-99	0	0	0
19-Oct-99	0	0	0
20-Oct-99	0	0	0
21-Oct-99	0	0	0
22-Oct-99	6.5	4.2	6.5
23-Oct-99	0	0	0
24-Oct-99	0	0	0
25-Oct-99	0	0	0
26-Oct-99	0	0	0
27-Oct-99	0	0	0
28-Oct-99	0	0	0
29-Oct-99	0	0	0
30-Oct-99	0	0	0
31-Oct-99	0.8	1.0	0.8
01-Nov-99	0	0	0
02-Nov-99	42.4	0	42.4
03-Nov-99	4.4	0	4.4
04-Nov-99	0.6	0.2	0.6
05-Nov-99	0	0	0
06-Nov-99	0	0	0
07-Nov-99	0	0	0
08-Nov-99	0	2.6	0
09-Nov-99	0	0	0
10-Nov-99	8	0	8.0
11-Nov-99	0	0	0
12-Nov-99	0	0	0
13-Nov-99	0	0	0
14-Nov-99	1	0.2	1.0
15-Nov-99	0	0	0
16-Nov-99	0	0	0

Date	**Climate Station**		
	Buttonville	**Cherrywood**	**Infill Data**
	[mm]	[mm]	[mm]
17-Nov-99	0	0	0
18-Nov-99	0	0	0
19-Nov-99	0	0	0
20-Nov-99	7.7	6.4	7.7
21-Nov-99	0	0	0
22-Nov-99	0.2	0.4	0.2
23-Nov-99	0	0	0
24-Nov-99	1.6	1.0	1.6
25-Nov-99	0	0	0
26-Nov-99	15	12.2	15.0
27-Nov-99	0	1.2	0
28-Nov-99	0	0	0
29-Nov-99	0	0	0
30-Nov-99	0	0	0
01-Dec-99	0	3.2	0
02-Dec-99	0	4.2	0
03-Dec-99	1	0	1.0
04-Dec-99	0	0	0
05-Dec-99	9	0	9.0
06-Dec-99	4	0	4.0
07-Dec-99	0	0	0
08-Dec-99	0	0	0
09-Dec-99	0	0	0
10-Dec-99	3.8	0	3.8
11-Dec-99	0	0	0
12-Dec-99	0	0	0
13-Dec-99	3.2	0.6	3.2
14-Dec-99	4.6	1.4	4.6
15-Dec-99	4.4	6.0	4.4
16-Dec-99	1	2.8	1.0
17-Dec-99	0	0	0
18-Dec-99	0	0	0
19-Dec-99	0	0	0
20-Dec-99	2.2	4.0	2.2
21-Dec-99	0	0	0
22-Dec-99	0	0	0
23-Dec-99	0	0	0
24-Dec-99	0	0	0
25-Dec-99	0	0	0
26-Dec-99	0	0	0
27-Dec-99	0	0	0
28-Dec-99	0.6	0	0.6
29-Dec-99	1.2	0.2	1.2
30-Dec-99	0	0	0

Date	Climate Station		
	Buttonville	Cherrywood	Infill Data
	[mm]	[mm]	[mm]
31-Dec-99	0	0	0
01-Jan-00	0	0	0
02-Jan-00	3.6	0	3.6
03-Jan-00	1	0.2	1.0
04-Jan-00	2.6	0	2.6
05-Jan-00	0	3.0	0
06-Jan-00	0	0	0
07-Jan-00	0	0	0
08-Jan-00	0	10.2	0
09-Jan-00	1	0	1.0
10-Jan-00	10	0	10.0
11-Jan-00	0	0	0
12-Jan-00	0	0	0
13-Jan-00	4.4	0.2	4.4
14-Jan-00	0	0	0
15-Jan-00	1	0	1.0
16-Jan-00	0	0.2	0
17-Jan-00	0	0	0
18-Jan-00	1.2	0	1.2
19-Jan-00	3.1	0	3.1
20-Jan-00	3.4	0.4	3.4
21-Jan-00	0	0	0
22-Jan-00	0	0	0
23-Jan-00	2.2	0.2	2.2
24-Jan-00	0	0	0
25-Jan-00	0	0	0
26-Jan-00	0	0	0
27-Jan-00	0	0	0
28-Jan-00	0	0	0
29-Jan-00	0	0	0
30-Jan-00	0.4	0	0.4
31-Jan-00	0.8	0	0.8
01-Feb-00	3.4	3.0	3.4
02-Feb-00	0	0	0
03-Feb-00	4.8	0.2	4.8
04-Feb-00	0	0.2	0
05-Feb-00	2.6	0	2.6
06-Feb-00	0	4.6	0
07-Feb-00	0	0	0
08-Feb-00	0	5.0	0
09-Feb-00	0	0.4	0
10-Feb-00	8.2	0	8.2
11-Feb-00	0.8	0	0.8
12-Feb-00	0	0	0

Date	Climate Station		
	Buttonville	Cherrywood	Infill Data
	[mm]	[mm]	[mm]
13-Feb-00	4.4	0.8	4.4
14-Feb-00	7	0.8	7.0
15-Feb-00	4.4	0	4.4
16-Feb-00	2.6	5.4	2.6
17-Feb-00	0	0	0
18-Feb-00	2.8	1.0	2.8
19-Feb-00	1	0	1.0
20-Feb-00	0	0	0
21-Feb-00	0	0	0
22-Feb-00	0	0	0
23-Feb-00	1.2	0.2	1.2
24-Feb-00	9.4	2.2	9.4
25-Feb-00	0	5.4	0
26-Feb-00	0	0	0
27-Feb-00	0.2	0	0.2
28-Feb-00	0	0	0
29-Feb-00	0	0	0
01-Mar-00	0.7	1.4	0.7
02-Mar-00	1	1.0	1.0
03-Mar-00	0	0	0
04-Mar-00	0	0.6	0
05-Mar-00	0	0	0
06-Mar-00	0	0	0
07-Mar-00	0	22.0	0
08-Mar-00	0	2.6	0
09-Mar-00	2.4	0.2	2.4
10-Mar-00		0	0
11-Mar-00	2	0	2.0
12-Mar-00	7.6	0	7.6
13-Mar-00	2.8	0	2.8
14-Mar-00	0.8	0.8	0.8
15-Mar-00	2	0.4	2.0
16-Mar-00	2.6	3.0	2.6
17-Mar-00	0	0	0
18-Mar-00	0	0	0
19-Mar-00	4.4	0.4	4.4
20-Mar-00	0.2	0.6	0.2
21-Mar-00	0	0	0
22-Mar-00	0	0	0
23-Mar-00	0	0	0
24-Mar-00	0	0	0
25-Mar-00	1.4	0.8	1.4
26-Mar-00	0	0	0
27-Mar-00	0	0.6	0

Date	Climate Station		
	Buttonville	Cherrywood	Infill Data
	[mm]	[mm]	[mm]
28-Mar-00	4.6	0	4.6
29-Mar-00	1.8	1.0	1.8
30-Mar-00	0	0	0
31-Mar-00	0	0	0
01-Apr-00	0	1.6	0
02-Apr-00	0.8	0	0.8
03-Apr-00	2.2	0	2.2
04-Apr-00	4.8	9.2	4.8
05-Apr-00	0.2	0	0.2
06-Apr-00	1.8	0	1.8
07-Apr-00	5.4	0	5.4
08-Apr-00	11.4	0	11.4
09-Apr-00	0	0.2	0
10-Apr-00	0.2	0	0.2
11-Apr-00	3.2	0	3.2
12-Apr-00	0.6	0	0.6
13-Apr-00	0	0	0
14-Apr-00	0	0	0
15-Apr-00	0	0	0
16-Apr-00	0	0	0
17-Apr-00	0	0	0
18-Apr-00	0.2	0	0.2
19-Apr-00	0	0	0
20-Apr-00	32	10.0	32.0
21-Apr-00	6.4	18.8	6.4
22-Apr-00	0.2	6.0	0.2
23-Apr-00	0	0	0
24-Apr-00	0	0	0
25-Apr-00	0	0	0
26-Apr-00	0	0	0
27-Apr-00	0	0	0
28-Apr-00	0	0	0
29-Apr-00	0	0	0
30-Apr-00	0	0	0
01-May-00	3	0	3.0
02-May-00	0	0	0
03-May-00	0	0	0
04-May-00	0	0	0
05-May-00	0	2.4	0
06-May-00	0	0	0
07-May-00	1.4	0	1.4
08-May-00	0	0	0
09-May-00	9.4	0	9.4
10-May-00	6.2	0	6.2

Date	Climate Station		
	Buttonville	Cherrywood	Infill Data
	[mm]	[mm]	[mm]
11-May-00	17.8	0	17.8
12-May-00	64.8	0	64.8
13-May-00	0	56.8	0
14-May-00	0	0	0
15-May-00	0	0	0
16-May-00	1.2	0	1.2
17-May-00	0.2	0.2	0.2
18-May-00	24	22.6	24.0
19-May-00	0	0	0
20-May-00	0	0	0
21-May-00	0	0	0
22-May-00	0	0	0
23-May-00	15.4	10.2	15.4
24-May-00	0.2	2.0	0.2
25-May-00	1.4	2.0	1.4
26-May-00	0	0.2	0
27-May-00	0	0	0
28-May-00	0	0	0
29-May-00	0	0	0
30-May-00	0	0	0
31-May-00	1.2	0	1.2
01-Jun-00	2.8	0	2.8
02-Jun-00	0.4	0	0.4
03-Jun-00	0	0	0
04-Jun-00	0	0.8	0
05-Jun-00	3.2	0	3.2
06-Jun-00	4.2	10.0	4.2
07-Jun-00	0	0.6	0
08-Jun-00	0	0	0
09-Jun-00	3.6	0	3.6
10-Jun-00	0	0	0
11-Jun-00	26	0	26.0
12-Jun-00	0.2	0	0.2
13-Jun-00	41	33.8	41.0
14-Jun-00	14.4	0.6	14.4
15-Jun-00	0	23.8	0
16-Jun-00	0.8	0.6	0.8
17-Jun-00	0	0.8	0
18-Jun-00	8.6	7.0	8.6
19-Jun-00	0	0.2	0
20-Jun-00	0	0.4	0
21-Jun-00	6.2	8.2	6.2
22-Jun-00	2.8	1.8	2.8
23-Jun-00	0	0	0

Date	Climate Station		
	Buttonville	Cherrywood	Infill Data
	[mm]	[mm]	[mm]
24-Jun-00	9.6	1.6	9.6
25-Jun-00	27.4	35.6	27.4
26-Jun-00	3.2	1.4	3.2
27-Jun-00	0.2	3.2	0.2
28-Jun-00	0	0	0
29-Jun-00	9.8	4.8	9.8
30-Jun-00	0	0	0
01-Jul-00	2.8	0	2.8
02-Jul-00	0.4	0	0.4
03-Jul-00	0	0	0
04-Jul-00	0	0.2	0
05-Jul-00	3.2	3.6	3.2
06-Jul-00	4.2	0	4.2
07-Jul-00	0	0	0
08-Jul-00	0	2.0	0
09-Jul-00	3.6	0	3.6
10-Jul-00	0	0	0
11-Jul-00	26	0	26.0
12-Jul-00	0.2	0	0.2
13-Jul-00	41	0	41.0
14-Jul-00	14.4	7.0	14.4
15-Jul-00	0	2.4	0
16-Jul-00	0.8	0.2	0.8
17-Jul-00	0	0.2	0
18-Jul-00	8.6	0.6	8.6
19-Jul-00	0	0	0
20-Jul-00	0	0.2	0
21-Jul-00	6.2	0	6.2
22-Jul-00	2.8	0	2.8
23-Jul-00	0	0	0
24-Jul-00	9.6	0	9.6
25-Jul-00	27.4	0	27.4
26-Jul-00	3.2	0	3.2
27-Jul-00	0.2	0	0.2
28-Jul-00	0	0	0
29-Jul-00	9.8	0	9.8
30-Jul-00	0	0.2	0
31-Jul-00		6.2	6.2
01-Aug-00	11	0	11.0
02-Aug-00	0	0	0
03-Aug-00	0	0	0
04-Aug-00	0	13.8	0
05-Aug-00	0	1.8	0
06-Aug-00	0.2	0.2	0.2

Date	Climate Station		
	Buttonville	Cherrywood	Infill Data
	[mm]	[mm]	[mm]
07-Aug-00	2.2	0	2.2
08-Aug-00	15.8	0.2	15.8
09-Aug-00	0	0	0
10-Aug-00	8.6	0	8.6
11-Aug-00	3.6	0	3.6
12-Aug-00	0	0	0
13-Aug-00	0.2	0	0.2
14-Aug-00	0	0	0
15-Aug-00	0.8	0	0.8
16-Aug-00	0	0	0
17-Aug-00	0	0	0
18-Aug-00	1.8	0.8	1.8
19-Aug-00	0.2	0.2	0.2
20-Aug-00	0	0	0
21-Aug-00	0	0	0
22-Aug-00	6	0	6.0
23-Aug-00	14.2	12.4	14.2
24-Aug-00	0.2	2.2	0.2
25-Aug-00	0	0.4	0
26-Aug-00	2.6	0	2.6
27-Aug-00	0.4	0.2	0.4
28-Aug-00	0	0	0
29-Aug-00	0	1.2	0
30-Aug-00	0	0	0
31-Aug-00	0	0	0
01-Sep-00	0	0	0
02-Sep-00	6.4	0	6.4
03-Sep-00	0.8	1.8	0.8
04-Sep-00	0	0	0
05-Sep-00	0	0.6	0
06-Sep-00	0	1.2	0
07-Sep-00	0	6.0	0
08-Sep-00	0	0.2	0
09-Sep-00	0	0	0
10-Sep-00	13.4	0	13.4
11-Sep-00	0.2	0	0.2
12-Sep-00	0.8	0	0.8
13-Sep-00	0	0	0
14-Sep-00	25.2	5.8	25.2
15-Sep-00	0	10.4	0
16-Sep-00	0	0.2	0
17-Sep-00	0	0	0
18-Sep-00	0	0	0
19-Sep-00	0	0	0

Date	Climate Station		
	Buttonville	Cherrywood	Infill Data
	[mm]	[mm]	[mm]
20-Sep-00	4.2	0	4.2
21-Sep-00	1.2	0.6	1.2
22-Sep-00	1.2	0	1.2
23-Sep-00	14.6	0	14.6
24-Sep-00	0	0.2	0
25-Sep-00	0	0	0
26-Sep-00	0	0	0
27-Sep-00	0	0	0
28-Sep-00	0	0	0
29-Sep-00	0	0	0
30-Sep-00	0	0	0
01-Oct-00	0	9.0	0
02-Oct-00	0	1.0	0
03-Oct-00	0	0.2	0
04-Oct-00	4.2	0	4.2
05-Oct-00	1.4	12.2	1.4
06-Oct-00	4.6	0	4.6
07-Oct-00	5.2	0	5.2
08-Oct-00	0	0	0
09-Oct-00	0	0	0
10-Oct-00	0	0	0
11-Oct-00	0	0.2	0
12-Oct-00	0	0	0
13-Oct-00	0	0	0
14-Oct-00	0	0	0
15-Oct-00	1.8	0	1.8
16-Oct-00	0	0	0
17-Oct-00	0	0	0
18-Oct-00	2	0	2.0
19-Oct-00	0	0	0
20-Oct-00	0	0	0
21-Oct-00	0	0	0
22-Oct-00	0	0	0
23-Oct-00	0.2	0	0.2
24-Oct-00	0.2	0	0.2
25-Oct-00	0	0	0
26-Oct-00	0	0	0
27-Oct-00	0.6	0	0.6
28-Oct-00	0	0	0
29-Oct-00	0	0	0
30-Oct-00		0	0
31-Oct-00		0	0
01-Nov-00	0	0.6	0
02-Nov-00	0	0.8	0

Date	Climate Station		
	Buttonville	Cherrywood	Infill Data
	[mm]	[mm]	[mm]
03-Nov-00	0	0	0
04-Nov-00	0	2.0	0
05-Nov-00	0.4	0.2	0.4
06-Nov-00	0	33.2	0
07-Nov-00	0	0	0
08-Nov-00	0	0.2	0
09-Nov-00	9.2	19.2	9.2
10-Nov-00	16.6	0	16.6
11-Nov-00	0	0.6	0
12-Nov-00	0	0.4	0
13-Nov-00	3.8	0.2	3.8
14-Nov-00	0	0	0
15-Nov-00	0	0	0
16-Nov-00	0.6	0	0.6
17-Nov-00	0	0	0
18-Nov-00	0	0	0
19-Nov-00	0	0	0
20-Nov-00	4.8	0	4.8
21-Nov-00	0	0	0
22-Nov-00	0.8	0	0.8
23-Nov-00	0	0	0
24-Nov-00	0	0	0
25-Nov-00	4.8	0	4.8
26-Nov-00	13.6	0.6	13.6
27-Nov-00	0.8	0.2	0.8
28-Nov-00	3.4	0.2	3.4
29-Nov-00	0	0.2	0
30-Nov-00	0	0	0
01-Dec-00	0	0	0
02-Dec-00	0	0	0
03-Dec-00	0	4.0	0
04-Dec-00	0	0.2	0
05-Dec-00	0	22.6	0
06-Dec-00	0	0.2	0
07-Dec-00	0	0	0
08-Dec-00	2.4	0.2	2.4
09-Dec-00	0	0.8	0
10-Dec-00	0	0	0
11-Dec-00	15.4	0	15.4
12-Dec-00	33.2	0.4	33.2
13-Dec-00	4.9	0	4.9
14-Dec-00	6.8	0	6.8
15-Dec-00	0	0	0
16-Dec-00	1.6	0	1.6

Date	Climate Station		
	Buttonville	Cherrywood	Infill Data
	[mm]	[mm]	[mm]
17-Dec-00	4.4	0	4.4
18-Dec-00	0	0	0
19-Dec-00	7.6	0	7.6
20-Dec-00	0	0	0
21-Dec-00	4	0	4.0
22-Dec-00	0	0	0
23-Dec-00	1.8	0	1.8
24-Dec-00	4	0	4.0
25-Dec-00	0	0	0
26-Dec-00	0	0	0
27-Dec-00	1	0.2	1.0
28-Dec-00	0	0	0
29-Dec-00	0	0	0
30-Dec-00	9.9	0.4	9.9
31-Dec-00	0	0	0

Appendix I: Temperature Input Data for Calibration

1997 - 2000

This table shows daily temperature values (average, maximum and minimum) considered during calibration of the Duffins Creek Water Balance Analysis System model. The last three columns, 'Infill Data', were used as input.

Date	**Temperature Gauge**													
	Stouffville					**Pearson**			**Buttonville**			**Selected Temperatures in Analysis**		
	Calc Daily (from hr)	Daily Values	Processed (Daily if avail or Calc daily)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min
01-Jan-97						-8.4	-3.3	-14.6	-9.1	-2.6	-17.2	**-9.1**	**-2.6**	**-17.2**
02-Jan-97						0.7	2.7	-3.3	0.5	2.3	-2.2	**0.5**	**2.3**	**-2.2**
03-Jan-97						3.0	5.5	2.1	2.7	4.5	1.2	**2.7**	**4.5**	**1.2**
04-Jan-97						2.3	3.0	1.2	1.6	2.3	0.8	**1.6**	**2.3**	**0.8**
05-Jan-97						3.7	8.8	-0.7	4.2	10.0	-0.3	**4.2**	**10.0**	**-0.3**
06-Jan-97						-3.0	-0.8	-4.0	-2.7	-0.7	-3.5	**-2.7**	**-0.7**	**-3.5**
07-Jan-97						-5.9	-4.3	-8.4	-5.8	-3.3	-8.7	**-5.8**	**-3.3**	**-8.7**
08-Jan-97						-8.0	-4.6	-10.4	-7.9	-4.6	-11.5	**-7.9**	**-4.6**	**-11.5**
09-Jan-97						-5.9	0.6	-11.0	-8.6	-1.8	-13.4	**-8.6**	**-1.8**	**-13.4**
10-Jan-97						-4.9	-1.0	-10.1	-4.3	0.0	-9.4	**-4.3**	**0**	**-9.4**
11-Jan-97						-9.6	-7.4	-11.6	-9.0	-7.0	-10.9	**-9.0**	**-7.0**	**-10.9**
12-Jan-97						-8.9	-6.9	-10.5	-7.8	-5.5	-10.0	**-7.8**	**-5.5**	**-10.0**
13-Jan-97						-6.8	-4.7	-8.7	-6.0	-4.1	-7.9	**-6.0**	**-4.1**	**-7.9**
14-Jan-97						-7.2	-4.3	-10.2	-6.2	-3.2	-9.2	**-6.2**	**-3.2**	**-9.2**
15-Jan-97						-5.1	0.4	-10.9	-4.6	0.6	-9.5	**-4.6**	**0.6**	**-9.5**
16-Jan-97						-5.2	3.3	-15.4	-5.3	3.3	-15.5	**-5.3**	**3.3**	**-15.5**
17-Jan-97						-15.9	-14.2	-17.4	-16.9	-13.9	-20.7	**-16.9**	**-13.9**	**-20.7**
18-Jan-97						-19.5	-15.0	-24.4	-20.1	-14.9	-25.6	**-20.1**	**-14.9**	**-25.6**
19-Jan-97						-12.6	-6.6	-19.0	-12.6	-6.7	-19.0	**-12.6**	**-6.7**	**-19.0**
20-Jan-97						-4.8	-0.6	-8.4	-4.7	0.0	-9.1	**-4.7**	**0**	**-9.1**
21-Jan-97						-7.9	-0.3	-14.8	-8.3	0.1	-18.2	**-8.3**	**0.1**	**-18.2**
22-Jan-97						4.5	6.8	-0.7	4.0	6.6	0.2	**4.0**	**6.6**	**0.2**
23-Jan-97						-8.6	2.8	-12.1	-9.1	3.3	-13.4	**-9.1**	**3.3**	**-13.4**
24-Jan-97						-6.0	-0.2	-12.2	-7.1	-0.2	-14.8	**-7.1**	**-0.2**	**-14.8**
25-Jan-97						-1.9	1.6	-9.8	-1.9	2.2	-10.1	**-1.9**	**2.2**	**-10.1**
26-Jan-97						-14.3	-10.4	-18.9	-15.5	-10.5	-20.7	**-15.5**	**-10.5**	**-20.7**

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	Calc Daily (from hr)	Daily Values	Processed (Daily if avail or Calc daily)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min
27-Jan-97						-7.0	-0.2	-13.3	-9.1	-3.1	-16.0	**-9.1**	**-3.1**	**-16.0**
28-Jan-97						-6.8	-0.8	-9.7	-6.7	-1.2	-9.4	**-6.7**	**-1.2**	**-9.4**
29-Jan-97						-13.6	-10.2	-15.7	-14.1	-10.2	-18.5	**-14.1**	**-10.2**	**-18.5**
30-Jan-97						-9.8	-3.6	-15.4	-12.0	-8.5	-16.6	**-12.0**	**-8.5**	**-16.6**
31-Jan-97						-2.4	1.0	-8.1	-3.1	0.8	-9.3	**-3.1**	**0.8**	**-9.3**
01-Feb-97						-1.1	1.1	-4.7	-1.6	0.7	-7.2	**-1.6**	**0.7**	**-7.2**
02-Feb-97						-0.3	1.3	-3.3	-1.0	1.0	-3.1	**-1.0**	**1.0**	**-3.1**
03-Feb-97						-0.9	0.7	-4.5	-1.1	1.0	-7.0	**-1.1**	**1.0**	**-7.0**
04-Feb-97						-0.7	1.2	-7.2	-1.3	1.2	-9.4	**-1.3**	**1.2**	**-9.4**
05-Feb-97						0.2	2.5	-2.8	0.3	2.7	-2.6	**0.3**	**2.7**	**-2.6**
06-Feb-97						-2.1	-1.0	-3.1	-2.1	-1.0	-2.9	**-2.1**	**-1.0**	**-2.9**
07-Feb-97						-2.7	-0.7	-6.1	-2.7	-0.6	-7.0	**-2.7**	**-0.6**	**-7.0**
08-Feb-97						-9.1	-6.5	-11.8	-10.2	-5.6	-16.3	**-10.2**	**-5.6**	**-16.3**
09-Feb-97						-8.6	-3.4	-14.9	-9.8	-2.0	-19.4	**-9.8**	**-2.0**	**-19.4**
10-Feb-97						-3.8	-1.9	-5.4	-5.3	-1.0	-14.4	**-5.3**	**-1.0**	**-14.4**
11-Feb-97						-3.4	-0.6	-6.0	-3.4	-0.1	-7.3	**-3.4**	**-0.1**	**-7.3**
12-Feb-97						-5.0	-1.2	-12.3	-5.0	-0.9	-13.7	**-5.0**	**-0.9**	**-13.7**
13-Feb-97						-11.8	-7.1	-17.7	-13.8	-8.2	-20.4	**-13.8**	**-8.2**	**-20.4**
14-Feb-97						-2.3	0.4	-7.2	-2.5	0.4	-8.6	**-2.5**	**0.4**	**-8.6**
15-Feb-97						-4.1	-0.6	-10.5	-4.3	0.4	-12.1	**-4.3**	**0.4**	**-12.1**
16-Feb-97						-10.6	-8.7	-13.7	-12.4	-10.4	-15.5	**-12.4**	**-10.4**	**-15.5**
17-Feb-97						-10.8	0.3	-20.6	-11.1	0.2	-22.6	**-11.1**	**0.2**	**-22.6**
18-Feb-97						5.1	8.8	0.4	5.4	9.1	1.0	**5.4**	**9.1**	**1.0**
19-Feb-97						5.2	8.8	-1.1	5.0	8.5	-1.2	**5.0**	**8.5**	**-1.2**
20-Feb-97						-0.9	1.4	-4.2	-2.4	0.7	-6.9	**-2.4**	**0.7**	**-6.9**
21-Feb-97						6.7	12.9	1.5	4.2	6.4	1.1	**4.2**	**6.4**	**1.1**

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22-Feb-97						-3.4	4.6	-8.9	-3.9	2.2	-9.2	**-3.9**	**2.2**	**-9.2**
23-Feb-97						-3.8	0.8	-7.9	-3.8	0.8	-8.0	**-3.8**	**0.8**	**-8.0**
24-Feb-97						-8.0	-3.0	-12.3	-9.1	-3.1	-13.3	**-9.1**	**-3.1**	**-13.3**
25-Feb-97						-6.2	-0.8	-11.2	-6.8	-1.6	-14.7	**-6.8**	**-1.6**	**-14.7**
26-Feb-97						2.8	9.4	-1.9	2.8	9.4	-1.3	**2.8**	**9.4**	**-1.3**
27-Feb-97						1.8	8.5	-3.0	1.5	8.2	-4.1	**1.5**	**8.2**	**-4.1**
28-Feb-97						-1.7	1.4	-4.3	-2.0	1.9	-5.5	**-2.0**	**1.9**	**-5.5**
01-Mar-97						4.0	11.7	-0.9	2.0	6.0	-1.8	**2.0**	**6.0**	**-1.8**
02-Mar-97						3.8	9.8	-1.8	3.2	8.5	-1.3	**3.2**	**8.5**	**-1.3**
03-Mar-97						-2.0	-0.6	-3.7	-2.2	0.0	-5.0	**-2.2**	**0**	**-5.0**
04-Mar-97						-0.4	2.2	-2.4	-0.8	2.4	-3.8	**-0.8**	**2.4**	**-3.8**
05-Mar-97						1.1	3.0	-1.1	0.7	3.5	-1.6	**0.7**	**3.5**	**-1.6**
06-Mar-97						-1.8	0.0	-4.0	-2.0	0.7	-4.4	**-2.0**	**0.7**	**-4.4**
07-Mar-97						-5.6	-3.2	-9.5	-5.3	-1.4	-9.8	**-5.3**	**-1.4**	**-9.8**
08-Mar-97						-4.6	-2.1	-10.3	-4.6	-1.2	-9.0	**-4.6**	**-1.2**	**-9.0**
09-Mar-97						-4.4	0.9	-14.0	-5.4	0.8	-14.3	**-5.4**	**0.8**	**-14.3**
10-Mar-97						2.2	3.6	0.9	2.3	3.6	0.8	**2.3**	**3.6**	**0.8**
11-Mar-97						-1.2	0.8	-4.9	-1.5	0.5	-6.1	**-1.5**	**0.5**	**-6.1**
12-Mar-97						-4.3	-1.5	-7.2	-5.5	-2.2	-9.3	**-5.5**	**-2.2**	**-9.3**
13-Mar-97						-6.2	-3.2	-10.6	-8.5	-3.7	-16.0	**-8.5**	**-3.7**	**-16.0**
14-Mar-97						-1.7	1.4	-4.5	-3.3	1.1	-8.2	**-3.3**	**1.1**	**-8.2**
15-Mar-97						-6.7	-3.5	-8.8	-6.2	-3.0	-9.2	**-6.2**	**-3.0**	**-9.2**
16-Mar-97						-8.3	-4.7	-13.6	-8.5	-4.0	-13.3	**-8.5**	**-4.0**	**-13.3**
17-Mar-97						0.7	6.0	-6.7	0.6	6.6	-11.5	**0.6**	**6.6**	**-11.5**
18-Mar-97						-3.1	-0.5	-6.3	-3.7	-0.3	-7.6	**-3.7**	**-0.3**	**-7.6**
19-Mar-97						-3.7	0.8	-9.3	-3.4	1.4	-9.3	**-3.4**	**1.4**	**-9.3**

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20-Mar-97						-0.5	1.8	-3.0	-0.3	3.2	-3.8	**-0.3**	**3.2**	**-3.8**
21-Mar-97						-0.1	1.5	-1.9	-0.7	0.4	-3.2	**-0.7**	**0.4**	**-3.2**
22-Mar-97						-3.5	0.3	-8.3	-4.4	0.2	-9.8	**-4.4**	**0.2**	**-9.8**
23-Mar-97						-6.4	-2.5	-10.1	-7.8	-3.5	-13.1	**-7.8**	**-3.5**	**-13.1**
24-Mar-97						-2.7	2.9	-8.9	-3.7	3.2	-13.4	**-3.7**	**3.2**	**-13.4**
25-Mar-97						2.5	8.1	-1.2	2.0	6.4	-1.8	**2.0**	**6.4**	**-1.8**
26-Mar-97						2.0	2.9	1.1	2.3	3.4	1.2	**2.3**	**3.4**	**1.2**
27-Mar-97						7.7	13.8	1.5	7.1	14.4	1.1	**7.1**	**14.4**	**1.1**
28-Mar-97						6.9	12.5	0.6	5.9	10.5	-1.4	**5.9**	**10.5**	**-1.4**
29-Mar-97						7.0	9.9	4.6	6.8	10.5	3.7	**6.8**	**10.5**	**3.7**
30-Mar-97						0.2	4.4	-4.8	-0.1	3.3	-5.2	**-0.1**	**3.3**	**-5.2**
31-Mar-97						-2.9	0.7	-5.6	-2.5	2.7	-5.9	**-2.5**	**2.7**	**-5.9**
01-Apr-97						3.1	9.8	-2.4	3.0	9.6	-3.0	**3.0**	**9.6**	**-3.0**
02-Apr-97						8.0	16.3	-1.2	8.5	18.1	0.2	**8.5**	**18.1**	**0.2**
03-Apr-97						9.7	15.1	4.9	8.1	15.8	-1.1	**8.1**	**15.8**	**-1.1**
04-Apr-97						7.7	13.8	0.8	8.6	15.0	1.0	**8.6**	**15.0**	**1.0**
05-Apr-97						9.2	11.6	6.9	9.1	12.1	6.8	**9.1**	**12.1**	**6.8**
06-Apr-97						15.2	22.4	7.9	15.4	23.3	7.9	**15.4**	**23.3**	**7.9**
07-Apr-97						2.0	7.0	-1.7	2.2	6.5	-1.7	**2.2**	**6.5**	**-1.7**
08-Apr-97						-3.0	-1.8	-5.6	-3.2	-1.2	-6.2	**-3.2**	**-1.2**	**-6.2**
09-Apr-97						-4.8	-0.3	-9.1	-5.6	-1.1	-9.9	**-5.6**	**-1.1**	**-9.9**
10-Apr-97						-0.9	4.4	-6.1	-0.5	5.8	-5.9	**-0.5**	**5.8**	**-5.9**
11-Apr-97						2.2	6.2	-3.1	1.9	6.0	-3.1	**1.9**	**6.0**	**-3.1**
12-Apr-97						1.3	3.2	0.3	1.2	2.2	0.2	**1.2**	**2.2**	**0.2**
13-Apr-97						1.7	3.5	0.6	1.8	3.5	0.6	**1.8**	**3.5**	**0.6**
14-Apr-97						2.8	7.7	-2.1	3.3	9.4	-2.3	**3.3**	**9.4**	**-2.3**

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15-Apr-97						6.8	13.0	-0.9	5.8	13.9	-3.9	**5.8**	**13.9**	**-3.9**
16-Apr-97						7.0	12.7	2.9	6.2	13.4	0.3	**6.2**	**13.4**	**0.3**
17-Apr-97						2.7	5.6	1.0	2.9	6.4	1.2	**2.9**	**6.4**	**1.2**
18-Apr-97						2.5	7.0	-1.3	2.4	6.9	-1.2	**2.4**	**6.9**	**-1.2**
19-Apr-97						1.4	3.3	-1.0	1.1	3.1	-0.8	**1.1**	**3.1**	**-0.8**
20-Apr-97						3.4	5.6	0.9	3.3	6.3	1.1	**3.3**	**6.3**	**1.1**
21-Apr-97						7.2	13.5	-0.8	7.6	14.1	0.0	**7.6**	**14.1**	**0**
22-Apr-97						7.8	11.9	2.9	8.5	14.3	0.2	**8.5**	**14.3**	**0.2**
23-Apr-97						9.9	15.5	3.7	10.2	16.5	2.9	**10.2**	**16.5**	**2.9**
24-Apr-97	7.3		7.3	9.9	5.7	9.3	14.8	5.0	10.0	16.0	5.0	**7.3**	**9.9**	**5.7**
25-Apr-97	9.8		9.8	15.2	4.9	9.6	16.3	3.4	10.8	17.0	4.8	**9.8**	**15.2**	**4.9**
26-Apr-97	9.6		9.6	15.6	4.0	10.3	17.2	2.8	10.6	17.4	2.8	**9.6**	**15.6**	**4.0**
27-Apr-97	9.8		9.8	14.6	5.6	8.9	13.2	2.9	9.1	13.6	2.2	**9.8**	**14.6**	**5.6**
28-Apr-97	7.2		7.2	10.4	3.5	8.2	11.8	6.2	8.1	12.0	3.9	**7.2**	**10.4**	**3.5**
29-Apr-97	11.6		11.6	18.6	3.2	11.8	18.9	3.3	11.4	19.0	0.3	**11.6**	**18.6**	**3.2**
30-Apr-97	14.2		14.2	22.9	6.0	15.5	22.3	0.0	15.0	21.6	8.4	**14.2**	**22.9**	**6.0**
01-May-97	8.4		8.4	13.6	3.4	8.6	14.6	4.0	8.4	13.3	2.8	**8.4**	**13.6**	**3.4**
02-May-97	6.9		6.9	12.9	0.5	7.6	12.5	1.1	7.2	12.2	1.4	**6.9**	**12.9**	**0.5**
03-May-97	5.4		5.4	8.5	2.7	5.9	8.1	3.6	5.3	8.6	2.5	**5.4**	**8.5**	**2.7**
04-May-97	6.2		6.2	11.6	0.6	7.2	12.4	1.8	6.6	11.4	1.5	**6.2**	**11.6**	**0.6**
05-May-97	8.0		8.0	15.6	-0.8	10.2	16.0	3.0	8.8	15.0	-1.3	**8.0**	**15.6**	**-0.8**
06-May-97	5.9		5.9	9.8	1.8	7.2	11.0	2.2	6.1	10.5	1.2	**5.9**	**9.8**	**1.8**
07-May-97	5.3		5.3	11.3	-0.9	6.5	12.5	0.3	5.7	12.5	-1.4	**5.3**	**11.3**	**-0.9**
08-May-97	6.7		6.7	14.2	0.1	7.2	12.2	2.5	5.8	12.7	-1.2	**6.7**	**14.2**	**0.1**
09-May-97	8.5		8.5	11.5	6.1	9.5	12.3	6.8	9.3	12.9	7.2	**8.5**	**11.5**	**6.1**
10-May-97	7.9		7.9	10.8	5.7	8.4	11.7	6.5	8.0	11.1	5.2	**7.9**	**10.8**	**5.7**

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11-May-97	10.2		10.2	18.0	3.7	10.2	18.0	3.9	10.4	17.9	3.4	**10.2**	**18.0**	**3.7**
12-May-97	9.7		9.7	14.1	5.7	11.1	14.1	6.5	10.6	14.4	6.5	**9.7**	**14.1**	**5.7**
13-May-97	7.7		7.7	13.9	1.7	9.1	15.8	3.7	8.2	15.3	1.3	**7.7**	**13.9**	**1.7**
14-May-97	7.2		7.2	13.3	1.4	8.1	11.9	4.7	7.2	12.1	2.6	**7.2**	**13.3**	**1.4**
15-May-97	6.9		6.9	9.2	3.2	7.5	10.1	3.8	7.2	9.5	3.2	**6.9**	**9.2**	**3.2**
16-May-97	6.2		6.2	10.8	3.4	7.2	10.9	4.4	6.8	11.0	3.6	**6.2**	**10.8**	**3.4**
17-May-97	6.3		6.3	10.8	3.6	7.2	12.1	4.8	6.7	12.5	2.6	**6.3**	**10.8**	**3.6**
18-May-97	7.1		7.1	11.8	1.7	8.1	12.5	2.1	6.8	11.6	-1.3	**7.1**	**11.8**	**1.7**
19-May-97	9.8		9.8	15.2	6.4	9.7	17.0	6.8	9.9	16.6	6.1	**9.8**	**15.2**	**6.4**
20-May-97	7.7		7.7	11.2	4.8	8.5	12.6	5.4	8.1	13.0	4.9	**7.7**	**11.2**	**4.8**
21-May-97	7.7		7.7	11.9	3.5	8.5	12.2	4.1	8.2	12.4	3.6	**7.7**	**11.9**	**3.5**
22-May-97	7.9		7.9	11.4	3.4	9.4	14.1	4.7	8.3	12.1	4.4	**7.9**	**11.4**	**3.4**
23-May-97	10.6		10.6	16.7	1.2	11.5	17.8	3.8	11.1	17.4	3.0	**10.6**	**16.7**	**1.2**
24-May-97	14.1		14.1	21.0	7.9	14.5	20.1	8.7	13.8	20.4	7.3	**14.1**	**21.0**	**7.9**
25-May-97	11.9		11.9	15.5	8.2	12.0	14.8	8.7	12.0	14.6	8.2	**11.9**	**15.5**	**8.2**
26-May-97	11.0		11.0	16.4	5.7	11.3	17.5	4.6	10.9	16.4	4.6	**11.0**	**16.4**	**5.7**
27-May-97	12.5		12.5	18.4	6.8	12.1	16.4	5.4	11.5	17.0	3.8	**12.5**	**18.4**	**6.8**
28-May-97	13.9		13.9	21.1	5.0	14.2	20.3	5.7	13.0	19.6	3.0	**13.9**	**21.1**	**5.0**
29-May-97	12.8		12.8	15.6	10.1	13.3	15.5	11.4	12.1	14.4	7.9	**12.8**	**15.6**	**10.1**
30-May-97	13.6		13.6	17.6	10.0	14.8	18.7	10.9	14.4	18.8	9.9	**13.6**	**17.6**	**10.0**
31-May-97	15.9		15.9	19.7	11.3	16.3	19.7	11.8	15.9	20.3	11.1	**15.9**	**19.7**	**11.3**
01-Jun-97	16.1		16.1	19.3	12.9	15.8	18.4	12.7	15.7	18.5	12.9	**16.1**	**19.3**	**12.9**
02-Jun-97	16.4		16.4	19.9	13.5	16.4	17.9	14.4	15.8	18.3	12.7	**16.4**	**19.9**	**13.5**
03-Jun-97	16.1		16.1	22.6	8.8	16.0	20.8	9.3	14.9	20.8	6.6	**16.1**	**22.6**	**8.8**
04-Jun-97	17.8		17.8	24.9	9.3	17.8	25.0	7.8	17.0	25.2	6.8	**17.8**	**24.9**	**9.3**
05-Jun-97	18.0		18.0	26.5	9.2	18.8	25.3	10.4	17.5	26.0	7.6	**18.0**	**26.5**	**9.2**

Date	Temperature Gauge													
	Stouffville					Pearson			Buttonville			Selected Temperatures in Analysis		
	Calc Daily (from hr)	Daily Values	Processed (Daily if avail or Calc daily)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min
06-Jun-97	19.6		19.6	25.9	13.9	19.5	24.4	14.1	18.9	24.8	11.2	**19.6**	**25.9**	**13.9**
07-Jun-97	16.3		16.3	20.1	13.7	16.2	19.4	13.2	16.2	19.2	14.1	**16.3**	**20.1**	**13.7**
08-Jun-97	18.2		18.2	25.7	12.1	18.9	24.6	13.3	17.9	24.0	11.9	**18.2**	**25.7**	**12.1**
09-Jun-97	20.7		20.7	28.3	11.9	21.4	28.3	12.6	20.3	28.2	10.5	**20.7**	**28.3**	**11.9**
10-Jun-97	22.8		22.8	29.3	15.5	23.2	29.6	16.3	22.8	29.9	13.9	**22.8**	**29.3**	**15.5**
11-Jun-97	23.0		23.0	28.9	18.4	23.9	30.0	16.8	23.2	30.4	15.0	**23.0**	**28.9**	**18.4**
12-Jun-97	19.8		19.8	28.0	15.2	21.9	26.4	18.2	20.6	27.1	16.8	**19.8**	**28.0**	**15.2**
13-Jun-97	18.7		18.7	24.3	12.9	20.0	25.3	15.1	19.1	25.0	12.3	**18.7**	**24.3**	**12.9**
14-Jun-97	14.9		14.9	19.6	10.7	15.5	21.1	10.0	15.2	20.2	9.1	**14.9**	**19.6**	**10.7**
15-Jun-97	15.8		15.8	22.0	9.8	15.4	21.3	7.2	15.1	21.6	5.6	**15.8**	**22.0**	**9.8**
16-Jun-97	16.7		16.7	24.0	9.8	18.7	26.1	12.8	17.4	24.6	7.8	**16.7**	**24.0**	**9.8**
17-Jun-97	17.3		17.3	22.3	14.1	18.3	21.2	15.3	18.1	22.1	14.1	**17.3**	**22.3**	**14.1**
18-Jun-97	16.8		16.8	19.9	14.0	17.1	20.7	13.9	17.4	21.2	13.8	**16.8**	**19.9**	**14.0**
19-Jun-97	18.3		18.3	23.9	13.9	18.7	22.9	13.3	19.2	24.4	13.5	**18.3**	**23.9**	**13.9**
20-Jun-97	17.6		17.6	18.8	16.3	18.8	21.6	17.2	18.1	20.8	17.0	**17.6**	**18.8**	**16.3**
21-Jun-97	22.3		22.3	28.9	17.3	24.3	29.9	18.7	23.8	30.2	17.9	**22.3**	**28.9**	**17.3**
22-Jun-97	21.4		21.4	26.2	15.5	22.6	27.0	18.5	22.6	28.0	18.5	**21.4**	**26.2**	**15.5**
23-Jun-97	20.5		20.5	26.8	14.6	21.9	27.3	15.3	22.2	28.1	15.4	**20.5**	**26.8**	**14.6**
24-Jun-97	20.7		20.7	28.2	16.5	22.3	27.6	18.1	21.6	29.0	18.1	**20.7**	**28.2**	**16.5**
25-Jun-97	23.4		23.4	29.6	16.4	25.5	31.0	17.4	26.1	32.8	17.3	**23.4**	**29.6**	**16.4**
26-Jun-97	21.9		21.9	25.9	17.1	22.7	27.4	17.9	24.1	30.7	16.6	**21.9**	**25.9**	**17.1**
27-Jun-97	20.6		20.6	27.2	14.6	21.3	27.0	13.1	21.2	27.6	13.6	**20.6**	**27.2**	**14.6**
28-Jun-97	21.8		21.8	28.9	14.6	23.7	28.8	16.6	22.5	28.2	14.0	**21.8**	**28.9**	**14.6**
29-Jun-97	22.5		22.5	29.7	15.1	24.2	29.6	18.4	22.8	29.1	13.8	**22.5**	**29.7**	**15.1**
30-Jun-97	23.1		23.1	29.1	18.0	24.9	29.3	20.5	23.2	28.5	17.4	**23.1**	**29.1**	**18.0**
01-Jul-97	22.2		22.2	26.7	18.5	23.9	27.0	20.5	22.1	25.6	17.7	**22.2**	**26.7**	**18.5**

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	Stouffville					Pearson			Buttonville			Selected Temperatures in Analysis		
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02-Jul-97	22.6		22.6	27.7	17.9	23.5	28.0	19.4	23.1	28.1	17.8	**22.6**	**27.7**	**17.9**
03-Jul-97	19.7		19.7	23.4	15.5	20.3	24.3	16.4	20.7	24.9	16.5	**19.7**	**23.4**	**15.5**
04-Jul-97	14.5		14.5	16.2	12.0	14.6	16.6	12.9	14.7	16.6	11.8	**14.5**	**16.2**	**12.0**
05-Jul-97	17.5		17.5	24.4	10.3	17.4	25.5	9.6	18.4	25.2	9.9	**17.5**	**24.4**	**10.3**
06-Jul-97	18.3		18.3	24.9	11.2	20.3	25.4	14.5	19.7	24.7	10.9	**18.3**	**24.9**	**11.2**
07-Jul-97	15.8		15.8	19.9	11.9	17.3	22.2	12.9	16.2	21.2	11.2	**15.8**	**19.9**	**11.9**
08-Jul-97	12.8		12.8	16.3	9.0	14.3	18.4	10.0	12.5	16.0	8.0	**12.8**	**16.3**	**9.0**
09-Jul-97	15.8		15.8	21.0	11.9	17.3	21.4	12.7	16.0	21.4	12.0	**15.8**	**21.0**	**11.9**
10-Jul-97	18.9		18.9	24.5	12.7	19.0	25.9	12.1	19.1	25.2	12.6	**18.9**	**24.5**	**12.7**
11-Jul-97	21.4		21.4	26.6	15.6	21.3	27.5	15.2	20.6	27.0	12.2	**21.4**	**26.6**	**15.6**
12-Jul-97	22.4		22.4	29.3	13.2	22.9	29.9	15.2	22.7	30.5	12.8	**22.4**	**29.3**	**13.2**
13-Jul-97	23.8		23.8	30.4	16.8	25.0	31.4	17.7	25.0	32.1	15.0	**23.8**	**30.4**	**16.8**
14-Jul-97	25.2		25.2	31.7	18.5	27.7	33.9	21.5	27.1	33.3	20.2	**25.2**	**31.7**	**18.5**
15-Jul-97	24.3		24.3	29.1	19.7	25.8	30.2	21.2	25.4	30.9	20.7	**24.3**	**29.1**	**19.7**
16-Jul-97	23.7		23.7	30.8	16.4	25.3	32.0	18.5	25.3	31.9	16.3	**23.7**	**30.8**	**16.4**
17-Jul-97	24.6		24.6	29.5	18.6	25.8	31.7	19.8	26.3	31.2	19.8	**24.6**	**29.5**	**18.6**
18-Jul-97	22.3		22.3	25.6	17.7	22.6	28.6	18.4	22.5	27.8	18.0	**22.3**	**25.6**	**17.7**
19-Jul-97	15.8		15.8	20.4	11.1	16.1	21.2	11.5	16.0	21.0	11.0	**15.8**	**20.4**	**11.1**
20-Jul-97	17.4		17.4	23.3	12.0	17.4	23.2	10.2	17.6	23.6	10.0	**17.4**	**23.3**	**12.0**
21-Jul-97	16.4		16.4	19.6	12.6	17.0	19.7	15.6	16.7	19.2	13.3	**16.4**	**19.6**	**12.6**
22-Jul-97	19.3		19.3	25.3	14.6	19.2	24.8	13.2	19.1	24.0	13.1	**19.3**	**25.3**	**14.6**
23-Jul-97	20.2		20.2	26.1	13.9	18.8	25.1	11.8	19.4	24.6	11.5	**20.2**	**26.1**	**13.9**
24-Jul-97	19.4		19.4	23.5	16.2	20.6	22.0	18.3	19.4	22.2	16.4	**19.4**	**23.5**	**16.2**
25-Jul-97	21.0		21.0	27.5	15.7	22.8	26.6	18.4	21.6	26.8	16.0	**21.0**	**27.5**	**15.7**
26-Jul-97	20.6		20.6	24.6	16.1	22.3	26.3	18.1	21.3	26.4	15.6	**20.6**	**24.6**	**16.1**
27-Jul-97	22.4		22.4	26.2	19.3	25.2	28.7	21.3	23.3	28.0	19.6	**22.4**	**26.2**	**19.3**

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	Stouffville					**Pearson**			**Buttonville**			**Selected Temperatures in Analysis**		
	Calc Daily (from hr)	Daily Values	Processed (Daily if avail or Calc daily)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min
28-Jul-97	21.9		21.9	27.1	18.3	22.5	28.8	18.2	23.2	29.0	17.6	**21.9**	**27.1**	**18.3**
29-Jul-97	18.5		18.5	23.1	13.3	18.8	24.7	13.5	18.8	24.3	12.2	**18.5**	**23.1**	**13.3**
30-Jul-97	20.6		20.6	27.2	14.1	19.8	27.5	12.0	20.7	27.4	12.6	**20.6**	**27.2**	**14.1**
31-Jul-97	21.3		21.3	27.6	15.3	23.1	29.4	16.2	21.7	28.2	13.5	**21.3**	**27.6**	**15.3**
01-Aug-97	18.9		18.9	24.2	14.5	21.8	25.4	17.4	21.2	24.8	15.1	**18.9**	**24.2**	**14.5**
02-Aug-97	22.1		22.1	28.7	15.6	26.0	31.0	20.2	24.2	30.8	19.1	**22.1**	**28.7**	**15.6**
03-Aug-97	20.1		20.1	23.6	16.4	21.2	25.7	17.2	20.4	25.0	15.5	**20.1**	**23.6**	**16.4**
04-Aug-97	18.5		18.5	23.7	12.6	19.5	24.0	13.5	18.4	24.2	11.9	**18.5**	**23.7**	**12.6**
05-Aug-97	17.2		17.2	21.6	13.9	17.5	22.6	13.2	17.3	22.4	12.9	**17.2**	**21.6**	**13.9**
06-Aug-97	16.4		16.4	22.9	10.9	16.4	22.2	10.3	16.5	23.1	9.1	**16.4**	**22.9**	**10.9**
07-Aug-97	18.6		18.6	26.7	9.7	19.9	27.5	12.1	19.1	28.5	8.3	**18.6**	**26.7**	**9.7**
08-Aug-97	20.5		20.5	28.6	13.5	22.7	28.9	15.7	21.6	29.0	12.6	**20.5**	**28.6**	**13.5**
09-Aug-97	21.6		21.6	29.3	14.6	22.8	29.3	15.4	21.9	29.5	13.4	**21.6**	**29.3**	**14.6**
10-Aug-97	21.6		21.6	28.3	16.3	22.9	27.6	17.5	22.3	27.7	14.9	**21.6**	**28.3**	**16.3**
11-Aug-97	17.7		17.7	20.9	13.4	16.5	22.3	12.9	17.9	23.0	12.6	**17.7**	**20.9**	**13.4**
12-Aug-97	16.4		16.4	22.6	10.2	16.6	22.9	10.4	16.0	20.5	9.6	**16.4**	**22.6**	**10.2**
13-Aug-97	18.1		18.1	19.7	14.3	17.5	22.3	13.9	18.4	20.2	13.2	**18.1**	**19.7**	**14.3**
14-Aug-97	15.6		15.6	20.9	10.6	16.1	22.2	9.8	15.5	22.4	10.2	**15.6**	**20.9**	**10.6**
15-Aug-97	17.5		17.5	22.5	11.7	19.3	23.7	13.2	18.0	24.7	11.5	**17.5**	**22.5**	**11.7**
16-Aug-97	21.5		21.5	28.6	15.5	25.1	30.4	19.1	23.3	30.6	17.4	**21.5**	**28.6**	**15.5**
17-Aug-97	17.2		17.2	20.3	14.8	17.4	21.4	14.5	17.1	20.2	14.2	**17.2**	**20.3**	**14.8**
18-Aug-97	16.2		16.2	21.5	11.1	16.9	22.1	11.1	16.1	21.7	10.6	**16.2**	**21.5**	**11.1**
19-Aug-97	17.0		17.0	23.3	11.5	17.0	22.6	11.1	16.5	22.1	9.6	**17.0**	**23.3**	**11.5**
20-Aug-97	16.3		16.3	20.7	12.6	16.8	21.6	0.0	15.5	20.0	10.0	**16.3**	**20.7**	**12.6**
21-Aug-97	14.9		14.9	17.9	12.7	17.3	20.4	14.6	15.5	18.4	13.7	**14.9**	**17.9**	**12.7**
22-Aug-97	15.6		15.6	20.1	12.2	16.8	19.3	14.1	15.6	19.0	13.4	**15.6**	**20.1**	**12.2**

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	Stouffville					Pearson			Buttonville			Selected Temperatures in Analysis		
	Calc Daily (from hr)	Daily Values	Processed (Daily if avail or Calc daily)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min
23-Aug-97	15.3		15.3	19.4	13.1	17.0	20.9	12.8	15.3	19.8	13.0	**15.3**	**19.4**	**13.1**
24-Aug-97	16.0		16.0	22.6	10.0	15.9	20.9	10.4	15.7	21.4	8.6	**16.0**	**22.6**	**10.0**
25-Aug-97	17.2		17.2	22.4	13.4	17.7	22.1	15.3	17.0	21.3	12.4	**17.2**	**22.4**	**13.4**
26-Aug-97	17.4		17.4	23.1	12.8	17.1	21.8	12.0	17.2	22.1	11.8	**17.4**	**23.1**	**12.8**
27-Aug-97	19.2		19.2	25.8	15.3	21.5	27.1	16.0	20.1	26.8	14.6	**19.2**	**25.8**	**15.3**
28-Aug-97	17.3		17.3	21.9	14.2	19.1	22.6	0.0	17.6	23.2	14.2	**17.3**	**21.9**	**14.2**
29-Aug-97	17.8		17.8	22.4	14.9	18.7	23.0	14.7	17.8	22.9	14.3	**17.8**	**22.4**	**14.9**
30-Aug-97	17.5		17.5	23.2	13.8	18.1	22.5	0.0	17.6	22.7	12.9	**17.5**	**23.2**	**13.8**
31-Aug-97	17.9		17.9	21.1	15.0	17.8	20.3	15.6	17.6	20.3	14.2	**17.9**	**21.1**	**15.0**
01-Sep-97	19.0		19.0	24.8	14.4	20.0	24.2	17.2	19.4	23.9	14.5	**19.0**	**24.8**	**14.4**
02-Sep-97	17.1		17.1	22.5	13.2	18.1	23.5	0.0	17.5	23.6	12.0	**17.1**	**22.5**	**13.2**
03-Sep-97	12.5		12.5	15.6	8.4	12.8	16.4	10.0	12.4	15.4	8.8	**12.5**	**15.6**	**8.4**
04-Sep-97	12.4		12.4	19.0	5.6	13.7	20.9	6.0	13.7	20.0	7.6	**12.4**	**19.0**	**5.6**
05-Sep-97	15.5		15.5	23.8	7.8	16.5	23.9	8.6	16.7	25.6	6.6	**15.5**	**23.8**	**7.8**
06-Sep-97	17.7		17.7	26.7	12.6	21.3	27.1	15.2	19.0	27.4	14.0	**17.7**	**26.7**	**12.6**
07-Sep-97	16.5		16.5	18.6	11.7	16.4	19.4	14.3	16.6	18.5	12.7	**16.5**	**18.6**	**11.7**
08-Sep-97	13.5		13.5	20.4	8.8	14.1	19.9	8.6	12.9	18.5	7.4	**13.5**	**20.4**	**8.8**
09-Sep-97	16.1		16.1	22.5	9.2	15.2	22.0	8.4	15.0	20.5	7.2	**16.1**	**22.5**	**9.2**
10-Sep-97	15.9		15.9	16.9	15.3	17.1	18.2	16.3	16.2	17.1	15.4	**15.9**	**16.9**	**15.3**
11-Sep-97	17.8		17.8	21.4	16.1	19.1	21.9	17.4	18.4	21.4	16.4	**17.8**	**21.4**	**16.1**
12-Sep-97	16.3		16.3	19.2	13.1	16.9	19.5	14.2	16.7	19.8	12.5	**16.3**	**19.2**	**13.1**
13-Sep-97	17.0		17.0	21.2	13.5	17.2	21.2	13.1	17.5	22.0	13.2	**17.0**	**21.2**	**13.5**
14-Sep-97	13.8		13.8	18.4	12.0	17.2	23.7	10.5	16.5	23.0	10.2	**13.8**	**18.4**	**12.0**
15-Sep-97	19.7		19.7	23.5	17.3	19.9	26.9	13.7	18.8	26.2	10.6	**19.7**	**23.5**	**17.3**
16-Sep-97	16.8		16.8	23.6	13.5	18.2	21.1	14.7	17.4	22.5	13.4	**16.8**	**23.6**	**13.5**
17-Sep-97	16.3		16.3	20.1	12.2	18.9	23.6	14.8	18.3	22.9	14.2	**16.3**	**20.1**	**12.2**

Date	Temperature Gauge													
	Stouffville					Pearson			Buttonville			Selected Temperatures in Analysis		
	Calc Daily (from hr)	Daily Values	Processed (Daily if avail or Calc daily)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min
18-Sep-97	16.4		16.4	25.2	9.7	18.6	25.7	11.9	18.9	26.4	10.4	**16.4**	**25.2**	**9.7**
19-Sep-97	16.0		16.0	18.7	13.0	19.3	22.2	16.6	18.5	22.3	13.1	**16.0**	**18.7**	**13.0**
20-Sep-97	13.6		13.6	18.8	8.8	13.9	20.3	7.6	14.7	20.8	8.7	**13.6**	**18.8**	**8.8**
21-Sep-97	8.8		8.8	14.5	3.2	10.5	15.9	5.7	10.4	16.1	4.1	**8.8**	**14.5**	**3.2**
22-Sep-97	11.1		11.1	18.3	4.3	12.8	18.4	6.3	13.5	19.5	6.9	**11.1**	**18.3**	**4.3**
23-Sep-97	11.7		11.7	15.7	7.1	11.8	17.1	7.0	13.6	17.3	7.1	**11.7**	**15.7**	**7.1**
24-Sep-97	8.6		8.6	15.9	0.9	10.0	16.7	3.0	11.2	18.9	1.7	**8.6**	**15.9**	**0.9**
25-Sep-97	11.3		11.3	13.9	8.4	13.4	16.0	10.1	14.9	17.5	12.5	**11.3**	**13.9**	**8.4**
26-Sep-97	9.4		9.4	13.0	7.0	9.4	14.4	5.6	11.6	15.7	6.8	**9.4**	**13.0**	**7.0**
27-Sep-97	9.6		9.6	16.7	3.7	9.0	16.0	2.3	10.9	17.3	2.8	**9.6**	**16.7**	**3.7**
28-Sep-97	13.9		13.9	19.2	9.7	13.4	19.9	6.5	16.1	21.6	9.0	**13.9**	**19.2**	**9.7**
29-Sep-97	14.6		14.6	20.9	10.5	16.8	21.9	12.4	16.7	21.8	12.0	**14.6**	**20.9**	**10.5**
30-Sep-97	12.6		12.6	16.3	8.0	12.5	18.2	8.8	13.3	17.5	7.0	**12.6**	**16.3**	**8.0**
01-Oct-97	5.8		5.8	9.2	1.7		10.5	3.0	5.9	9.6	3.0	**5.8**	**9.2**	**1.7**
02-Oct-97	5.7		5.7	9.8	0.0		13.1	1.6	6.5	12.4	-0.8	**5.7**	**9.8**	**-0.0**
03-Oct-97	13.0		13.0	20.2	9.4		20.8	11.5	13.9	19.6	10.5	**13.0**	**20.2**	**9.4**
04-Oct-97	15.7		15.7	21.4	11.2		22.4	12.0	16.4	22.1	10.6	**15.7**	**21.4**	**11.2**
05-Oct-97	15.9		15.9	24.5	8.8		25.6	12.6	17.4	24.1	11.2	**15.9**	**24.5**	**8.8**
06-Oct-97	16.9		16.9	23.6	12.1		25.0	13.9	18.2	24.1	10.0	**16.9**	**23.6**	**12.1**
07-Oct-97	16.1		16.1	19.8	12.1		22.3	13.0	15.8	20.5	11.2	**16.1**	**19.8**	**12.1**
08-Oct-97	16.7		16.7	23.2	13.1		22.3	11.8	15.7	21.2	11.6	**16.7**	**23.2**	**13.1**
09-Oct-97	17.4		17.4	22.3	13.4		23.9	12.9	17.2	22.3	11.4	**17.4**	**22.3**	**13.4**
10-Oct-97	12.5		12.5	16.6	6.8		18.3	6.7	12.6	17.4	5.1	**12.5**	**16.6**	**6.8**
11-Oct-97	8.7		8.7	15.7	3.8		14.3	4.0	7.8	13.8	2.3	**8.7**	**15.7**	**3.8**
12-Oct-97	11.0		11.0	19.1	4.8		18.0	2.8	9.4	18.2	2.3	**11.0**	**19.1**	**4.8**
13-Oct-97	15.2		15.2	21.2	9.5		21.3	6.9	13.6	19.9	5.4	**15.2**	**21.2**	**9.5**

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14-Oct-97	12.9		12.9	17.2	7.6		18.8	9.3	12.9	18.1	6.8	**12.9**	**17.2**	**7.6**
15-Oct-97	7.4		7.4	11.2	2.7		12.0	4.4	7.4	11.5	2.1	**7.4**	**11.2**	**2.7**
16-Oct-97	7.8		7.8	11.7	4.8		12.7	4.0	7.4	12.5	2.1	**7.8**	**11.7**	**4.8**
17-Oct-97	5.1		5.1	10.0	0.9		12.2	1.7	5.1	11.1	-0.3	**5.1**	**10.0**	**0.9**
18-Oct-97	5.8		5.8	13.5	0.5		12.8	-0.8	4.8	13.1	-2.1	**5.8**	**13.5**	**0.5**
19-Oct-97	6.5		6.5	15.1	0.6		14.1	0.0	5.7	14.0	-1.5	**6.5**	**15.1**	**0.6**
20-Oct-97	7.3		7.3	10.5	3.3		11.4	3.2	7.2	10.9	1.9	**7.3**	**10.5**	**3.3**
21-Oct-97	3.3		3.3	8.4	-0.7		9.9	1.9	4.2	9.1	0.9	**3.3**	**8.4**	**-0.7**
22-Oct-97	-0.2		-0.2	2.1	-2.6		3.6	-1.6	0.2	2.5	-2.4	**-0.2**	**2.1**	**-2.6**
23-Oct-97	1.3		1.3	4.4	-2.6		4.5	0.8	2.2	3.8	-0.6	**1.3**	**4.4**	**-2.6**
24-Oct-97	4.7		4.7	8.4	2.3		8.4	3.5	5.2	7.8	3.3	**4.7**	**8.4**	**2.3**
25-Oct-97	3.3		3.3	7.4	-0.6		9.1	-0.2	3.4	8.0	-1.5	**3.3**	**7.4**	**-0.6**
26-Oct-97	0.3		0.3	3.3	-1.7		4.2	-1.9	-0.1	3.6	-3.5	**0.3**	**3.3**	**-1.7**
27-Oct-97	1.0		1.0	2.0	0.4		3.3	0.2	1.1	2.4	0.0	**1.0**	**2.0**	**0.4**
28-Oct-97	1.9		1.9	5.4	0.1		6.8	-0.2	2.6	5.9	-0.3	**1.9**	**5.4**	**0.1**
29-Oct-97	5.4		5.4	10.7	0.9		12.0	4.5	6.4	10.9	0.9	**5.4**	**10.7**	**0.9**
30-Oct-97	4.9		4.9	10.6	0.2		11.4	0.6	5.1	10.4	-0.6	**4.9**	**10.6**	**0.2**
31-Oct-97	8.6		8.6	12.9	5.0		15.3	5.2	8.1	13.5	4.4	**8.6**	**12.9**	**5.0**
01-Nov-97	10.6		10.6	12.8	7.6	10.1	13.1	7.8	10.3	12.8	7.0	**10.6**	**12.8**	**7.6**
02-Nov-97	8.8		8.8	11.9	2.6	8.1	12.6	4.4	9.0	11.8	3.9	**8.8**	**11.9**	**2.6**
03-Nov-97	4.8		4.8	9.1	1.6	6.6	10.0	3.4	5.2	8.9	1.7	**4.8**	**9.1**	**1.6**
04-Nov-97	3.7		3.7	7.8	0.6	4.2	7.9	0.6	3.9	7.4	0.5	**3.7**	**7.8**	**0.6**
05-Nov-97	4.9		4.9	7.4	1.5	6.3	8.2	4.3	5.6	7.5	3.4	**4.9**	**7.4**	**1.5**
06-Nov-97	6.4		6.4	10.0	2.5	6.9	10.0	0.0	5.8	9.6	1.2	**6.4**	**10.0**	**2.5**
07-Nov-97	6.5		6.5	10.0	3.7	6.0	9.8	2.3	6.0	10.5	3.3	**6.5**	**10.0**	**3.7**
08-Nov-97	6.1		6.1	11.4	1.9	7.3	11.4	2.6	5.7	11.3	2.2	**6.1**	**11.4**	**1.9**

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09-Nov-97	4.4		4.4	8.8	1.8	5.3	9.6	1.4	4.0	8.9	1.1	**4.4**	**8.8**	**1.8**
10-Nov-97	3.0		3.0	6.0	1.0	3.3	6.7	0.7	3.2	6.6	0.4	**3.0**	**6.0**	**1.0**
11-Nov-97	-0.5		-0.5	2.9	-3.1	0.3	4.1	-3.3	-0.2	3.7	-3.1	**-0.5**	**2.9**	**-3.1**
12-Nov-97	-1.6		-1.6	0.7	-6.1	0.0	2.6	-3.2	-1.2	1.6	-7.0	**-1.6**	**0.7**	**-6.1**
13-Nov-97	-1.9		-1.9	2.7	-6.5	-0.7	3.6	-5.1	-2.5	2.2	-7.9	**-1.9**	**2.7**	**-6.5**
14-Nov-97	-4.0		-4.0	0.0	-5.4	-1.2	1.6	-3.9	-3.7	0.3	-4.8	**-4.0**	**-0.0**	**-5.4**
15-Nov-97	-3.6		-3.6	-2.0	-4.7	-2.3	-0.8	-3.9	-3.5	-1.6	-4.6	**-3.6**	**-2.0**	**-4.7**
16-Nov-97	-4.1		-4.1	-1.7	-7.6	-4.6	-0.1	-8.8	-3.9	-0.2	-7.7	**-4.1**	**-1.7**	**-7.6**
17-Nov-97	-0.3		-0.3	0.9	-1.4	-0.2	0.7	-1.0	0.0	1.0	-0.9	**-0.3**	**0.9**	**-1.4**
18-Nov-97	-1.0		-1.0	1.9	-3.3	-0.4	3.0	-3.6	-0.2	2.5	-2.7	**-1.0**	**1.9**	**-3.3**
19-Nov-97	0.5		0.5	2.5	-2.2	1.2	2.8	-0.5	1.4	3.0	0.0	**0.5**	**2.5**	**-2.2**
20-Nov-97	0.6		0.6	2.6	-1.9	1.7	3.5	-2.0	1.1	3.1	-2.0	**0.6**	**2.6**	**-1.9**
21-Nov-97	1.8		1.8	3.6	-1.6	2.9	5.7	-0.1	2.4	4.6	-1.4	**1.8**	**3.6**	**-1.6**
22-Nov-97	-2.5		-2.5	-1.6	-3.3	-1.8	-0.1	-3.2	-2.6	-1.1	-3.8	**-2.5**	**-1.6**	**-3.3**
23-Nov-97	-0.9		-0.9	1.9	-3.4	0.9	2.8	-1.8	-0.8	2.6	-3.7	**-0.9**	**1.9**	**-3.4**
24-Nov-97	-4.5		-4.5	-1.9	-7.1	-4.3	-1.6	-6.3	-4.3	-1.7	-6.9	**-4.5**	**-1.9**	**-7.1**
25-Nov-97	-1.4		-1.4	3.9	-8.3	0.1	6.1	-6.2	0.0	5.8	-7.2	**-1.4**	**3.9**	**-8.3**
26-Nov-97	3.3		3.3	4.3	2.6	5.5	9.0	2.4	5.2	7.8	0.9	**3.3**	**4.3**	**2.6**
27-Nov-97						2.1	5.8	-1.5	0.8	3.3	-2.4	**0.8**	**3.3**	**-2.4**
28-Nov-97						5.2	7.6	4.2	5.0	6.8	2.6	**5.0**	**6.8**	**2.6**
29-Nov-97						2.3	5.8	-1.2	0.4	5.5	-4.3	**0.4**	**5.5**	**-4.3**
30-Nov-97						2.2	3.7	0.2	1.0	2.0	-2.2	**1.0**	**2.0**	**-2.2**
01-Dec-97						0.0	1.5	-2.0	-1.3	0.8	-2.7	**-1.3**	**0.8**	**-2.7**
02-Dec-97						-0.5	3.4	-4.3	-2.6	1.0	-5.3	**-2.6**	**1.0**	**-5.3**
03-Dec-97						-2.0	2.7	-5.8	-2.9	1.5	-9.1	**-2.9**	**1.5**	**-9.1**
04-Dec-97						2.3	3.4	0.7	2.2	4.5	0.3	**2.2**	**4.5**	**0.3**

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05-Dec-97						0.9	3.2	-0.8	0.4	2.6	-2.0	**0.4**	**2.6**	**-2.0**
06-Dec-97						0.1	2.3	-1.8	-0.7	1.1	-2.4	**-0.7**	**1.1**	**-2.4**
07-Dec-97						2.3	4.7	-0.6	0.6	3.0	-1.3	**0.6**	**3.0**	**-1.3**
08-Dec-97						0.8	2.4	-0.1	-0.3	2.1	-1.5	**-0.3**	**2.1**	**-1.5**
09-Dec-97						0.8	1.5	0.0	-0.7	0.2	-1.7	**-0.7**	**0.2**	**-1.7**
10-Dec-97						-1.5	0.4	-2.8	-2.8	-1.0	-5.2	**-2.8**	**-1.0**	**-5.2**
11-Dec-97						-4.1	-3.1	-5.1	-4.5	-3.5	-5.9	**-4.5**	**-3.5**	**-5.9**
12-Dec-97						-3.2	-0.5	-5.5	-2.7	-0.6	-4.6	**-2.7**	**-0.6**	**-4.6**
13-Dec-97						-0.2	1.8	-2.1	-0.7	1.3	-2.4	**-0.7**	**1.3**	**-2.4**
14-Dec-97						-3.1	1.3	-7.3	-3.7	0.5	-8.9	**-3.7**	**0.5**	**-8.9**
15-Dec-97						2.2	7.9	-5.0	1.3	7.8	-5.3	**1.3**	**7.8**	**-5.3**
16-Dec-97						4.8	9.0	1.1	3.5	9.3	0.0	**3.5**	**9.3**	**0**
17-Dec-97						1.7	5.8	-1.7	1.4	5.4	-1.7	**1.4**	**5.4**	**-1.7**
18-Dec-97						0.2	4.2	-3.9	-1.3	2.5	-7.3	**-1.3**	**2.5**	**-7.3**
19-Dec-97						3.8	6.0	1.5	3.0	5.1	1.6	**3.0**	**5.1**	**1.6**
20-Dec-97						-2.1	2.1	-4.6	-0.8	1.3	-5.5	**-0.8**	**1.3**	**-5.5**
21-Dec-97						-5.2	-1.1	-9.2	-6.9	-2.4	-11.6	**-6.9**	**-2.4**	**-11.6**
22-Dec-97						-4.1	0.8	-8.8	-4.4	-0.5	-10.8	**-4.4**	**-0.5**	**-10.8**
23-Dec-97						0.5	2.5	-1.6	0.0	1.4	-2.3	**0.0**	**1.4**	**-2.3**
24-Dec-97						1.8	2.4	1.0	0.2	1.8	-1.1	**0.2**	**1.8**	**-1.1**
25-Dec-97						2.2	3.7	0.8	1.2	2.8	-0.3	**1.2**	**2.8**	**-0.3**
26-Dec-97						0.9	2.1	-0.1	0.0	1.2	-0.7	**0.0**	**1.2**	**-0.7**
27-Dec-97						-1.8	2.9	-4.4	-1.3	1.5	-6.5	**-1.3**	**1.5**	**-6.5**
28-Dec-97						-5.5	-1.0	-10.1	-5.4	-1.6	-9.3	**-5.4**	**-1.6**	**-9.3**
29-Dec-97						0.1	1.1	-0.9	-1.0	0.1	-3.6	**-1.0**	**0.1**	**-3.6**
30-Dec-97						-6.2	-0.8	-10.7	-4.2	-1.9	-11.8	**-4.2**	**-1.9**	**-11.8**

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31-Dec-97						-14.2	-11.2	-16.7	-15.1	-12.2	-18.2	**-15.1**	**-12.2**	**-18.2**
01-Jan-98	-6.1	-5.9	-5.9	0.3	-16.7	-5.4			-4.8	1.9	-14.8	**-5.9**	**0.3**	**-16.7**
02-Jan-98	2.5	2.7	2.7	5.2	0.2	4.2			3.5	6.8	-0.2	**2.7**	**5.2**	**0.2**
03-Jan-98	5.9	5.9	5.9	7.3	4.9	6.9			7.1	8.4	6.2	**5.9**	**7.3**	**4.9**
04-Jan-98	-1.4	-1.8	-1.8	5.4	-4.7	0.7			-1.7	4.9	-5.1	**-1.8**	**5.4**	**-4.7**
05-Jan-98	-0.1	0.3	0.3	3.6	-4.1	1.6			-0.7	2.8	-4.2	**0.3**	**3.6**	**-4.1**
06-Jan-98	6.0	6.0	6.0	9.4	3.4	7.1			5.7	9.9	1.8	**6.0**	**9.4**	**3.4**
07-Jan-98	4.1	4.0	4.0	5.5	3.1	4.9			3.7	4.8	2.8	**4.0**	**5.5**	**3.1**
08-Jan-98	0.6	0.5	0.5	2.6	-0.6	1.7			0.6	2.5	-0.8	**0.5**	**2.6**	**-0.6**
09-Jan-98	-0.4	-0.4	-0.4	0.7	-1.3	1.3			-0.2	2.1	-1.4	**-0.4**	**0.7**	**-1.3**
10-Jan-98	-1.4	-1.7	-1.7	0.4	-6.0	-1.8			-0.9	2.2	-5.9	**-1.7**	**0.4**	**-6.0**
11-Jan-98	-7.4	-7.6	-7.6	-6.2	-10.2	-7.0			-7.2	-5.9	-9.8	**-7.6**	**-6.2**	**-10.2**
12-Jan-98	-5.6	-5.2	-5.2	0.7	-11.0	-3.6			-5.3	1.3	-11.7	**-5.2**	**0.7**	**-11.0**
13-Jan-98	-4.1	-4.5	-4.5	1.9	-9.2	-2.4			-4.2	3.5	-9.1	**-4.5**	**1.9**	**-9.2**
14-Jan-98	-10.7	-10.8	-10.8	-8.6	-13.1	-8.4			-10.2	-8.9	-12.1	**-10.8**	**-8.6**	**-13.1**
15-Jan-98	-10.9	-10.9	-10.9	-10.3	-11.4	-7.3			-10.4	-9.6	-11.4	**-10.9**	**-10.3**	**-11.4**
16-Jan-98	-8.9	-8.7	-8.7	-6.9	-11.1	-7.9			-8.5	-6.6	-10.7	**-8.7**	**-6.9**	**-11.1**
17-Jan-98	-6.4	-6.4	-6.4	-4.9	-7.5	-5.4			-6.6	-5.4	-7.4	**-6.4**	**-4.9**	**-7.5**
18-Jan-98	-4.9	-4.8	-4.8	-2.5	-7.2	-3.4			-5.1	-2.6	-7.6	**-4.8**	**-2.5**	**-7.2**
19-Jan-98	-2.8	-2.9	-2.9	-0.4	-4.7	-2.1			-2.7	-0.4	-5.1	**-2.9**	**-0.4**	**-4.7**
20-Jan-98	-4.9	-5.0	-5.0	-0.8	-8.1	-4.5			-5.6	-1.0	-11.7	**-5.0**	**-0.8**	**-8.1**
21-Jan-98	-5.7	-5.7	-5.7	-3.8	-7.3	-4.0			-5.9	-2.9	-10.5	**-5.7**	**-3.8**	**-7.3**
22-Jan-98	-9.4	-9.5	-9.5	-7.1	-12.3	-7.6			-9.6	-7.2	-12.1	**-9.5**	**-7.1**	**-12.3**
23-Jan-98	-3.4	-3.0	-3.0	1.4	-9.6	-2.9			-3.0	1.9	-9.9	**-3.0**	**1.4**	**-9.6**
24-Jan-98	-1.1	-1.2	-1.2	0.1	-2.5	-1.1			-1.1	-0.1	-2.7	**-1.2**	**0.1**	**-2.5**
25-Jan-98	-3.2	-3.3	-3.3	-0.2	-6.5	-4.0			-3.0	-0.3	-7.6	**-3.3**	**-0.2**	**-6.5**

Date	Temperature Gauge													
	Stouffville					Pearson			Buttonville			Selected Temperatures in Analysis		
	Calc Daily (from hr)	Daily Values	Processed (Daily if avail or Calc daily)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min
26-Jan-98	-9.4	-9.7	-9.7	-5.4	-11.5	-7.1			-9.5	-5.4	-11.4	**-9.7**	**-5.4**	**-11.5**
27-Jan-98	-5.6	-5.1	-5.1	-0.3	-11.4	-4.2			-6.1	-1.0	-11.5	**-5.1**	**-0.3**	**-11.4**
28-Jan-98	-0.6	-0.7	-0.7	1.1	-2.5	-2.3			-0.9	0.7	-3.9	**-0.7**	**1.1**	**-2.5**
29-Jan-98	-0.4	-0.3	-0.3	0.4	-1.3	0.9			-0.5	0.4	-1.4	**-0.3**	**0.4**	**-1.3**
30-Jan-98	-1.3	-1.5	-1.5	-0.2	-3.5	-0.7			-1.2	0.1	-3.3	**-1.5**	**-0.2**	**-3.5**
31-Jan-98	-3.7	-3.8	-3.8	0.4	-9.2	-2.6			-3.6	0.9	-11.1	**-3.8**	**0.4**	**-9.2**
01-Feb-98	-1.7	-1.5	-1.5	3.2	-6.2	0.3			-0.6	3.2	-3.1	**-1.5**	**3.2**	**-6.2**
02-Feb-98	1.7	1.8	1.8	4.4	-0.4	2.0			0.7	5.2	-4.1	**1.8**	**4.4**	**-0.4**
03-Feb-98	-2.8	-3.1	-3.1	1.5	-7.4	-3.0			-3.0	1.2	-7.7	**-3.1**	**1.5**	**-7.4**
04-Feb-98	-6.2	-6.1	-6.1	-3.7	-9.3	-5.5			-5.9	-2.9	-9.8	**-6.1**	**-3.7**	**-9.3**
05-Feb-98	-5.2	-5.2	-5.2	-1.5	-8.4	-4.7			-5.3	-1.7	-8.3	**-5.2**	**-1.5**	**-8.4**
06-Feb-98	-4.1	-4.1	-4.1	0.1	-7.3	-3.6			-4.6	0.3	-9.2	**-4.1**	**0.1**	**-7.3**
07-Feb-98	-4.2	-4.3	-4.3	0.8	-7.7	-3.3			-5.1	0.6	-9.8	**-4.3**	**0.8**	**-7.7**
08-Feb-98	-3.9	-3.9	-3.9	3.2	-8.1	-3.1			-4.8	2.6	-10.8	**-3.9**	**3.2**	**-8.1**
09-Feb-98	-3.3	-3.2	-3.2	2.9	-8.3	-0.9			-3.8	4.3	-10.3	**-3.2**	**2.9**	**-8.3**
10-Feb-98	-0.5	-0.5	-0.5	6.1	-4.0	0.9			-0.8	6.5	-5.4	**-0.5**	**6.1**	**-4.0**
11-Feb-98	1.7	1.9	1.9	5.6	-2.8	2.0			0.7	4.7	-3.6	**1.9**	**5.6**	**-2.8**
12-Feb-98	1.3	1.1	1.1	2.8	-1.5	1.2			1.2	2.9	-1.4	**1.1**	**2.8**	**-1.5**
13-Feb-98	-5.9	-6.2	-6.2	-1.8	-9.5	-5.0			-5.2	-1.7	-8.6	**-6.2**	**-1.8**	**-9.5**
14-Feb-98	-10.8	-10.9	-10.9	-6.9	-14.5	-8.7			-10.5	-6.8	-14.0	**-10.9**	**-6.9**	**-14.5**
15-Feb-98	-8.1	-7.8	-7.8	-3.0	-12.9	-7.0			-8.5	-2.9	-13.7	**-7.8**	**-3.0**	**-12.9**
16-Feb-98	-1.6	-1.3	-1.3	2.3	-5.8	-1.6			-2.5	1.9	-8.5	**-1.3**	**2.3**	**-5.8**
17-Feb-98	1.0	1.0	1.0	2.6	-0.1	1.7			1.0	2.6	0.0	**1.0**	**2.6**	**-0.1**
18-Feb-98	1.6	1.6	1.6	2.1	1.0	2.1			1.5	2.1	0.6	**1.6**	**2.1**	**1.0**
19-Feb-98	1.6	1.6	1.6	2.3	1.0	2.4			1.5	2.6	0.7	**1.6**	**2.3**	**1.0**
20-Feb-98	1.3	1.3	1.3	2.6	0.4	2.4			1.3	2.8	0.2	**1.3**	**2.6**	**0.4**

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21-Feb-98	0.1	0.0	0.0	1.0	-0.8	1.9			0.2	1.5	-0.9	**0**	**1.0**	**-0.8**
22-Feb-98	0.2	0.2	0.2	2.1	-0.9	1.8			0.2	1.9	-2.6	**0.2**	**2.1**	**-0.9**
23-Feb-98	0.8	0.9	0.9	4.5	-2.3	3.1			0.4	5.2	-3.8	**0.9**	**4.5**	**-2.3**
24-Feb-98	0.8	0.8	0.8	2.5	-0.5	1.9			0.5	3.0	-1.2	**0.8**	**2.5**	**-0.5**
25-Feb-98	2.4	2.5	2.5	6.1	0.0	3.7			2.5	6.5	-0.2	**2.5**	**6.1**	**0**
26-Feb-98	3.0	3.0	3.0	8.8	-1.3	3.9			2.7	9.0	-2.0	**3.0**	**8.8**	**-1.3**
27-Feb-98	1.4	1.3	1.3	5.1	-2.1	2.3			0.8	4.8	-3.5	**1.3**	**5.1**	**-2.1**
28-Feb-98	3.9	4.0	4.0	8.3	-0.5	4.1			3.6	9.2	-2.0	**4.0**	**8.3**	**-0.5**
01-Mar-98	2.5	2.4	2.4	5.6	0.6	5.1			3.0	6.8	1.1	**2.4**	**5.6**	**0.6**
02-Mar-98	2.2	2.2	2.2	6.5	-0.5	4.0			3.0	6.5	0.8	**2.2**	**6.5**	**-0.5**
03-Mar-98	1.1	1.1	1.1	3.2	-0.4	2.8			1.6	3.7	0.1	**1.1**	**3.2**	**-0.4**
04-Mar-98	0.6	0.5	0.5	2.6	-0.4	1.7			0.6	2.6	-0.8	**0.5**	**2.6**	**-0.4**
05-Mar-98	-0.2	-0.2	-0.2	1.3	-1.4	1.5			-0.1	1.8	-1.3	**-0.2**	**1.3**	**-1.4**
06-Mar-98	-0.2	-0.2	-0.2	1.9	-1.3	1.0			-0.3	1.5	-1.5	**-0.2**	**1.9**	**-1.3**
07-Mar-98	0.9	0.9	0.9	4.9	-2.3	2.2			0.9	4.8	-3.1	**0.9**	**4.9**	**-2.3**
08-Mar-98	0.4	0.5	0.5	2.4	-0.9	1.8			0.5	2.7	-1.8	**0.5**	**2.4**	**-0.9**
09-Mar-98	4.3	4.0	4.0	9.0	-2.1	3.5			4.3	11.0	-3.1	**4.0**	**9.0**	**-2.1**
10-Mar-98	-9.1	-9.5	-9.5	-3.5	-11.4	-7.9			-8.9	-4.2	-10.8	**-9.5**	**-3.5**	**-11.4**
11-Mar-98	-11.8	-11.7	-11.7	-9.1	-15.6	-10.0			-11.2	-8.2	-15.4	**-11.7**	**-9.1**	**-15.6**
12-Mar-98	-9.8	-9.9	-9.9	-5.9	-14.3	-7.7			-9.0	-5.6	-13.5	**-9.9**	**-5.9**	**-14.3**
13-Mar-98	-5.0	-4.7	-4.7	0.2	-10.8	-2.6			-3.6	0.0	-7.4	**-4.7**	**0.2**	**-10.8**
14-Mar-98	-1.1	-1.1	-1.1	0.7	-2.9	-2.0			-1.2	0.4	-3.6	**-1.1**	**0.7**	**-2.9**
15-Mar-98	-6.2	-6.5	-6.5	-2.9	-9.1	-5.8			-6.3	-3.7	-9.3	**-6.5**	**-2.9**	**-9.1**
16-Mar-98	-7.3	-7.3	-7.3	0.0	-13.2	-6.0			-7.6	-1.3	-13.7	**-7.3**	**0**	**-13.2**
17-Mar-98	-2.5	-2.1	-2.1	3.4	-10.8	-2.0			-3.4	2.6	-12.0	**-2.1**	**3.4**	**-10.8**
18-Mar-98	0.6	0.6	0.6	1.1	-0.1	1.0			0.1	1.0	-1.2	**0.6**	**1.1**	**-0.1**

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19-Mar-98	0.3	0.3	0.3	0.7	-0.2	0.8			0.3	0.9	-0.3	**0.3**	**0.7**	**-0.2**
20-Mar-98	-1.5	-1.5	-1.5	-0.4	-2.5	-0.3			-1.2	-0.3	-2.3	**-1.5**	**-0.4**	**-2.5**
21-Mar-98	-2.7	-2.8	-2.8	-0.8	-3.5	-1.6			-2.8	-0.7	-3.7	**-2.8**	**-0.8**	**-3.5**
22-Mar-98	-2.5	-2.6	-2.6	-1.1	-3.4	-3.1			-2.6	-0.9	-3.8	**-2.6**	**-1.1**	**-3.4**
23-Mar-98	-2.2	-2.3	-2.3	1.9	-4.9	-2.7			-2.3	1.9	-6.9	**-2.3**	**1.9**	**-4.9**
24-Mar-98	-2.9	-2.8	-2.8	4.0	-10.7	-1.9			-2.4	4.1	-11.3	**-2.8**	**4.0**	**-10.7**
25-Mar-98	0.3	0.6	0.6	6.2	-6.7	1.8			0.1	6.0	-8.1	**0.6**	**6.2**	**-6.7**
26-Mar-98	8.9	9.2	9.2	15.5	2.7	11.5			11.9	19.0	3.2	**9.2**	**15.5**	**2.7**
27-Mar-98	13.6	13.8	13.8	21.1	7.7	16.9			17.3	22.2	12.1	**13.8**	**21.1**	**7.7**
28-Mar-98	13.6	13.4	13.4	21.3	7.3	17.1			14.0	22.3	6.6	**13.4**	**21.3**	**7.3**
29-Mar-98	10.4	10.3	10.3	14.5	6.8	14.0			11.7	15.8	6.9	**10.3**	**14.5**	**6.8**
30-Mar-98	15.2	15.6	15.6	23.4	5.6	16.2			16.8	25.0	6.2	**15.6**	**23.4**	**5.6**
31-Mar-98	16.8	16.5	16.5	23.8	9.0	16.4			18.3	24.3	9.4	**16.5**	**23.8**	**9.0**
01-Apr-98	7.2	7.1	7.1	11.0	5.3	8.9			6.8	11.6	4.6	**7.1**	**11.0**	**5.3**
02-Apr-98	5.5	5.4	5.4	8.0	3.6	7.5			6.0	9.2	3.4	**5.4**	**8.0**	**3.6**
03-Apr-98	4.5	4.5	4.5	6.4	2.8	7.3			5.0	8.2	3.1	**4.5**	**6.4**	**2.8**
04-Apr-98	3.7	3.5	3.5	6.6	0.6	4.4			3.8	7.1	-0.6	**3.5**	**6.6**	**0.6**
05-Apr-98	2.8	2.8	2.8	7.9	-1.0	4.4			2.8	7.9	-1.5	**2.8**	**7.9**	**-1.0**
06-Apr-98	4.1	4.1	4.1	10.0	-1.1	5.4			4.3	10.8	-1.4	**4.1**	**10.0**	**-1.1**
07-Apr-98	6.6	6.7	6.7	14.0	0.7	5.9			6.2	13.1	-2.8	**6.7**	**14.0**	**0.7**
08-Apr-98	7.1	7.3	7.3	10.6	3.5	7.6			6.6	10.5	2.2	**7.3**	**10.6**	**3.5**
09-Apr-98	7.2	7.1	7.1	10.1	4.4	7.7			7.0	9.8	4.4	**7.1**	**10.1**	**4.4**
10-Apr-98	4.5	4.4	4.4	9.9	-0.4	5.6			4.7	11.4	-0.3	**4.4**	**9.9**	**-0.4**
11-Apr-98	6.0	6.0	6.0	13.1	0.2	6.0			5.9	12.8	-2.1	**6.0**	**13.1**	**0.2**
12-Apr-98	7.8	8.0	8.0	16.7	-0.3	9.6			7.0	16.7	-2.1	**8.0**	**16.7**	**-0.3**
13-Apr-98	11.2	11.4	11.4	17.2	3.3	9.6			8.9	15.5	0.1	**11.4**	**17.2**	**3.3**

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14-Apr-98	12.4	12.4	12.4	16.7	8.2	10.9			11.2	15.7	4.3	**12.4**	**16.7**	**8.2**
15-Apr-98	12.0	11.9	11.9	15.1	10.0	11.9			12.6	16.0	10.0	**11.9**	**15.1**	**10.0**
16-Apr-98	9.7	9.8	9.8	11.5	6.8	10.4			9.3	13.1	6.6	**9.8**	**11.5**	**6.8**
17-Apr-98	7.4	7.1	7.1	11.2	4.2	8.0			7.4	10.9	4.7	**7.1**	**11.2**	**4.2**
18-Apr-98	8.9	9.0	9.0	16.5	1.6	9.9			10.0	17.0	3.3	**9.0**	**16.5**	**1.6**
19-Apr-98	8.6	8.5	8.5	11.5	6.0	9.5			8.0	11.4	5.5	**8.5**	**11.5**	**6.0**
20-Apr-98	9.6	9.6	9.6	14.8	5.0	10.4			9.8	15.6	4.5	**9.6**	**14.8**	**5.0**
21-Apr-98	11.0	11.0	11.0	17.9	2.3	10.6			9.7	18.0	0.6	**11.0**	**17.9**	**2.3**
22-Apr-98	11.6	11.7	11.7	18.2	2.2	10.4			10.7	18.5	0.6	**11.7**	**18.2**	**2.2**
23-Apr-98	13.3	13.4	13.4	19.9	7.0	11.4			12.9	19.4	4.7	**13.4**	**19.9**	**7.0**
24-Apr-98	12.2	12.0	12.0	19.4	6.9	12.3			11.4	19.4	4.2	**12.0**	**19.4**	**6.9**
25-Apr-98	6.4	6.2	6.2	10.6	1.9	7.8			6.6	11.9	2.3	**6.2**	**10.6**	**1.9**
26-Apr-98	6.2	6.1	6.1	10.7	2.8	6.6			6.1	11.0	2.7	**6.1**	**10.7**	**2.8**
27-Apr-98	3.3	3.3	3.3	8.0	-1.3	3.7			3.7	9.4	-2.6	**3.3**	**8.0**	**-1.3**
28-Apr-98	8.1	8.2	8.2	15.6	0.7	8.4			7.9	16.5	-1.4	**8.2**	**15.6**	**0.7**
29-Apr-98	11.2	11.4	11.4	19.1	2.5	10.3			10.4	18.2	-0.6	**11.4**	**19.1**	**2.5**
30-Apr-98	13.8	13.8	13.8	21.3	5.2	14.8			13.6	20.0	4.5	**13.8**	**21.3**	**5.2**
01-May-98	15.1	15.3	15.3	20.6	8.9	15.0			13.9	20.1	7.6	**15.3**	**20.6**	**8.9**
02-May-98	14.8	14.7	14.7	16.8	12.9	15.2			14.2	16.8	12.4	**14.7**	**16.8**	**12.9**
03-May-98	15.1	15.1	15.1	19.0	11.6	15.5			15.7	18.2	11.7	**15.1**	**19.0**	**11.6**
04-May-98	13.4	13.4	13.4	17.0	9.4	13.9			13.2	16.1	9.4	**13.4**	**17.0**	**9.4**
05-May-98	16.2	16.1	16.1	21.5	12.2	16.5			15.9	20.7	12.4	**16.1**	**21.5**	**12.2**
06-May-98	16.4	16.4	16.4	23.2	11.2	16.4			15.7	22.4	9.4	**16.4**	**23.2**	**11.2**
07-May-98	17.8	18.0	18.0	24.2	11.6	17.1			16.7	22.2	10.4	**18.0**	**24.2**	**11.6**
08-May-98	17.5	17.5	17.5	20.7	14.2	18.6			17.4	20.6	14.5	**17.5**	**20.7**	**14.2**
09-May-98	17.0	17.0	17.0	22.3	12.7	17.4			17.4	22.8	13.5	**17.0**	**22.3**	**12.7**

Date	Temperature Gauge														
	Stouffville					Pearson			Buttonville			Selected Temperatures in Analysis		
	Calc Daily (from hr)	Daily Values	Processed (Daily if avail or Calc daily)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min
10-May-98	14.4	14.3	14.3	16.0	13.1	13.8			14.5	16.0	13.0	**14.3**	**16.0**	**13.1**
11-May-98	13.8	13.7	13.7	15.8	12.3	13.3			13.8	15.9	12.3	**13.7**	**15.8**	**12.3**
12-May-98	13.5	13.6	13.6	17.7	9.6	13.4			13.4	16.5	9.8	**13.6**	**17.7**	**9.6**
13-May-98	16.1	16.2	16.2	20.9	11.3	16.9			15.8	19.2	11.4	**16.2**	**20.9**	**11.3**
14-May-98	19.2	19.3	19.3	26.8	10.7	19.0			19.4	26.3	10.2	**19.3**	**26.8**	**10.7**
15-May-98	21.6	21.6	21.6	29.3	15.3	21.3			22.3	29.0	13.4	**21.6**	**29.3**	**15.3**
16-May-98	19.6	19.6	19.6	25.8	13.5	20.9			19.7	25.4	12.4	**19.6**	**25.8**	**13.5**
17-May-98	20.2	20.3	20.3	25.4	14.1	20.5			21.7	27.2	15.5	**20.3**	**25.4**	**14.1**
18-May-98	20.8	20.8	20.8	26.5	16.3	22.0			22.2	28.4	17.2	**20.8**	**26.5**	**16.3**
19-May-98	19.9	19.9	19.9	26.5	15.2	23.9			20.1	26.5	15.4	**19.9**	**26.5**	**15.2**
20-May-98	20.1	20.0	20.0	26.7	14.4	19.5			20.9	28.2	13.9	**20.0**	**26.7**	**14.4**
21-May-98	11.2	10.9	10.9	13.8	7.6	10.6			11.7	14.5	7.6	**10.9**	**13.8**	**7.6**
22-May-98	11.3	11.4	11.4	16.2	5.3	12.1			12.3	18.0	6.4	**11.4**	**16.2**	**5.3**
23-May-98	14.7	14.8	14.8	20.9	7.4	14.1			15.4	21.8	7.3	**14.8**	**20.9**	**7.4**
24-May-98	18.0	18.1	18.1	24.5	11.1	15.6			17.9	24.0	9.9	**18.1**	**24.5**	**11.1**
25-May-98	17.3	17.2	17.2	21.3	14.0	16.2			17.7	21.9	14.5	**17.2**	**21.3**	**14.0**
26-May-98	16.0	15.9	15.9	21.2	10.9	15.1			16.4	23.4	10.6	**15.9**	**21.2**	**10.9**
27-May-98	16.6	16.7	16.7	25.2	7.7	15.7			16.8	24.8	5.8	**16.7**	**25.2**	**7.7**
28-May-98	19.8	20.0	20.0	27.0	11.4	21.0			21.4	28.2	10.4	**20.0**	**27.0**	**11.4**
29-May-98	20.6	20.4	20.4	25.7	15.7	21.6			22.6	29.0	16.7	**20.4**	**25.7**	**15.7**
30-May-98	16.8	16.8	16.8	23.4	9.7	16.6			17.5	23.7	10.6	**16.8**	**23.4**	**9.7**
31-May-98	17.6	17.3	17.3	25.5	10.4	18.0			18.7	27.6	10.0	**17.3**	**25.5**	**10.4**
01-Jun-98	12.0	12.0	12.0	18.3	7.1	12.5			12.3	17.8	7.4	**12.0**	**18.3**	**7.1**
02-Jun-98	13.2	13.1	13.1	24.1	7.3	16.9			14.0	25.8	7.6	**13.1**	**24.1**	**7.3**
03-Jun-98	8.8	8.7	8.7	12.6	3.6	10.0			9.3	14.1	4.8	**8.7**	**12.6**	**3.6**
04-Jun-98	9.4	9.5	9.5	15.0	2.2	11.2			10.8	16.2	3.6	**9.5**	**15.0**	**2.2**

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	Stouffville					**Pearson**			**Buttonville**			**Selected Temperatures in Analysis**		
	Calc Daily (from hr)	Daily Values	Processed (Daily if avail or Calc daily)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min
05-Jun-98	10.1	10.2	10.2	14.8	3.6	9.4			10.8	16.0	5.0	**10.2**	**14.8**	**3.6**
06-Jun-98	10.6	10.4	10.4	14.3	6.1	11.4			11.4	15.0	6.8	**10.4**	**14.3**	**6.1**
07-Jun-98	10.2	10.3	10.3	13.6	5.0	11.4			11.0	13.8	6.6	**10.3**	**13.6**	**5.0**
08-Jun-98	13.4	13.5	13.5	18.6	7.7	13.9			14.1	19.9	7.5	**13.5**	**18.6**	**7.7**
09-Jun-98	16.5	16.5	16.5	23.5	10.4	14.8			16.3	22.5	7.6	**16.5**	**23.5**	**10.4**
10-Jun-98	15.9	16.0	16.0	20.9	9.6	14.3			15.2	20.0	8.8	**16.0**	**20.9**	**9.6**
11-Jun-98	16.0	16.0	16.0	19.1	13.8	17.1			15.7	18.3	13.6	**16.0**	**19.1**	**13.8**
12-Jun-98	20.1	20.2	20.2	26.9	15.2	22.6			21.1	28.6	14.4	**20.2**	**26.9**	**15.2**
13-Jun-98	19.4	19.2	19.2	23.8	15.7	18.5			20.2	24.8	15.5	**19.2**	**23.8**	**15.7**
14-Jun-98	18.1	18.1	18.1	23.9	13.4	18.8			18.8	24.8	13.0	**18.1**	**23.9**	**13.4**
15-Jun-98	19.1	19.0	19.0	24.4	14.8	20.0			19.9	24.8	15.8	**19.0**	**24.4**	**14.8**
16-Jun-98	18.5	18.5	18.5	23.6	14.6	20.1			18.4	23.9	13.6	**18.5**	**23.6**	**14.6**
17-Jun-98	19.9	19.9	19.9	24.1	16.4	20.9			20.3	25.3	15.8	**19.9**	**24.1**	**16.4**
18-Jun-98	20.7	20.7	20.7	25.2	16.2	20.9			21.6	26.9	16.7	**20.7**	**25.2**	**16.2**
19-Jun-98	21.9	22.0	22.0	27.9	15.8	20.8			21.9	27.2	15.1	**22.0**	**27.9**	**15.8**
20-Jun-98	23.2	23.3	23.3	28.9	17.5	24.9			24.2	28.6	18.9	**23.3**	**28.9**	**17.5**
21-Jun-98	23.5	23.5	23.5	29.9	16.7	23.6			23.8	30.8	15.9	**23.5**	**29.9**	**16.7**
22-Jun-98	24.4	24.4	24.4	30.5	19.3	26.4			24.5	31.3	18.8	**24.4**	**30.5**	**19.3**
23-Jun-98	20.9	20.9	20.9	26.1	17.8	22.4			21.2	25.1	17.7	**20.9**	**26.1**	**17.8**
24-Jun-98	23.4	23.5	23.5	29.5	17.2	23.5			24.0	30.6	15.5	**23.5**	**29.5**	**17.2**
25-Jun-98	24.3	24.3	24.3	30.6	19.0	26.1			25.5	32.0	20.3	**24.3**	**30.6**	**19.0**
26-Jun-98	21.8	21.7	21.7	27.3	18.5	24.6			22.9	30.2	18.8	**21.7**	**27.3**	**18.5**
27-Jun-98	22.3	22.2	22.2	26.8	18.7	22.8			23.1	27.5	19.4	**22.2**	**26.8**	**18.7**
28-Jun-98	21.3	21.4	21.4	26.8	16.5	22.2			21.5	25.2	16.2	**21.4**	**26.8**	**16.5**
29-Jun-98	23.5	23.6	23.6	29.4	17.7	24.9			25.5	31.3	17.7	**23.6**	**29.4**	**17.7**
30-Jun-98	19.7	19.6	19.6	22.3	16.5	20.2			20.8	23.3	16.7	**19.6**	**22.3**	**16.5**

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	Stouffville					**Pearson**			**Buttonville**			**Selected Temperatures in Analysis**		
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01-Jul-98	19.1	19.1	19.1	22.8	15.1	19.4			19.8	23.6	15.2	**19.1**	**22.8**	**15.1**
02-Jul-98	20.7	20.7	20.7	27.0	15.5	20.1			21.4	27.3	14.6	**20.7**	**27.0**	**15.5**
03-Jul-98	21.9	22.1	22.1	29.9	12.9	22.3			23.3	31.2	12.8	**22.1**	**29.9**	**12.9**
04-Jul-98	18.8	18.6	18.6	20.9	14.9	18.6			19.2	21.2	14.6	**18.6**	**20.9**	**14.9**
05-Jul-98	18.4	18.4	18.4	23.9	13.5	18.5			19.0	24.1	13.2	**18.4**	**23.9**	**13.5**
06-Jul-98	17.6	17.7	17.7	22.6	13.9	18.8			17.5	22.5	12.8	**17.7**	**22.6**	**13.9**
07-Jul-98	16.7	16.7	16.7	18.1	14.6	17.5			16.7	18.3	14.7	**16.7**	**18.1**	**14.6**
08-Jul-98	20.1	20.2	20.2	23.7	17.6	21.1			20.5	24.2	17.8	**20.2**	**23.7**	**17.6**
09-Jul-98	21.5	21.5	21.5	28.4	16.2	22.6			21.8	29.0	15.8	**21.5**	**28.4**	**16.2**
10-Jul-98	18.1	18.0	18.0	22.0	14.8	18.0			18.4	22.3	14.2	**18.0**	**22.0**	**14.8**
11-Jul-98	19.2	19.3	19.3	24.5	13.4	18.4			19.7	24.9	14.2	**19.3**	**24.5**	**13.4**
12-Jul-98	20.9	20.9	20.9	26.4	15.0	19.4			20.8	26.6	12.3	**20.9**	**26.4**	**15.0**
13-Jul-98	22.9	23.0	23.0	30.0	17.5	24.1			24.7	29.3	19.6	**23.0**	**30.0**	**17.5**
14-Jul-98	23.6	23.7	23.7	31.7	16.3	24.8			26.0	32.4	19.3	**23.7**	**31.7**	**16.3**
15-Jul-98	25.1	25.2	25.2	32.1	18.9	26.9			26.7	33.4	19.6	**25.2**	**32.1**	**18.9**
16-Jul-98	23.8	23.7	23.7	29.9	20.0	25.5			25.3	31.2	21.0	**23.7**	**29.9**	**20.0**
17-Jul-98	21.3	21.2	21.2	24.8	17.3	20.7			21.7	25.7	17.0	**21.2**	**24.8**	**17.3**
18-Jul-98	20.5	20.5	20.5	26.6	14.5	21.0			21.0	28.0	13.5	**20.5**	**26.6**	**14.5**
19-Jul-98	18.9	19.0	19.0	24.5	13.1	19.6			20.0	25.8	12.0	**19.0**	**24.5**	**13.1**
20-Jul-98	23.4	23.4	23.4	29.9	17.7	25.1			24.7	31.3	18.5	**23.4**	**29.9**	**17.7**
21-Jul-98	24.3	24.5	24.5	30.0	18.7	27.0			26.0	32.4	18.5	**24.5**	**30.0**	**18.7**
22-Jul-98	23.7	23.6	23.6	27.5	19.7	25.3			25.4	29.8	21.1	**23.6**	**27.5**	**19.7**
23-Jul-98	21.1	20.9	20.9	26.5	16.2	22.2			22.9	29.9	17.0	**20.9**	**26.5**	**16.2**
24-Jul-98	17.3	17.3	17.3	21.5	12.5	18.8			18.6	22.9	13.8	**17.3**	**21.5**	**12.5**
25-Jul-98	17.1	17.1	17.1	22.8	11.8	17.5			17.9	22.8	10.3	**17.1**	**22.8**	**11.8**
26-Jul-98	18.5	18.5	18.5	24.4	13.9	19.0			19.9	26.2	12.2	**18.5**	**24.4**	**13.9**

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27-Jul-98	19.2	19.3	19.3	24.9	12.9	22.1			22.0	27.4	14.6	**19.3**	**24.9**	**12.9**
28-Jul-98	21.2	21.4	21.4	27.7	13.9	22.9			23.9	30.0	14.9	**21.4**	**27.7**	**13.9**
29-Jul-98	20.5	20.3	20.3	25.6	15.8	22.6			22.6	28.0	17.6	**20.3**	**25.6**	**15.8**
30-Jul-98	18.5	18.5	18.5	21.6	15.0	19.1			20.1	23.7	16.1	**18.5**	**21.6**	**15.0**
31-Jul-98	18.8	18.8	18.8	23.2	13.8	18.9			19.4	25.1	13.4	**18.8**	**23.2**	**13.8**
01-Aug-98	19.3	19.2	19.2	25.5	14.0				20.2	26.1	13.3	**19.2**	**25.5**	**14.0**
02-Aug-98	19.6	19.7	19.7	27.4	12.2				21.6	27.8	11.6	**19.7**	**27.4**	**12.2**
03-Aug-98	21.7	21.7	21.7	28.6	15.3				22.4	29.2	13.8	**21.7**	**28.6**	**15.3**
04-Aug-98	22.5	22.6	22.6	29.2	17.8				23.3	28.8	17.5	**22.6**	**29.2**	**17.8**
05-Aug-98	22.2	22.2	22.2	27.3	19.5				23.0	27.4	19.7	**22.2**	**27.3**	**19.5**
06-Aug-98	19.8	19.8	19.8	21.2	18.7				20.9	22.3	19.6	**19.8**	**21.2**	**18.7**
07-Aug-98	20.1	20.2	20.2	23.4	18.8				21.1	24.2	19.5	**20.2**	**23.4**	**18.8**
08-Aug-98	23.1	23.1	23.1	28.4	18.8				24.4	28.9	20.7	**23.1**	**28.4**	**18.8**
09-Aug-98	23.3	23.3	23.3	29.8	19.0				24.3	30.8	19.5	**23.3**	**29.8**	**19.0**
10-Aug-98	22.8	22.8	22.8	27.1	20.2				24.0	29.0	21.4	**22.8**	**27.1**	**20.2**
11-Aug-98	20.2	20.0	20.0	24.4	16.9				21.0	25.2	17.3	**20.0**	**24.4**	**16.9**
12-Aug-98	18.5	19.9	19.9	24.8	13.4				19.6	25.0	14.1	**19.9**	**24.8**	**13.4**
13-Aug-98	18.0	18.0	18.0	25.4	12.4				18.7	24.6	12.0	**18.0**	**25.4**	**12.4**
14-Aug-98	19.6	19.6	19.6	26.9	12.9				20.3	26.7	13.0	**19.6**	**26.9**	**12.9**
15-Aug-98	20.5	20.6	20.6	28.0	14.5				22.6	29.4	16.6	**20.6**	**28.0**	**14.5**
16-Aug-98	20.0	19.9	19.9	25.7	15.1				20.3	25.0	14.5	**19.9**	**25.7**	**15.1**
17-Aug-98	22.2	22.3	22.3	30.0	15.9				23.2	31.6	15.7	**22.3**	**30.0**	**15.9**
18-Aug-98	17.3	16.9	16.9	20.9	12.4				18.0	21.8	12.1	**16.9**	**20.9**	**12.4**
19-Aug-98	14.9	14.8	14.8	21.1	9.3				15.8	22.2	9.5	**14.8**	**21.1**	**9.3**
20-Aug-98	17.6	17.9	17.9	24.8	9.4				19.1	25.9	8.6	**17.9**	**24.8**	**9.4**
21-Aug-98	22.1	22.1	22.1	28.2	18.5				23.7	27.7	19.1	**22.1**	**28.2**	**18.5**

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	Calc Daily (from hr)	Daily Values	Processed (Daily if avail or Calc daily)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min
22-Aug-98	21.5	21.5	21.5	26.7	17.1				23.0	28.1	18.6	**21.5**	**26.7**	**17.1**
23-Aug-98	19.8	20.1	20.1	25.1	16.4				21.9	27.4	17.5	**20.1**	**25.1**	**16.4**
24-Aug-98	22.8	22.6	22.6	28.8	17.2				26.2	31.4	18.5	**22.6**	**28.8**	**17.2**
25-Aug-98	20.7	20.6	20.6	25.2	18.1				22.9	28.2	18.9	**20.6**	**25.2**	**18.1**
26-Aug-98	20.4	20.5	20.5	24.9	16.5				21.6	26.1	17.6	**20.5**	**24.9**	**16.5**
27-Aug-98	21.4	21.4	21.4	27.7	16.7				22.0	28.8	14.9	**21.4**	**27.7**	**16.7**
28-Aug-98	20.3	20.3	20.3	27.2	14.8				20.8	26.7	14.8	**20.3**	**27.2**	**14.8**
29-Aug-98	20.9	20.8	20.8	26.8	16.9				21.8	26.8	17.3	**20.8**	**26.8**	**16.9**
30-Aug-98	19.0	19.0	19.0	24.6	13.6				20.2	26.2	12.9	**19.0**	**24.6**	**13.6**
31-Aug-98	18.0	17.9	17.9	22.6	13.5				19.1	24.2	13.3	**17.9**	**22.6**	**13.5**
01-Sep-98	17.2		17.2	23.1	12.3	17.4			18.0	23.1	10.3	**17.2**	**23.1**	**12.3**
02-Sep-98	17.1		17.1	21.4	15.0	20.1			19.3	23.0	16.0	**17.1**	**21.4**	**15.0**
03-Sep-98	16.5		16.5	21.8	13.0	18.4			18.0	22.1	14.1	**16.5**	**21.8**	**13.0**
04-Sep-98	16.1		16.1	20.7	12.3	17.8			17.1	23.2	12.6	**16.1**	**20.7**	**12.3**
05-Sep-98	18.1		18.1	27.4	9.3	20.4			20.1	29.4	9.7	**18.1**	**27.4**	**9.3**
06-Sep-98	21.8		21.8	30.3	14.2	25.8			24.8	32.5	18.7	**21.8**	**30.3**	**14.2**
07-Sep-98	17.6		17.6	21.6	12.1	18.0			18.3	23.2	12.9	**17.6**	**21.6**	**12.1**
08-Sep-98	12.4		12.4	16.5	10.3	14.6			13.1	18.5	10.4	**12.4**	**16.5**	**10.3**
09-Sep-98	13.0		13.0	16.2	10.6	13.9			13.5	17.4	10.0	**13.0**	**16.2**	**10.6**
10-Sep-98	14.5		14.5	21.1	7.2	15.9			15.4	23.4	6.8	**14.5**	**21.1**	**7.2**
11-Sep-98	19.2		19.2	28.3	10.6	22.5			22.1	29.6	14.2	**19.2**	**28.3**	**10.6**
12-Sep-98	19.4		19.4	24.0	15.3	19.5			21.0	25.4	15.4	**19.4**	**24.0**	**15.3**
13-Sep-98	16.5		16.5	23.8	11.1	17.6			16.4	23.0	9.6	**16.5**	**23.8**	**11.1**
14-Sep-98	18.7		18.7	24.2	14.6	20.1			18.9	23.3	14.3	**18.7**	**24.2**	**14.6**
15-Sep-98	20.0		20.0	23.9	18.2	23.8			21.1	26.7	19.0	**20.0**	**23.9**	**18.2**
16-Sep-98	16.5		16.5	23.2	10.8	15.6			17.2	21.8	10.6	**16.5**	**23.2**	**10.8**

Date	**Temperature Gauge**													
	Stouffville					**Pearson**			**Buttonville**			**Selected Temperatures in Analysis**		
	Calc Daily (from hr)	Daily Values	Processed (Daily if avail or Calc daily)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min
17-Sep-98	15.9		15.9	23.4	8.7	16.5			16.7	25.0	7.9	**15.9**	**23.4**	**8.7**
18-Sep-98	17.5		17.5	26.2	12.0	18.4			17.7	25.2	11.6	**17.5**	**26.2**	**12.0**
19-Sep-98	18.7		18.7	25.9	12.2	19.7			19.5	27.2	11.8	**18.7**	**25.9**	**12.2**
20-Sep-98	19.9		19.9	26.9	15.2	21.0			20.7	27.3	14.9	**19.9**	**26.9**	**15.2**
21-Sep-98	19.4		19.4	25.7	13.9	21.5			21.5	27.5	14.4	**19.4**	**25.7**	**13.9**
22-Sep-98	12.6		12.6	14.8	6.9	12.2			13.2	16.1	6.8	**12.6**	**14.8**	**6.9**
23-Sep-98	9.2		9.2	15.2	3.7	10.7			9.8	17.7	3.3	**9.2**	**15.2**	**3.7**
24-Sep-98	10.9		10.9	18.7	4.3	13.6			12.1	19.9	3.5	**10.9**	**18.7**	**4.3**
25-Sep-98	16.2		16.2	23.7	11.3	20.4			18.4	23.0	13.7	**16.2**	**23.7**	**11.3**
26-Sep-98	17.0		17.0	23.2	12.4	22.5			18.5	27.6	11.6	**17.0**	**23.2**	**12.4**
27-Sep-98	19.0		19.0	23.6	13.6	20.3			21.3	26.0	14.9	**19.0**	**23.6**	**13.6**
28-Sep-98	13.0		13.0	17.0	8.2	14.2			13.9	18.7	7.3	**13.0**	**17.0**	**8.2**
29-Sep-98	13.0		13.0	21.1	5.5	14.6			14.2	21.7	4.2	**13.0**	**21.1**	**5.5**
30-Sep-98	15.8		15.8	22.1	11.2	17.4			17.0	22.1	12.3	**15.8**	**22.1**	**11.2**
01-Oct-98	9.9		9.9	13.5	6.5	10.5			10.6	14.2	7.0	**9.9**	**13.5**	**6.5**
02-Oct-98	9.0		9.0	12.5	4.6	10.0			9.5	13.7	5.8	**9.0**	**12.5**	**4.6**
03-Oct-98	7.8		7.8	10.3	3.9	8.4			8.6	11.5	3.4	**7.8**	**10.3**	**3.9**
04-Oct-98	8.1		8.1	15.3	3.6	8.8			7.8	15.4	0.6	**8.1**	**15.3**	**3.6**
05-Oct-98	9.5		9.5	16.6	3.6	9.0			8.6	14.7	1.4	**9.5**	**16.6**	**3.6**
06-Oct-98	11.3		11.3	16.0	7.1	12.4			11.5	14.6	7.6	**11.3**	**16.0**	**7.1**
07-Oct-98	14.3		14.3	16.8	11.6	16.7			15.4	18.9	12.5	**14.3**	**16.8**	**11.6**
08-Oct-98	12.5		12.5	14.3	8.2	11.8			12.9	15.6	8.4	**12.5**	**14.3**	**8.2**
09-Oct-98	9.9		9.9	15.6	4.6	10.9			10.0	16.4	4.0	**9.9**	**15.6**	**4.6**
10-Oct-98	11.1		11.1	16.4	7.0	11.7			11.3	17.6	6.2	**11.1**	**16.4**	**7.0**
11-Oct-98	12.5		12.5	18.8	8.3	14.3			13.1	19.6	8.5	**12.5**	**18.8**	**8.3**
12-Oct-98	10.7		10.7	15.9	5.6	11.8			11.2	15.1	5.3	**10.7**	**15.9**	**5.6**

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	Stouffville					**Pearson**			**Buttonville**			**Selected Temperatures in Analysis**		
	Calc Daily (from hr)	Daily Values	Processed (Daily if avail or Calc daily)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min
13-Oct-98	12.2		12.2	18.0	7.8	13.5			12.2	18.5	8.1	**12.2**	**18.0**	**7.8**
14-Oct-98	6.9		6.9	9.9	5.0	8.3			7.5	10.7	5.2	**6.9**	**9.9**	**5.0**
15-Oct-98	6.8		6.8	11.0	3.2	8.6			7.2	11.7	3.0	**6.8**	**11.0**	**3.2**
16-Oct-98	7.9		7.9	14.9	2.3	8.4			7.6	14.8	0.6	**7.9**	**14.9**	**2.3**
17-Oct-98	11.8		11.8	15.3	8.0	12.3			11.6	15.8	5.7	**11.8**	**15.3**	**8.0**
18-Oct-98	14.9		14.9	20.9	10.7	17.5			16.8	23.0	11.5	**14.9**	**20.9**	**10.7**
19-Oct-98	10.9		10.9	14.7	6.9	12.2			12.1	14.8	9.7	**10.9**	**14.7**	**6.9**
20-Oct-98	7.2		7.2	11.7	3.4	10.0			8.5	12.4	4.9	**7.2**	**11.7**	**3.4**
21-Oct-98	3.8		3.8	6.3	0.7	5.7			4.9	7.6	1.3	**3.8**	**6.3**	**0.7**
22-Oct-98	5.0		5.0	8.8	0.0	6.6			5.6	9.8	1.6	**5.0**	**8.8**	**0**
23-Oct-98	8.3		8.3	18.7	-0.6	10.8			10.2	19.0	-0.2	**8.3**	**18.7**	**-0.6**
24-Oct-98	12.5		12.5	21.1	6.1	15.1			14.3	21.5	8.9	**12.5**	**21.1**	**6.1**
25-Oct-98	11.4		11.4	17.8	7.8	12.9			11.8	19.2	8.2	**11.4**	**17.8**	**7.8**
26-Oct-98	9.3		9.3	12.8	7.3	10.3			9.5	11.6	8.6	**9.3**	**12.8**	**7.3**
27-Oct-98	10.7		10.7	20.0	5.8	11.9			10.4	19.6	3.5	**10.7**	**20.0**	**5.8**
28-Oct-98	11.7		11.7	14.8	8.7	11.9			12.7	15.5	7.5	**11.7**	**14.8**	**8.7**
29-Oct-98	6.3		6.3	10.5	1.7	7.3			6.6	11.6	2.0	**6.3**	**10.5**	**1.7**
30-Oct-98	4.5		4.5	10.9	-1.4	7.4			5.1	12.6	-1.2	**4.5**	**10.9**	**-1.4**
31-Oct-98	5.9		5.9	12.0	-0.1	7.2			6.2	13.3	0.2	**5.9**	**12.0**	**-0.1**
01-Nov-98	6.8		6.8	9.8	3.5				6.8	10.6	3.0	**6.8**	**9.8**	**3.5**
02-Nov-98	3.8		3.8	4.6	1.8				3.9	5.6	1.7	**3.8**	**4.6**	**1.8**
03-Nov-98	1.3		1.3	4.1	-0.4				1.3	5.6	-1.9	**1.3**	**4.1**	**-0.4**
04-Nov-98	0.3		0.3	3.9	-4.1				0.3	4.4	-5.0	**0.3**	**3.9**	**-4.1**
05-Nov-98	1.5		1.5	2.7	0.2				1.4	3.2	-2.4	**1.5**	**2.7**	**0.2**
06-Nov-98	1.6		1.6	5.6	-2.6				2.2	6.8	-2.6	**1.6**	**5.6**	**-2.6**
07-Nov-98	3.7		3.7	5.8	0.5				4.4	6.3	2.2	**3.7**	**5.8**	**0.5**

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08-Nov-98	4.0		4.0	6.1	2.0				5.1	7.2	3.1	**4.0**	**6.1**	**2.0**
09-Nov-98	4.4		4.4	7.2	2.4				5.1	8.1	3.3	**4.4**	**7.2**	**2.4**
10-Nov-98	6.8		6.8	10.3	4.5				7.5	11.8	4.1	**6.8**	**10.3**	**4.5**
11-Nov-98	5.5		5.5	9.5	3.9				6.5	11.2	4.8	**5.5**	**9.5**	**3.9**
12-Nov-98	3.5		3.5	8.3	-0.7				4.5	9.6	1.4	**3.5**	**8.3**	**-0.7**
13-Nov-98	0.8		0.8	4.8	-2.2				1.9	4.8	-1.0	**0.8**	**4.8**	**-2.2**
14-Nov-98	3.6		3.6	7.7	-2.2				4.8	9.7	-1.4	**3.6**	**7.7**	**-2.2**
15-Nov-98	4.4		4.4	8.2	0.5				5.2	9.9	2.0	**4.4**	**8.2**	**0.5**
16-Nov-98	0.9		0.9	1.8	0.3				1.1	1.9	0.4	**0.9**	**1.8**	**0.3**
17-Nov-98	-0.2		-0.2	1.4	-2.3				0.2	2.5	-2.3	**-0.2**	**1.4**	**-2.3**
18-Nov-98	0.5		0.5	6.2	-4.4				1.0	7.8	-5.3	**0.5**	**6.2**	**-4.4**
19-Nov-98	6.0		6.0	11.1	2.6				7.0	13.7	2.5	**6.0**	**11.1**	**2.6**
20-Nov-98	2.9		2.9	4.4	1.1				3.6	5.1	2.0	**2.9**	**4.4**	**1.1**
21-Nov-98	0.1		0.1	1.2	-3.6				0.8	2.3	-2.3	**0.1**	**1.2**	**-3.6**
22-Nov-98	1.1		1.1	6.6	-5.6				1.4	8.2	-6.6	**1.1**	**6.6**	**-5.6**
23-Nov-98	8.4		8.4	12.4	4.7				9.7	14.2	5.2	**8.4**	**12.4**	**4.7**
24-Nov-98	3.8		3.8	5.3	0.0				4.6	7.3	1.3	**3.8**	**5.3**	**0**
25-Nov-98	1.8		1.8	5.6	-2.3				2.2	6.3	-2.6	**1.8**	**5.6**	**-2.3**
26-Nov-98	4.9		4.9	7.2	2.7				5.4	8.4	3.1	**4.9**	**7.2**	**2.7**
27-Nov-98	2.6		2.6	4.5	0.4				3.2	5.3	0.3	**2.6**	**4.5**	**0.4**
28-Nov-98	3.9		3.9	10.2	-0.8				5.3	12.0	0.3	**3.9**	**10.2**	**-0.8**
29-Nov-98	4.7		4.7	6.5	2.0				4.7	6.8	1.4	**4.7**	**6.5**	**2.0**
30-Nov-98	12.0		12.0	16.0	6.9				12.8	17.8	5.3	**12.0**	**16.0**	**6.9**
01-Dec-98						6.9			6.7	9.8	4.4	**6.7**	**9.8**	**4.4**
02-Dec-98						10.5			10.0	14.6	5.2	**10.0**	**14.6**	**5.2**
03-Dec-98						9.7			10.2	13.7	4.7	**10.2**	**13.7**	**4.7**

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04-Dec-98						9.8			9.2	15.4	2.6	**9.2**	**15.4**	**2.6**
05-Dec-98						4.2			2.9	4.0	1.3	**2.9**	**4.0**	**1.3**
06-Dec-98						11.3			8.4	15.5	3.4	**8.4**	**15.5**	**3.4**
07-Dec-98						7.9			4.6	16.5	-2.5	**4.6**	**16.5**	**-2.5**
08-Dec-98						1.4			0.8	4.2	-2.4	**0.8**	**4.2**	**-2.4**
09-Dec-98						3.3			1.9	7.0	-2.0	**1.9**	**7.0**	**-2.0**
10-Dec-98						3.2			2.3	6.4	-2.2	**2.3**	**6.4**	**-2.2**
11-Dec-98						2.8			2.2	6.6	-0.4	**2.2**	**6.6**	**-0.4**
12-Dec-98						4.6			3.4	7.8	-0.8	**3.4**	**7.8**	**-0.8**
13-Dec-98						3.2			1.5	7.9	-4.0	**1.5**	**7.9**	**-4.0**
14-Dec-98						-0.3			-1.4	3.3	-7.0	**-1.4**	**3.3**	**-7.0**
15-Dec-98						5.5			4.3	9.9	0.8	**4.3**	**9.9**	**0.8**
16-Dec-98						2.5			1.7	5.6	-0.8	**1.7**	**5.6**	**-0.8**
17-Dec-98						-2.3			-1.5	0.6	-5.4	**-1.5**	**0.6**	**-5.4**
18-Dec-98						-2.8			-5.4	0.2	-10.6	**-5.4**	**0.2**	**-10.6**
19-Dec-98						3.2			3.6	5.6	0.6	**3.6**	**5.6**	**0.6**
20-Dec-98						-1.9			-2.8	0.0	-4.4	**-2.8**	**0**	**-4.4**
21-Dec-98						2.0			0.3	3.6	-3.7	**0.3**	**3.6**	**-3.7**
22-Dec-98						-6.5			-6.8	-0.9	-11.6	**-6.8**	**-0.9**	**-11.6**
23-Dec-98						-10.1			-9.8	-6.4	-13.5	**-9.8**	**-6.4**	**-13.5**
24-Dec-98						-7.5			-7.8	-5.4	-10.4	**-7.8**	**-5.4**	**-10.4**
25-Dec-98						-5.9			-5.6	-2.3	-9.4	**-5.6**	**-2.3**	**-9.4**
26-Dec-98						-4.1			-3.0	-0.4	-7.2	**-3.0**	**-0.4**	**-7.2**
27-Dec-98						-2.8			-3.2	3.2	-12.2	**-3.2**	**3.2**	**-12.2**
28-Dec-98						0.8			0.1	3.3	-6.0	**0.1**	**3.3**	**-6.0**
29-Dec-98						-3.9			-1.9	2.4	-10.4	**-1.9**	**2.4**	**-10.4**

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	Calc Daily (from hr)	Daily Values	Processed (Daily if avail or Calc daily)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min
30-Dec-98						-13.4			-14.4	-11.3	-18.7	**-14.4**	**-11.3**	**-18.7**
31-Dec-98						-8.3			-10.9	-6.4	-15.6	**-10.9**	**-6.4**	**-15.6**
01-Jan-99						-13.3			-15.0	-9.6	-17.7	**-15.0**	**-9.6**	**-17.7**
02-Jan-99						-10.2			-14.5	-10.1	-18.4	**-14.5**	**-10.1**	**-18.4**
03-Jan-99						-5.1			-5.8	0.8	-9.6	**-5.8**	**0.8**	**-9.6**
04-Jan-99						-10.6			-10.4	-8.5	-12.0	**-10.4**	**-8.5**	**-12.0**
05-Jan-99						-11.3			-11.1	-7.3	-14.2	**-11.1**	**-7.3**	**-14.2**
06-Jan-99						-8.3			-8.6	-3.9	-13.6	**-8.6**	**-3.9**	**-13.6**
07-Jan-99						-11.5			-11.4	-9.5	-13.7	**-11.4**	**-9.5**	**-13.7**
08-Jan-99						-11.7			-11.9	-7.4	-20.5	**-11.9**	**-7.4**	**-20.5**
09-Jan-99						-9.5			-8.6	-5.6	-12.6	**-8.6**	**-5.6**	**-12.6**
10-Jan-99						-12.4			-15.7	-8.8	-25.2	**-15.7**	**-8.8**	**-25.2**
11-Jan-99						-12.5			-13.8	-12.5	-18.1	**-13.8**	**-12.5**	**-18.1**
12-Jan-99						-7.6			-8.5	-5.2	-12.0	**-8.5**	**-5.2**	**-12.0**
13-Jan-99						-16.3			-17.2	-11.0	-24.0	**-17.2**	**-11.0**	**-24.0**
14-Jan-99						-18.2			-20.9	-13.4	-26.6	**-20.9**	**-13.4**	**-26.6**
15-Jan-99						-11.6			-12.1	-8.4	-14.8	**-12.1**	**-8.4**	**-14.8**
16-Jan-99						-5.1			-3.6	2.1	-14.5	**-3.6**	**2.1**	**-14.5**
17-Jan-99						-1.3			-1.0	2.5	-5.3	**-1.0**	**2.5**	**-5.3**
18-Jan-99						2.9			2.0	4.5	0.4	**2.0**	**4.5**	**0.4**
19-Jan-99						0.0			0.0	0.7	-0.8	**0**	**0.7**	**-0.8**
20-Jan-99						-1.3			-1.3	1.6	-6.7	**-1.3**	**1.6**	**-6.7**
21-Jan-99						-0.5			-1.6	3.1	-8.4	**-1.6**	**3.1**	**-8.4**
22-Jan-99						1.3			0.4	2.6	-1.4	**0.4**	**2.6**	**-1.4**
23-Jan-99						5.9			4.7	8.5	2.6	**4.7**	**8.5**	**2.6**
24-Jan-99						3.5			2.0	6.7	-0.6	**2.0**	**6.7**	**-0.6**

Date	Temperature Gauge													
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25-Jan-99						-2.1			-2.1	-0.7	-6.0	**-2.1**	**-0.7**	**-6.0**
26-Jan-99						-2.3			-1.5	0.2	-3.6	**-1.5**	**0.2**	**-3.6**
27-Jan-99						-3.3			-3.4	-0.6	-9.7	**-3.4**	**-0.6**	**-9.7**
28-Jan-99						-5.2			-5.8	-2.2	-8.5	**-5.8**	**-2.2**	**-8.5**
29-Jan-99						-5.1			-7.2	-3.3	-13.2	**-7.2**	**-3.3**	**-13.2**
30-Jan-99						-3.2			-3.1	-0.8	-8.8	**-3.1**	**-0.8**	**-8.8**
31-Jan-99						-5.4			-7.1	-2.8	-10.9	**-7.1**	**-2.8**	**-10.9**
01-Feb-99						-4.2			-5.6	0.4	-13.6	**-5.6**	**0.4**	**-13.6**
02-Feb-99						2.5			1.5	4.0	-0.5	**1.5**	**4.0**	**-0.5**
03-Feb-99						2.7			2.1	5.3	-0.8	**2.1**	**5.3**	**-0.8**
04-Feb-99						-0.4			1.0	3.9	-4.1	**1.0**	**3.9**	**-4.1**
05-Feb-99						-4.1			-5.0	-2.6	-7.7	**-5.0**	**-2.6**	**-7.7**
06-Feb-99						0.9			0.4	2.9	-2.1	**0.4**	**2.9**	**-2.1**
07-Feb-99						-2.3			-1.7	0.1	-5.8	**-1.7**	**0.1**	**-5.8**
08-Feb-99						-4.3			-4.7	-1.0	-9.9	**-4.7**	**-1.0**	**-9.9**
09-Feb-99						3.1			3.1	7.4	-0.8	**3.1**	**7.4**	**-0.8**
10-Feb-99						1.4			0.7	3.4	-2.6	**0.7**	**3.4**	**-2.6**
11-Feb-99						2.5			1.5	4.8	-2.6	**1.5**	**4.8**	**-2.6**
12-Feb-99						4.9			1.6	12.7	-5.6	**1.6**	**12.7**	**-5.6**
13-Feb-99						-5.7			-6.4	-3.3	-9.4	**-6.4**	**-3.3**	**-9.4**
14-Feb-99						-5.2			-6.8	-0.4	-15.8	**-6.8**	**-0.4**	**-15.8**
15-Feb-99						1.3			0.0	5.3	-3.8	**0.0**	**5.3**	**-3.8**
16-Feb-99						3.3			1.1	5.4	-3.1	**1.1**	**5.4**	**-3.1**
17-Feb-99						2.3			1.6	4.2	-0.1	**1.6**	**4.2**	**-0.1**
18-Feb-99						-2.6			-1.7	0.1	-5.8	**-1.7**	**0.1**	**-5.8**
19-Feb-99						-5.8			-6.5	-4.2	-9.1	**-6.5**	**-4.2**	**-9.1**

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	Stouffville					**Pearson**			**Buttonville**			**Selected Temperatures in Analysis**		
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20-Feb-99						-5.5			-6.5	-2.6	-9.9	**-6.5**	**-2.6**	**-9.9**
21-Feb-99						-9.0			-9.1	-6.7	-12.6	**-9.1**	**-6.7**	**-12.6**
22-Feb-99						-11.0			-12.2	-6.7	-17.1	**-12.2**	**-6.7**	**-17.1**
23-Feb-99						-8.7			-9.4	-4.7	-14.7	**-9.4**	**-4.7**	**-14.7**
24-Feb-99						-4.2			-5.3	-1.0	-9.8	**-5.3**	**-1.0**	**-9.8**
25-Feb-99						-0.4			-1.4	2.8	-4.6	**-1.4**	**2.8**	**-4.6**
26-Feb-99						0.4			-0.6	5.2	-5.5	**-0.6**	**5.2**	**-5.5**
27-Feb-99						0.3			-1.3	3.1	-7.0	**-1.3**	**3.1**	**-7.0**
28-Feb-99						3.7			2.9	5.5	1.0	**2.9**	**5.5**	**1.0**
01-Mar-99						1.0			0.4	2.2	-2.2	**0.4**	**2.2**	**-2.2**
02-Mar-99						0.3			-0.4	4.4	-4.7	**-0.4**	**4.4**	**-4.7**
03-Mar-99						-1.2			-0.6	0.5	-3.0	**-0.6**	**0.5**	**-3.0**
04-Mar-99						-4.3			-5.1	-3.6	-6.3	**-5.1**	**-3.6**	**-6.3**
05-Mar-99						-6.5			-7.2	-4.0	-11.2	**-7.2**	**-4.0**	**-11.2**
06-Mar-99						-9.5			-9.9	-6.8	-12.2	**-9.9**	**-6.8**	**-12.2**
07-Mar-99						-11.9			-12.2	-8.0	-16.4	**-12.2**	**-8.0**	**-16.4**
08-Mar-99						-9.7			-9.9	-3.3	-18.0	**-9.9**	**-3.3**	**-18.0**
09-Mar-99						-6.8			-6.7	-4.2	-11.7	**-6.7**	**-4.2**	**-11.7**
10-Mar-99						-6.2			-6.1	-2.7	-12.0	**-6.1**	**-2.7**	**-12.0**
11-Mar-99						-3.4			-3.0	0.2	-6.0	**-3.0**	**0.2**	**-6.0**
12-Mar-99						-3.7			-3.9	-1.4	-7.4	**-3.9**	**-1.4**	**-7.4**
13-Mar-99						-2.5			-2.8	1.5	-6.5	**-2.8**	**1.5**	**-6.5**
14-Mar-99						-0.5			-1.8	3.0	-6.3	**-1.8**	**3.0**	**-6.3**
15-Mar-99						-0.5			-1.3	3.9	-6.3	**-1.3**	**3.9**	**-6.3**
16-Mar-99						2.8			3.0	8.7	-3.2	**3.0**	**8.7**	**-3.2**
17-Mar-99						6.3			6.0	12.1	-1.9	**6.0**	**12.1**	**-1.9**

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18-Mar-99						4.0			4.3	10.4	-0.4	**4.3**	**10.4**	**-0.4**
19-Mar-99						1.3			-0.6	3.0	-2.4	**-0.6**	**3.0**	**-2.4**
20-Mar-99						1.5			0.5	5.9	-5.2	**0.5**	**5.9**	**-5.2**
21-Mar-99						4.6			3.3	8.4	-0.1	**3.3**	**8.4**	**-0.1**
22-Mar-99						0.9			0.7	2.1	-0.8	**0.7**	**2.1**	**-0.8**
23-Mar-99						2.2			1.7	7.2	-2.7	**1.7**	**7.2**	**-2.7**
24-Mar-99						3.3			1.9	6.8	-1.9	**1.9**	**6.8**	**-1.9**
25-Mar-99						0.0			-1.4	2.5	-4.9	**-1.4**	**2.5**	**-4.9**
26-Mar-99						1.8			1.5	8.0	-3.8	**1.5**	**8.0**	**-3.8**
27-Mar-99						4.4			3.4	12.2	-4.6	**3.4**	**12.2**	**-4.6**
28-Mar-99						8.6			7.6	16.4	-0.1	**7.6**	**16.4**	**-0.1**
29-Mar-99						8.9			8.4	13.8	1.5	**8.4**	**13.8**	**1.5**
30-Mar-99						8.8			8.8	15.9	2.3	**8.8**	**15.9**	**2.3**
31-Mar-99						13.9			13.5	21.2	2.5	**13.5**	**21.2**	**2.5**
01-Apr-99	11.1	11.1	11.1	15.9	5.7	13.1			12.8	16.0	7.1	**11.1**	**15.9**	**5.7**
02-Apr-99	6.8	6.5	6.5	11.4	4.4	8.1			6.4	11.4	4.6	**6.5**	**11.4**	**4.4**
03-Apr-99	9.6	9.9	9.9	18.4	3.1	10.3			10.2	20.4	4.1	**9.9**	**18.4**	**3.1**
04-Apr-99	4.7	4.1	4.1	13.0	0.8	6.8			4.8	12.2	0.9	**4.1**	**13.0**	**0.8**
05-Apr-99	3.5	3.6	3.6	9.0	-1.9	3.7			3.0	7.8	-2.2	**3.6**	**9.0**	**-1.9**
06-Apr-99	7.4	7.6	7.6	12.4	3.3	8.9			7.7	13.2	3.5	**7.6**	**12.4**	**3.3**
07-Apr-99	9.1	9.1	9.1	15.7	4.7	10.9			10.2	16.6	5.4	**9.1**	**15.7**	**4.7**
08-Apr-99	9.1	9.0	9.0	14.1	3.8	11.1			9.8	16.4	3.6	**9.0**	**14.1**	**3.8**
09-Apr-99	5.7	5.6	5.6	9.1	3.5	6.0			5.8	10.1	3.6	**5.6**	**9.1**	**3.5**
10-Apr-99	3.6	3.5	3.5	9.2	-0.8	4.5			4.3	9.6	-1.2	**3.5**	**9.2**	**-0.8**
11-Apr-99	2.5	2.6	2.6	7.0	0.0	3.1			2.4	6.1	0.2	**2.6**	**7.0**	**0**
12-Apr-99	4.2	4.2	4.2	8.6	-0.1	4.8			4.7	9.6	0.2	**4.2**	**8.6**	**-0.1**

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13-Apr-99	5.0	5.0	5.0	10.7	-0.4	#N/A			6.0	11.9	-0.2	**5.0**	**10.7**	**-0.4**
14-Apr-99	7.9	8.0	8.0	14.1	2.2	10.3			9.1	15.4	2.8	**8.0**	**14.1**	**2.2**
15-Apr-99	8.8	8.9	8.9	14.4	1.7	8.4			8.2	14.7	0.0	**8.9**	**14.4**	**1.7**
16-Apr-99	5.0	4.9	4.9	6.8	3.9	5.9			5.4	7.4	4.1	**4.9**	**6.8**	**3.9**
17-Apr-99	6.5	6.5	6.5	10.9	3.4	7.4			7.3	12.2	3.7	**6.5**	**10.9**	**3.4**
18-Apr-99	7.3	7.3	7.3	11.6	2.6	7.6			7.9	12.8	1.9	**7.3**	**11.6**	**2.6**
19-Apr-99	6.3	6.3	6.3	11.0	2.9	7.9			6.9	11.0	4.4	**6.3**	**11.0**	**2.9**
20-Apr-99	7.2	7.1	7.1	11.6	2.8	7.7			7.5	12.0	2.9	**7.1**	**11.6**	**2.8**
21-Apr-99	8.6	8.8	8.8	15.3	1.7	9.5			8.4	14.6	0.9	**8.8**	**15.3**	**1.7**
22-Apr-99	9.6	9.6	9.6	13.5	7.4	9.5			9.2	13.1	7.2	**9.6**	**13.5**	**7.4**
23-Apr-99	6.9	6.6	6.6	10.9	3.0	6.5			7.1	11.3	3.2	**6.6**	**10.9**	**3.0**
24-Apr-99	3.9	3.9	3.9	9.6	-0.9	5.4			4.4	11.0	-1.2	**3.9**	**9.6**	**-0.9**
25-Apr-99	8.6	8.8	8.8	17.0	-2.1	8.4			9.7	17.3	-1.7	**8.8**	**17.0**	**-2.1**
26-Apr-99	10.9	10.9	10.9	14.6	6.3	11.2			11.6	15.8	6.6	**10.9**	**14.6**	**6.3**
27-Apr-99	6.8	6.7	6.7	12.6	1.4	5.8			7.2	12.2	0.7	**6.7**	**12.6**	**1.4**
28-Apr-99	9.5	9.6	9.6	14.7	3.8	9.9			8.9	13.9	3.1	**9.6**	**14.7**	**3.8**
29-Apr-99	12.1	12.3	12.3	18.8	4.5	10.5			11.8	18.2	3.6	**12.3**	**18.8**	**4.5**
30-Apr-99	13.4	13.4	13.4	20.6	7.1	12.7			13.7	21.5	5.6	**13.4**	**20.6**	**7.1**
01-May-99	13.9	13.9	13.9	22.4	4.4	13.7			13.6	21.9	2.2	**13.9**	**22.4**	**4.4**
02-May-99	16.2	16.3	16.3	24.3	7.0	15.8			16.3	23.5	7.9	**16.3**	**24.3**	**7.0**
03-May-99	17.4	17.4	17.4	24.1	10.5	16.4			16.6	23.9	7.6	**17.4**	**24.1**	**10.5**
04-May-99	17.7	17.7	17.7	24.8	10.8	17.6			17.4	24.3	9.1	**17.7**	**24.8**	**10.8**
05-May-99	18.3	18.5	18.5	24.1	12.0	17.6			17.6	23.2	10.8	**18.5**	**24.1**	**12.0**
06-May-99	19.2	19.0	19.0	23.8	13.7	19.3			18.8	23.6	13.9	**19.0**	**23.8**	**13.7**
07-May-99	16.5	16.5	16.5	23.2	12.3	18.5			17.4	24.6	12.7	**16.5**	**23.2**	**12.3**
08-May-99	13.8	13.8	13.8	15.6	11.4	14.8			14.5	16.5	12.3	**13.8**	**15.6**	**11.4**

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09-May-99	11.2	11.0	11.0	15.1	5.8	10.3			12.3	16.4	6.5	**11.0**	**15.1**	**5.8**
10-May-99	10.4	10.5	10.5	16.9	3.5	11.1			11.1	18.7	2.3	**10.5**	**16.9**	**3.5**
11-May-99	11.2	11.1	11.1	16.3	7.1	10.5			10.9	14.8	5.9	**11.1**	**16.3**	**7.1**
12-May-99	10.9	10.9	10.9	17.0	6.7	11.1			10.9	17.8	4.1	**10.9**	**17.0**	**6.7**
13-May-99	9.7	9.6	9.6	16.1	4.4	9.6			9.9	15.8	2.8	**9.6**	**16.1**	**4.4**
14-May-99	13.6	13.9	13.9	21.2	4.9	12.2			13.1	19.3	4.3	**13.9**	**21.2**	**4.9**
15-May-99	15.5	15.5	15.5	22.0	8.8	15.5			15.0	20.8	8.0	**15.5**	**22.0**	**8.8**
16-May-99	16.2	16.3	16.3	22.8	10.0	16.4			16.2	22.4	9.0	**16.3**	**22.8**	**10.0**
17-May-99	17.4	17.5	17.5	24.0	10.5	18.5			17.3	23.8	9.5	**17.5**	**24.0**	**10.5**
18-May-99	19.2	19.2	19.2	27.0	14.5	21.4			21.2	28.2	15.5	**19.2**	**27.0**	**14.5**
19-May-99	12.6	12.3	12.3	16.2	7.9	13.6			14.1	18.4	8.1	**12.3**	**16.2**	**7.9**
20-May-99	12.7	12.8	12.8	20.1	4.4	13.7			14.3	22.0	4.9	**12.8**	**20.1**	**4.4**
21-May-99	15.5	15.6	15.6	22.9	8.8	16.6			16.4	23.4	9.1	**15.6**	**22.9**	**8.8**
22-May-99	16.9	17.0	17.0	23.3	11.6	17.8			17.7	24.0	12.2	**17.0**	**23.3**	**11.6**
23-May-99	15.0	14.9	14.9	18.9	12.2	15.0			16.0	18.6	12.8	**14.9**	**18.9**	**12.2**
24-May-99	12.6	12.4	12.4	13.9	9.4	12.5			13.6	15.5	10.5	**12.4**	**13.9**	**9.4**
25-May-99	8.2	8.1	8.1	9.6	7.0	9.6			9.4	10.7	8.4	**8.1**	**9.6**	**7.0**
26-May-99	10.5	10.4	10.4	14.1	8.2	10.5			11.5	14.6	8.0	**10.4**	**14.1**	**8.2**
27-May-99	14.1	14.2	14.2	21.5	5.3	14.7			16.1	23.4	5.5	**14.2**	**21.5**	**5.3**
28-May-99	19.6	19.7	19.7	27.3	9.6	20.1			21.7	30.6	10.6	**19.7**	**27.3**	**9.6**
29-May-99	20.3	20.3	20.3	28.9	12.0	20.7			21.6	30.4	10.1	**20.3**	**28.9**	**12.0**
30-May-99	21.7	21.7	21.7	30.5	13.3	24.2			23.7	32.0	13.6	**21.7**	**30.5**	**13.3**
31-May-99	19.8	19.8	19.8	26.0	13.5	20.6			21.5	27.4	13.1	**19.8**	**26.0**	**13.5**
01-Jun-99	19.0	19.0	19.0	23.0	17.0	21.4			21.1	25.4	18.5	**19.0**	**23.0**	**17.0**
02-Jun-99	19.0	18.9	18.9	21.5	17.0	20.9			20.9	24.0	18.8	**18.9**	**21.5**	**17.0**
03-Jun-99	14.6	14.4	14.4	17.0	10.4	14.6			15.9	19.0	11.0	**14.4**	**17.0**	**10.4**

Date	Temperature Gauge													
	Stouffville					Pearson			Buttonville			Selected Temperatures in Analysis		
	Calc Daily (from hr)	Daily Values	Processed (Daily if avail or Calc daily)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min
04-Jun-99	15.4	15.4	15.4	22.7	9.5	15.1			16.4	22.3	9.7	**15.4**	**22.7**	**9.5**
05-Jun-99	16.4	16.5	16.5	23.8	10.1	17.9			17.0	25.6	10.8	**16.5**	**23.8**	**10.1**
06-Jun-99	22.7	22.9	22.9	31.3	13.7	23.2			25.3	34.0	13.9	**22.9**	**31.3**	**13.7**
07-Jun-99	25.3	25.4	25.4	32.9	19.5	27.5			28.8	34.9	23.0	**25.4**	**32.9**	**19.5**
08-Jun-99	22.7	22.5	22.5	26.6	18.8	23.4			24.4	28.2	19.6	**22.5**	**26.6**	**18.8**
09-Jun-99	20.3	20.2	20.2	28.1	15.0	20.9			20.4	26.7	14.8	**20.2**	**28.1**	**15.0**
10-Jun-99	21.0	21.1	21.1	26.3	15.0	22.3			20.7	25.4	16.0	**21.1**	**26.3**	**15.0**
11-Jun-99	22.1	22.1	22.1	27.0	17.0	23.0			23.1	26.8	18.2	**22.1**	**27.0**	**17.0**
12-Jun-99	22.7	22.7	22.7	28.5	17.9	23.7			23.2	28.0	18.5	**22.7**	**28.5**	**17.9**
13-Jun-99	22.0	22.0	22.0	28.4	15.7	23.7			22.1	27.6	15.4	**22.0**	**28.4**	**15.7**
14-Jun-99	17.8	17.7	17.7	19.6	14.2	16.7			18.3	20.7	13.5	**17.7**	**19.6**	**14.2**
15-Jun-99	11.7	11.5	11.5	15.2	7.3	12.3			11.6	15.1	6.8	**11.5**	**15.2**	**7.3**
16-Jun-99	12.5	12.6	12.6	17.5	6.9	13.0			12.3	16.5	5.8	**12.6**	**17.5**	**6.9**
17-Jun-99	13.5	13.5	13.5	17.7	9.5	14.9			13.4	18.4	9.1	**13.5**	**17.7**	**9.5**
18-Jun-99	15.9	15.9	15.9	22.5	8.2	15.8			15.8	23.5	6.4	**15.9**	**22.5**	**8.2**
19-Jun-99	17.2	17.3	17.3	24.7	9.2	17.9			17.3	23.7	8.1	**17.3**	**24.7**	**9.2**
20-Jun-99	19.1	19.1	19.1	25.9	12.6	20.8			19.0	25.0	12.6	**19.1**	**25.9**	**12.6**
21-Jun-99	20.4	20.4	20.4	27.2	12.7	20.7			19.9	26.0	11.8	**20.4**	**27.2**	**12.7**
22-Jun-99	20.7	20.8	20.8	27.8	13.1	21.3			20.2	26.8	11.4	**20.8**	**27.8**	**13.1**
23-Jun-99	21.4	21.4	21.4	29.4	14.2	23.2			21.2	28.0	13.2	**21.4**	**29.4**	**14.2**
24-Jun-99	20.9	21.0	21.0	28.6	16.0	23.6			21.4	27.2	15.4	**21.0**	**28.6**	**16.0**
25-Jun-99	22.4	22.4	22.4	28.6	17.4	24.7			23.4	28.6	17.9	**22.4**	**28.6**	**17.4**
26-Jun-99	23.7	23.7	23.7	30.8	16.3	24.4			24.0	29.9	14.8	**23.7**	**30.8**	**16.3**
27-Jun-99	20.7	20.8	20.8	24.7	17.3	23.4			20.5	24.1	16.5	**20.8**	**24.7**	**17.3**
28-Jun-99	22.8	22.8	22.8	27.9	20.0	25.4			23.2	28.2	20.3	**22.8**	**27.9**	**20.0**
29-Jun-99	18.7	18.4	18.4	20.8	11.1	17.7			19.5	22.2	13.0	**18.4**	**20.8**	**11.1**

Date	Temperature Gauge													
	Stouffville					Pearson			Buttonville			Selected Temperatures in Analysis		
	Calc Daily (from hr)	Daily Values	Processed (Daily if avail or Calc daily)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min
30-Jun-99	16.2	16.1	16.1	22.5	11.4	17.1			15.6	20.8	10.0	**16.1**	**22.5**	**11.4**
01-Jul-99	18.4	18.6	18.6	23.3	11.5	19.1			18.2	24.0	11.1	**18.6**	**23.3**	**11.5**
02-Jul-99	21.2	21.3	21.3	26.9	16.4	23.8			22.0	27.0	17.8	**21.3**	**26.9**	**16.4**
03-Jul-99	22.2	22.3	22.3	28.6	16.6	23.6			22.7	28.2	16.3	**22.3**	**28.6**	**16.6**
04-Jul-99	26.8	27.0	27.0	32.2	20.3	29.5			27.9	32.9	21.2	**27.0**	**32.2**	**20.3**
05-Jul-99	28.2	28.1	28.1	32.6	23.7	30.4			29.4	33.5	25.3	**28.1**	**32.6**	**23.7**
06-Jul-99	25.0	24.8	24.8	29.0	19.5	26.1			26.3	30.5	20.0	**24.8**	**29.0**	**19.5**
07-Jul-99	20.8	20.6	20.6	26.2	15.1	22.6			21.5	27.3	15.6	**20.6**	**26.2**	**15.1**
08-Jul-99	18.3	18.3	18.3	23.1	13.7	19.5			19.5	24.6	13.9	**18.3**	**23.1**	**13.7**
09-Jul-99	16.9	16.9	16.9	23.5	13.7	21.7			17.2	25.3	13.3	**16.9**	**23.5**	**13.7**
10-Jul-99	17.0	16.7	16.7	20.0	13.5	18.7			17.2	20.8	13.9	**16.7**	**20.0**	**13.5**
11-Jul-99	17.5	17.6	17.6	24.6	11.1	18.5			18.3	24.4	10.9	**17.6**	**24.6**	**11.1**
12-Jul-99	19.0	19.0	19.0	25.9	12.6	20.6			18.9	25.6	11.0	**19.0**	**25.9**	**12.6**
13-Jul-99	19.6	19.6	19.6	27.3	12.8	21.8			20.0	26.9	11.7	**19.6**	**27.3**	**12.8**
14-Jul-99	20.5	20.6	20.6	28.1	14.0	22.7			21.4	28.0	12.9	**20.6**	**28.1**	**14.0**
15-Jul-99	23.7	24.0	24.0	31.0	16.5	27.0			25.1	32.2	15.6	**24.0**	**31.0**	**16.5**
16-Jul-99	25.5	25.5	25.5	32.0	19.1	27.9			27.7	33.2	20.5	**25.5**	**32.0**	**19.1**
17-Jul-99	24.4	24.4	24.4	32.7	19.1	28.4			26.5	34.5	19.7	**24.4**	**32.7**	**19.1**
18-Jul-99	23.8	23.7	23.7	30.3	18.9	26.3			24.2	30.4	19.2	**23.7**	**30.3**	**18.9**
19-Jul-99	20.5	20.5	20.5	23.8	18.1	20.9			20.5	23.8	18.1	**20.5**	**23.8**	**18.1**
20-Jul-99	21.2	21.1	21.1	26.2	17.0	21.2			21.0	24.9	16.2	**21.1**	**26.2**	**17.0**
21-Jul-99	20.0	19.9	19.9	26.3	14.2	22.9			20.2	25.6	13.5	**19.9**	**26.3**	**14.2**
22-Jul-99	23.7	23.8	23.8	31.3	15.0	25.2			24.1	32.0	14.5	**23.8**	**31.3**	**15.0**
23-Jul-99	25.2	25.2	25.2	31.5	18.0	27.8			26.6	32.0	19.4	**25.2**	**31.5**	**18.0**
24-Jul-99	23.9	23.7	23.7	32.4	17.7	27.3			25.8	34.0	19.4	**23.7**	**32.4**	**17.7**
25-Jul-99	22.9	23.1	23.1	28.0	17.3	25.9			23.9	29.4	18.6	**23.1**	**28.0**	**17.3**

Date	Temperature Gauge													
	Stouffville					**Pearson**			**Buttonville**			**Selected Temperatures in Analysis**		
	Calc Daily (from hr)	Daily Values	Processed (Daily if avail or Calc daily)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min
26-Jul-99	24.1	24.1	24.1	29.4	19.4	26.2			24.7	31.0	19.3	**24.1**	**29.4**	**19.4**
27-Jul-99	24.1	23.9	23.9	30.2	18.9	25.9			25.0	31.6	20.0	**23.9**	**30.2**	**18.9**
28-Jul-99	21.6	21.6	21.6	28.9	14.3	23.5			23.4	30.0	14.4	**21.6**	**28.9**	**14.3**
29-Jul-99	23.1	23.1	23.1	29.6	17.6	25.3			24.8	30.6	18.7	**23.1**	**29.6**	**17.6**
30-Jul-99	25.2	25.3	25.3	32.3	18.9	28.6			26.7	33.4	19.1	**25.3**	**32.3**	**18.9**
31-Jul-99	21.3	21.2	21.2	24.5	18.6	24.8			22.0	25.6	18.3	**21.2**	**24.5**	**18.6**
01-Aug-99	21.7	21.6	21.6	25.4	17.9	22.9			22.2	25.8	18.2	**21.6**	**25.4**	**17.9**
02-Aug-99	19.0	18.8	18.8	23.3	14.6	20.8			19.5	24.4	14.4	**18.8**	**23.3**	**14.6**
03-Aug-99	18.8	18.9	18.9	25.8	12.6	20.8			19.6	25.4	13.6	**18.9**	**25.8**	**12.6**
04-Aug-99	17.2	17.1	17.1	20.2	15.4	19.9			17.5	21.6	14.7	**17.1**	**20.2**	**15.4**
05-Aug-99	17.9	17.8	17.8	22.8	13.2	19.3			18.0	23.4	13.1	**17.8**	**22.8**	**13.2**
06-Aug-99	15.5	15.6	15.6	22.1	9.4	19.2			16.4	23.4	11.1	**15.6**	**22.1**	**9.4**
07-Aug-99	16.9	17.0	17.0	23.0	11.2	18.1			17.1	22.3	10.1	**17.0**	**23.0**	**11.2**
08-Aug-99	18.1	18.0	18.0	22.6	14.0	19.3			18.4	23.0	13.4	**18.0**	**22.6**	**14.0**
09-Aug-99	15.0	14.9	14.9	20.1	8.4	16.8			15.5	21.2	9.4	**14.9**	**20.1**	**8.4**
10-Aug-99	13.9	14.1	14.1	15.7	12.0	16.6			14.3	16.0	12.7	**14.1**	**15.7**	**12.0**
11-Aug-99	18.8	18.8	18.8	23.7	15.7	21.2			19.3	25.0	15.8	**18.8**	**23.7**	**15.7**
12-Aug-99	20.7	20.8	20.8	27.4	14.3	22.4			21.7	27.6	14.2	**20.8**	**27.4**	**14.3**
13-Aug-99	21.0	21.0	21.0	25.3	18.0	23.7			22.3	26.7	19.2	**21.0**	**25.3**	**18.0**
14-Aug-99	17.6	17.3	17.3	22.4	14.8	19.2			17.5	22.4	14.2	**17.3**	**22.4**	**14.8**
15-Aug-99	17.8	17.7	17.7	23.5	13.0	19.5			17.7	23.7	11.6	**17.7**	**23.5**	**13.0**
16-Aug-99	17.6	17.8	17.8	22.8	12.3	20.0			18.7	23.2	11.3	**17.8**	**22.8**	**12.3**
17-Aug-99	20.8	20.8	20.8	27.4	16.2	23.9			22.2	27.5	17.7	**20.8**	**27.4**	**16.2**
18-Aug-99	18.7	18.6	18.6	23.4	15.6	19.9			18.6	23.8	14.4	**18.6**	**23.4**	**15.6**
19-Aug-99	18.8	18.9	18.9	22.6	14.9	19.1			18.5	22.4	14.1	**18.9**	**22.6**	**14.9**
20-Aug-99	17.1	17.0	17.0	18.6	16.1	17.8			17.0	18.2	15.9	**17.0**	**18.6**	**16.1**

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	Stouffville					**Pearson**			**Buttonville**			**Selected Temperatures in Analysis**		
	Calc Daily (from hr)	Daily Values	Processed (Daily if avail or Calc daily)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min
21-Aug-99	18.8	18.8	18.8	23.3	15.7	20.1			18.6	22.9	15.7	**18.8**	**23.3**	**15.7**
22-Aug-99	19.9	19.9	19.9	27.0	14.9	20.8			19.7	25.2	13.7	**19.9**	**27.0**	**14.9**
23-Aug-99	19.8	19.8	19.8	27.3	13.7	21.6			20.2	26.8	13.4	**19.8**	**27.3**	**13.7**
24-Aug-99	21.8	21.9	21.9	27.4	16.1	23.1			21.5	25.5	15.8	**21.9**	**27.4**	**16.1**
25-Aug-99	21.0	21.0	21.0	25.0	17.9	22.6			21.1	24.1	17.6	**21.0**	**25.0**	**17.9**
26-Aug-99	21.6	21.7	21.7	26.8	18.5	23.4			21.3	25.7	19.0	**21.7**	**26.8**	**18.5**
27-Aug-99	21.7	21.6	21.6	28.5	17.1	23.3			22.3	28.9	16.8	**21.6**	**28.5**	**17.1**
28-Aug-99	22.7	22.7	22.7	29.8	16.1	24.6			24.1	31.2	18.5	**22.7**	**29.8**	**16.1**
29-Aug-99	15.6	15.4	15.4	18.6	12.3	16.5			15.7	19.6	10.8	**15.4**	**18.6**	**12.3**
30-Aug-99	13.9	13.9	13.9	21.0	8.7	14.7			14.4	21.1	8.9	**13.9**	**21.0**	**8.7**
31-Aug-99	15.9	15.9	15.9	24.5	9.2	17.1			16.0	23.0	8.6	**15.9**	**24.5**	**9.2**
01-Sep-99	17.7	17.8	17.8	28.0	10.0	19.3			18.3	27.1	9.1	**17.8**	**28.0**	**10.0**
02-Sep-99	20.5	20.7	20.7	30.3	11.8	22.1			20.5	30.2	10.6	**20.7**	**30.3**	**11.8**
03-Sep-99	22.9	22.8	22.8	31.2	16.3	23.6			22.5	31.9	13.1	**22.8**	**31.2**	**16.3**
04-Sep-99	22.8	22.8	22.8	30.7	17.0	24.1			23.0	28.8	16.6	**22.8**	**30.7**	**17.0**
05-Sep-99	21.9	21.9	21.9	25.9	19.0	24.1			22.0	25.8	18.8	**21.9**	**25.9**	**19.0**
06-Sep-99	22.2	22.1	22.1	27.3	18.8	23.7			22.5	26.9	18.9	**22.1**	**27.3**	**18.8**
07-Sep-99	20.4	20.5	20.5	22.9	18.6	21.8			20.5	23.4	18.1	**20.5**	**22.9**	**18.6**
08-Sep-99	20.8	20.7	20.7	26.3	17.2	23.4			22.3	26.5	18.8	**20.7**	**26.3**	**17.2**
09-Sep-99	19.0	18.9	18.9	24.1	16.1	20.8			20.5	23.8	16.0	**18.9**	**24.1**	**16.1**
10-Sep-99	16.0	15.8	15.8	20.6	12.1	17.4			16.4	20.4	11.6	**15.8**	**20.6**	**12.1**
11-Sep-99	15.7	15.6	15.6	20.7	11.6	17.3			16.9	21.8	10.6	**15.6**	**20.7**	**11.6**
12-Sep-99	16.1	16.3	16.3	24.0	8.5	17.9			15.9	22.2	7.1	**16.3**	**24.0**	**8.5**
13-Sep-99	17.5	17.4	17.4	18.6	16.5	19.3			18.9	20.8	17.3	**17.4**	**18.6**	**16.5**
14-Sep-99	15.8	15.6	15.6	21.6	10.4	16.7			16.5	21.4	10.4	**15.6**	**21.6**	**10.4**
15-Sep-99	13.7	13.9	13.9	21.1	7.5	15.4			14.5	20.5	7.2	**13.9**	**21.1**	**7.5**

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	Calc Daily (from hr)	Daily Values	Processed (Daily if avail or Calc daily)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min
16-Sep-99	14.7	14.5	14.5	17.9	12.5	15.7			14.6	18.2	11.8	**14.5**	**17.9**	**12.5**
17-Sep-99	14.0	14.0	14.0	19.1	9.9	15.9			14.3	19.7	9.6	**14.0**	**19.1**	**9.9**
18-Sep-99	15.1	15.0	15.0	21.9	10.2	15.9			14.8	21.8	7.6	**15.0**	**21.9**	**10.2**
19-Sep-99	15.4	15.4	15.4	23.8	9.4	17.3			15.5	23.6	7.3	**15.4**	**23.8**	**9.4**
20-Sep-99	12.8	12.6	12.6	17.2	8.5	13.6			12.5	18.6	8.9	**12.6**	**17.2**	**8.5**
21-Sep-99	7.9	7.8	7.8	11.9	4.9	9.9			8.3	13.3	4.2	**7.8**	**11.9**	**4.9**
22-Sep-99	9.2	9.3	9.3	17.0	2.1	10.6			9.6	17.8	1.6	**9.3**	**17.0**	**2.1**
23-Sep-99	13.4	13.7	13.7	21.5	6.0	18.1			15.9	24.4	6.9	**13.7**	**21.5**	**6.0**
24-Sep-99	13.1	12.9	12.9	16.4	9.2	15.2			13.3	17.5	9.9	**12.9**	**16.4**	**9.2**
25-Sep-99	11.0	10.9	10.9	17.1	7.5	12.5			11.1	16.2	6.3	**10.9**	**17.1**	**7.5**
26-Sep-99	13.6	13.8	13.8	21.4	7.3	14.7			12.6	19.2	5.7	**13.8**	**21.4**	**7.3**
27-Sep-99	17.3	17.4	17.4	23.7	12.8	18.4			17.8	23.3	11.0	**17.4**	**23.7**	**12.8**
28-Sep-99	19.8	19.8	19.8	26.3	15.8	21.8			20.0	25.1	14.9	**19.8**	**26.3**	**15.8**
29-Sep-99	17.5	17.3	17.3	19.7	11.7	16.6			17.5	20.4	10.9	**17.3**	**19.7**	**11.7**
30-Sep-99	10.9	10.9	10.9	14.9	8.8	13.1			12.8	17.8	8.8	**10.9**	**14.9**	**8.8**
01-Oct-99	11.1	10.9	10.9	15.7	6.0	11.7			13.6	18.2	7.0	**10.9**	**15.7**	**6.0**
02-Oct-99	9.1	9.2	9.2	11.9	4.8	10.3			10.3	12.8	5.8	**9.2**	**11.9**	**4.8**
03-Oct-99	7.5	7.3	7.3	10.5	3.4	7.8			9.3	12.6	5.7	**7.3**	**10.5**	**3.4**
04-Oct-99	4.3	4.3	4.3	7.3	1.3	5.9			5.4	8.8	2.2	**4.3**	**7.3**	**1.3**
05-Oct-99	6.9	7.0	7.0	11.7	1.8	7.7			8.7	13.0	2.5	**7.0**	**11.7**	**1.8**
06-Oct-99	5.2	4.8	4.8	9.3	-1.2	5.1			7.1	11.4	1.1	**4.8**	**9.3**	**-1.2**
07-Oct-99	1.6	1.7	1.7	8.1	-3.4	2.9			2.8	7.3	-2.6	**1.7**	**8.1**	**-3.4**
08-Oct-99	10.1	10.6	10.6	17.2	0.9	11.9			12.3	18.8	3.4	**10.6**	**17.2**	**0.9**
09-Oct-99	14.0	13.8	13.8	21.1	9.6	16.7			16.7	21.9	10.8	**13.8**	**21.1**	**9.6**
10-Oct-99	15.0	15.1	15.1	19.7	9.8	16.5			17.2	22.6	11.0	**15.1**	**19.7**	**9.8**
11-Oct-99	11.2	10.8	10.8	15.6	5.3	11.5			13.3	18.8	7.3	**10.8**	**15.6**	**5.3**

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12-Oct-99	8.3	8.6	8.6	12.4	4.0	8.8			9.8	14.0	5.0	**8.6**	**12.4**	**4.0**
13-Oct-99	11.2	10.9	10.9	19.3	3.2	11.5			12.8	22.1	4.0	**10.9**	**19.3**	**3.2**
14-Oct-99	4.6	4.6	4.6	9.0	1.7	7.0			6.1	11.2	3.0	**4.6**	**9.0**	**1.7**
15-Oct-99	8.9	9.0	9.0	14.4	2.9	10.3			9.9	15.7	3.4	**9.0**	**14.4**	**2.9**
16-Oct-99	14.4	14.8	14.8	21.6	7.1	16.4			16.2	23.1	6.4	**14.8**	**21.6**	**7.1**
17-Oct-99	11.4	10.9	10.9	17.9	8.5	10.3			12.8	20.6	9.1	**10.9**	**17.9**	**8.5**
18-Oct-99	5.8	5.5	5.5	8.2	2.1	5.1			6.6	9.9	1.8	**5.5**	**8.2**	**2.1**
19-Oct-99	5.6	5.8	5.8	10.5	1.2	5.7			6.4	11.4	0.3	**5.8**	**10.5**	**1.2**
20-Oct-99	6.7	6.6	6.6	11.3	2.0	8.4			8.3	13.3	2.5	**6.6**	**11.3**	**2.0**
21-Oct-99	6.2	6.5	6.5	12.3	-0.6	7.3			8.5	13.5	1.1	**6.5**	**12.3**	**-0.6**
22-Oct-99	7.9	7.7	7.7	10.9	3.7	8.6			10.3	12.4	6.2	**7.7**	**10.9**	**3.7**
23-Oct-99	5.6	5.7	5.7	8.2	2.2	6.3			7.2	10.1	4.9	**5.7**	**8.2**	**2.2**
24-Oct-99	4.3	4.2	4.2	6.5	2.3	5.6			5.8	7.7	3.4	**4.2**	**6.5**	**2.3**
25-Oct-99	7.2	7.4	7.4	14.0	2.4	8.6			9.5	15.5	4.9	**7.4**	**14.0**	**2.4**
26-Oct-99	8.7	8.6	8.6	13.7	5.3	10.5			11.2	16.2	7.2	**8.6**	**13.7**	**5.3**
27-Oct-99	4.0	3.8	3.8	7.7	-0.1	4.9			5.2	8.5	-0.2	**3.8**	**7.7**	**-0.1**
28-Oct-99	6.9	7.3	7.3	16.0	-1.0	10.0			7.5	16.8	-1.4	**7.3**	**16.0**	**-1.0**
29-Oct-99	8.5	8.4	8.4	13.0	4.0	9.4			9.2	13.8	3.0	**8.4**	**13.0**	**4.0**
30-Oct-99	12.1	12.1	12.1	21.4	6.9	13.9			13.0	22.4	7.0	**12.1**	**21.4**	**6.9**
31-Oct-99	12.2	12.3	12.3	16.5	8.0	12.7			14.3	18.8	7.0	**12.3**	**16.5**	**8.0**
01-Nov-99	9.5	9.5	9.5	17.7	2.8	10.8			9.7	18.2	2.3	**9.5**	**17.7**	**2.8**
02-Nov-99	7.1	6.8	6.8	10.7	2.5	7.7			6.2	9.9	1.6	**6.8**	**10.7**	**2.5**
03-Nov-99	0.2	0.2	0.2	1.8	-1.0	1.8			0.6	1.7	-0.2	**0.2**	**1.8**	**-1.0**
04-Nov-99	1.8	1.8	1.8	6.0	-0.5	4.7			3.1	6.4	-0.2	**1.8**	**6.0**	**-0.5**
05-Nov-99	7.9	8.1	8.1	16.0	-0.5	10.9			9.6	16.2	0.0	**8.1**	**16.0**	**-0.5**
06-Nov-99	4.7	4.5	4.5	7.7	1.8	4.7			4.8	7.8	1.1	**4.5**	**7.7**	**1.8**

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07-Nov-99	1.5	1.4	1.4	4.3	-1.6	2.8			1.7	4.8	-1.1	**1.4**	**4.3**	**-1.6**
08-Nov-99	2.7	2.9	2.9	5.7	-0.9	5.9			4.0	7.8	0.1	**2.9**	**5.7**	**-0.9**
09-Nov-99	10.8	11.3	11.3	20.0	2.1	14.4			12.1	21.4	1.5	**11.3**	**20.0**	**2.1**
10-Nov-99	9.7	9.0	9.0	16.2	1.4	8.4			11.0	16.1	1.5	**9.0**	**16.2**	**1.4**
11-Nov-99	-1.6	-1.6	-1.6	2.6	-4.2	0.1			-1.3	1.9	-4.0	**-1.6**	**2.6**	**-4.2**
12-Nov-99	2.3	2.6	2.6	5.2	-1.4	3.6			2.6	5.9	-1.8	**2.6**	**5.2**	**-1.4**
13-Nov-99	5.9	5.9	5.9	8.4	4.2	9.2			6.7	8.3	4.7	**5.9**	**8.4**	**4.2**
14-Nov-99	6.5	6.4	6.4	10.3	3.1	8.2			6.8	11.6	2.7	**6.4**	**10.3**	**3.1**
15-Nov-99	0.1	-0.2	-0.2	2.6	-3.1	0.5			0.2	2.6	-3.4	**-0.2**	**2.6**	**-3.1**
16-Nov-99	-2.8	-2.8	-2.8	-0.8	-4.8	-1.0			-2.6	-0.2	-4.8	**-2.8**	**-0.8**	**-4.8**
17-Nov-99	-1.8	-1.6	-1.6	1.9	-4.9	0.0			-1.0	2.8	-4.8	**-1.6**	**1.9**	**-4.9**
18-Nov-99	2.7	2.8	2.8	6.7	-2.3	4.7			3.8	6.6	-1.0	**2.8**	**6.7**	**-2.3**
19-Nov-99	8.1	8.4	8.4	12.7	3.4	10.5			8.6	14.4	1.7	**8.4**	**12.7**	**3.4**
20-Nov-99	7.9	7.8	7.8	10.6	6.1	10.1			8.5	12.6	7.1	**7.8**	**10.6**	**6.1**
21-Nov-99	6.7	6.7	6.7	8.4	5.8	8.2			7.0	8.8	5.4	**6.7**	**8.4**	**5.8**
22-Nov-99	10.4	10.6	10.6	15.9	7.5	12.1			10.8	15.6	6.8	**10.6**	**15.9**	**7.5**
23-Nov-99	11.0	10.9	10.9	14.5	5.8	11.8			10.2	13.9	5.6	**10.9**	**14.5**	**5.8**
24-Nov-99	9.0	8.7	8.7	12.2	5.0	9.2			9.2	13.1	5.0	**8.7**	**12.2**	**5.0**
25-Nov-99	3.0	3.0	3.0	6.5	0.0	4.1			3.0	6.5	-0.4	**3.0**	**6.5**	**0**
26-Nov-99	4.4	4.4	4.4	6.5	3.0	5.4			4.3	5.9	2.5	**4.4**	**6.5**	**3.0**
27-Nov-99	4.7	4.6	4.6	8.0	2.3	5.4			5.1	8.4	2.7	**4.6**	**8.0**	**2.3**
28-Nov-99	2.6	2.5	2.5	4.4	-0.4	3.4			2.7	5.2	0.6	**2.5**	**4.4**	**-0.4**
29-Nov-99	-1.2	-1.4	-1.4	0.4	-4.3	-1.4			-1.1	0.6	-4.4	**-1.4**	**0.4**	**-4.3**
30-Nov-99	-5.1	-5.2	-5.2	-2.4	-6.8	-4.0			-5.1	-1.5	-8.2	**-5.2**	**-2.4**	**-6.8**
01-Dec-99						-2.9			-4.2	0.6	-10.1	**-4.2**	**0.6**	**-10.1**
02-Dec-99						2.8			2.1	4.6	-0.6	**2.1**	**4.6**	**-0.6**

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03-Dec-99						8.6			6.9	10.8	2.9	**6.9**	**10.8**	**2.9**
04-Dec-99						10.5			9.6	11.5	7.9	**9.6**	**11.5**	**7.9**
05-Dec-99						10.2			10.6	12.7	6.6	**10.6**	**12.7**	**6.6**
06-Dec-99						3.6			3.1	6.1	0.2	**3.1**	**6.1**	**0.2**
07-Dec-99						1.3			0.3	1.6	-2.0	**0.3**	**1.6**	**-2.0**
08-Dec-99						2.2			-0.2	4.9	-4.3	**-0.2**	**4.9**	**-4.3**
09-Dec-99						4.5			1.9	8.5	-3.0	**1.9**	**8.5**	**-3.0**
10-Dec-99						3.7			3.6	6.9	0.0	**3.6**	**6.9**	**0**
11-Dec-99						-0.8			-1.5	0.7	-4.2	**-1.5**	**0.7**	**-4.2**
12-Dec-99						-1.3			-2.0	1.7	-5.8	**-2.0**	**1.7**	**-5.8**
13-Dec-99						1.8			0.2	3.1	-1.9	**0.2**	**3.1**	**-1.9**
14-Dec-99						1.1			-0.9	0.8	-2.2	**-0.9**	**0.8**	**-2.2**
15-Dec-99						4.9			3.8	6.8	0.0	**3.8**	**6.8**	**0**
16-Dec-99						1.4			1.8	3.8	-0.4	**1.8**	**3.8**	**-0.4**
17-Dec-99						-2.4			-3.3	-1.0	-5.1	**-3.3**	**-1.0**	**-5.1**
18-Dec-99						-3.9			-5.7	-1.9	-9.7	**-5.7**	**-1.9**	**-9.7**
19-Dec-99						-1.9			-3.8	-0.1	-9.6	**-3.8**	**-0.1**	**-9.6**
20-Dec-99						2.3			2.6	7.0	-2.6	**2.6**	**7.0**	**-2.6**
21-Dec-99						-5.8			-5.8	-3.0	-8.5	**-5.8**	**-3.0**	**-8.5**
22-Dec-99						-6.9			-7.7	-5.5	-9.4	**-7.7**	**-5.5**	**-9.4**
23-Dec-99						-8.0			-8.0	-5.1	-11.3	**-8.0**	**-5.1**	**-11.3**
24-Dec-99						-8.0			-10.0	-4.6	-13.8	**-10.0**	**-4.6**	**-13.8**
25-Dec-99						-6.2			-7.5	-1.5	-14.7	**-7.5**	**-1.5**	**-14.7**
26-Dec-99						-2.4			-3.4	0.0	-6.2	**-3.4**	**0**	**-6.2**
27-Dec-99						-10.1			-10.0	-7.7	-13.8	**-10.0**	**-7.7**	**-13.8**
28-Dec-99						-9.5			-8.9	-4.7	-15.7	**-8.9**	**-4.7**	**-15.7**

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29-Dec-99						-4.4			-6.1	1.7	-14.0	**-6.1**	**1.7**	**-14.0**
30-Dec-99						-1.8			-2.7	3.8	-9.4	**-2.7**	**3.8**	**-9.4**
31-Dec-99						-3.9			-6.5	0.1	-12.7	**-6.5**	**0.1**	**-12.7**
01-Jan-00									1.3	7.1	-2.0	**1.3**	**7.1**	**-2.0**
02-Jan-00									2.9	10.8	-3.4	**2.9**	**10.8**	**-3.4**
03-Jan-00									0.7	11.1	-2.3	**0.7**	**11.1**	**-2.3**
04-Jan-00									1.1	9.1	-6.1	**1.1**	**9.1**	**-6.1**
05-Jan-00									-7.2	-4.8	-9.9	**-7.2**	**-4.8**	**-9.9**
06-Jan-00									-0.9	1.6	-6.0	**-0.9**	**1.6**	**-6.0**
07-Jan-00									-1.9	0.3	-4.2	**-1.9**	**0.3**	**-4.2**
08-Jan-00									-0.9	4.2	-7.1	**-0.9**	**4.2**	**-7.1**
09-Jan-00									2.6	4.1	1.2	**2.6**	**4.1**	**1.2**
10-Jan-00									3.4	6.0	1.7	**3.4**	**6.0**	**1.7**
11-Jan-00									2.8	5.0	0.1	**2.8**	**5.0**	**0.1**
12-Jan-00									-1.9	0.1	-4.4	**-1.9**	**0.1**	**-4.4**
13-Jan-00									-10.6	-5.0	-15.6	**-10.6**	**-5.0**	**-15.6**
14-Jan-00									-13.1	-9.3	-16.6	**-13.1**	**-9.3**	**-16.6**
15-Jan-00									-5.9	-0.8	-10.4	**-5.9**	**-0.8**	**-10.4**
16-Jan-00									-6.0	1.3	-18.1	**-6.0**	**1.3**	**-18.1**
17-Jan-00									-19.1	-15.3	-23.4	**-19.1**	**-15.3**	**-23.4**
18-Jan-00									-13.7	-9.9	-17.4	**-13.7**	**-9.9**	**-17.4**
19-Jan-00									-8.6	-1.8	-17.4	**-8.6**	**-1.8**	**-17.4**
20-Jan-00									-9.9	-5.5	-18.9	**-9.9**	**-5.5**	**-18.9**
21-Jan-00									-19.5	-16.1	-22.8	**-19.5**	**-16.1**	**-22.8**
22-Jan-00									-19.3	-13.4	-25.4	**-19.3**	**-13.4**	**-25.4**
23-Jan-00									-7.4	-3.0	-14.4	**-7.4**	**-3.0**	**-14.4**

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24-Jan-00									-9.2	-5.7	-15.3	**-9.2**	**-5.7**	**-15.3**
25-Jan-00									-11.6	-7.0	-18.3	**-11.6**	**-7.0**	**-18.3**
26-Jan-00									-12.7	-7.0	-17.2	**-12.7**	**-7.0**	**-17.2**
27-Jan-00									-17.0	-13.1	-21.2	**-17.0**	**-13.1**	**-21.2**
28-Jan-00									-13.8	-7.7	-19.5	**-13.8**	**-7.7**	**-19.5**
29-Jan-00									-8.9	0.5	-17.6	**-8.9**	**0.5**	**-17.6**
30-Jan-00									-3.6	-0.3	-9.0	**-3.6**	**-0.3**	**-9.0**
31-Jan-00									-2.1	-1.4	-3.8	**-2.1**	**-1.4**	**-3.8**
01-Feb-00									-5.8	-3.8	-9.2	**-5.8**	**-3.8**	**-9.2**
02-Feb-00									-10.3	-6.5	-15.8	**-10.3**	**-6.5**	**-15.8**
03-Feb-00									-4.8	-2.7	-7.3	**-4.8**	**-2.7**	**-7.3**
04-Feb-00									-8.2	-5.6	-10.5	**-8.2**	**-5.6**	**-10.5**
05-Feb-00									-6.3	-2.6	-12.5	**-6.3**	**-2.6**	**-12.5**
06-Feb-00									-6.4	-1.3	-11.9	**-6.4**	**-1.3**	**-11.9**
07-Feb-00									-5.4	-1.4	-11.7	**-5.4**	**-1.4**	**-11.7**
08-Feb-00									-9.9	-3.3	-19.6	**-9.9**	**-3.3**	**-19.6**
09-Feb-00									-0.2	2.9	-4.2	**-0.2**	**2.9**	**-4.2**
10-Feb-00									-6.6	-3.4	-8.5	**-6.6**	**-3.4**	**-8.5**
11-Feb-00									-8.5	-6.4	-12.3	**-8.5**	**-6.4**	**-12.3**
12-Feb-00									-12.5	-5.9	-22.0	**-12.5**	**-5.9**	**-22.0**
13-Feb-00									-6.1	-3.3	-11.2	**-6.1**	**-3.3**	**-11.2**
14-Feb-00									-5.7	-4.0	-6.8	**-5.7**	**-4.0**	**-6.8**
15-Feb-00									-5.1	-0.5	-10.8	**-5.1**	**-0.5**	**-10.8**
16-Feb-00									-3.0	0.2	-8.3	**-3.0**	**0.2**	**-8.3**
17-Feb-00									-9.9	-5.6	-16.2	**-9.9**	**-5.6**	**-16.2**
18-Feb-00									-6.5	-4.2	-10.9	**-6.5**	**-4.2**	**-10.9**

Date	Temperature Gauge													
	Stouffville					Pearson			Buttonville			Selected Temperatures in Analysis		
	Calc Daily (from hr)	Daily Values	Processed (Daily if avail or Calc daily)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min
19-Feb-00									-6.5	-2.3	-11.4	**-6.5**	**-2.3**	**-11.4**
20-Feb-00									-3.2	-0.6	-6.5	**-3.2**	**-0.6**	**-6.5**
21-Feb-00									-0.9	2.4	-4.1	**-0.9**	**2.4**	**-4.1**
22-Feb-00									3.4	7.1	-2.2	**3.4**	**7.1**	**-2.2**
23-Feb-00									6.6	10.6	3.2	**6.6**	**10.6**	**3.2**
24-Feb-00									4.8	9.4	1.8	**4.8**	**9.4**	**1.8**
25-Feb-00									4.0	5.5	1.0	**4.0**	**5.5**	**1.0**
26-Feb-00									5.6	10.0	0.8	**5.6**	**10.0**	**0.8**
27-Feb-00									7.3	14.4	3.9	**7.3**	**14.4**	**3.9**
28-Feb-00									1.2	3.8	-2.7	**1.2**	**3.8**	**-2.7**
29-Feb-00									-0.7	5.3	-6.5	**-0.7**	**5.3**	**-6.5**
01-Mar-00									3.6	10.3	-0.8	**3.6**	**10.3**	**-0.8**
02-Mar-00									-0.9	1.6	-2.5	**-0.9**	**1.6**	**-2.5**
03-Mar-00									-1.1	3.0	-4.1	**-1.1**	**3.0**	**-4.1**
04-Mar-00									1.6	8.2	-5.6	**1.6**	**8.2**	**-5.6**
05-Mar-00									2.8	4.9	0.7	**2.8**	**4.9**	**0.7**
06-Mar-00									3.7	10.8	-3.1	**3.7**	**10.8**	**-3.1**
07-Mar-00									5.1	14.3	-2.2	**5.1**	**14.3**	**-2.2**
08-Mar-00									9.7	21.4	-1.0	**9.7**	**21.4**	**-1.0**
09-Mar-00									8.0	20.8	-4.0	**8.0**	**20.8**	**-4.0**
10-Mar-00									-5.9	-4.2	-6.6	**-5.9**	**-4.2**	**-6.6**
11-Mar-00									-2.5	1.5	-5.6	**-2.5**	**1.5**	**-5.6**
12-Mar-00									-1.3	2.5	-4.0	**-1.3**	**2.5**	**-4.0**
13-Mar-00									-1.5	0.9	-6.3	**-1.5**	**0.9**	**-6.3**
14-Mar-00									4.2	8.8	-0.2	**4.2**	**8.8**	**-0.2**
15-Mar-00									5.1	9.8	0.7	**5.1**	**9.8**	**0.7**

Date	Temperature Gauge													
	Stouffville					**Pearson**			**Buttonville**			**Selected Temperatures in Analysis**		
	Calc Daily (from hr)	Daily Values	Processed (Daily if avail or Calc daily)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min
16-Mar-00									0.2	8.8	-2.6	**0.2**	**8.8**	**-2.6**
17-Mar-00									-4.5	-1.7	-7.6	**-4.5**	**-1.7**	**-7.6**
18-Mar-00									-4.0	-0.5	-8.4	**-4.0**	**-0.5**	**-8.4**
19-Mar-00									0.5	3.6	-6.0	**0.5**	**3.6**	**-6.0**
20-Mar-00									5.5	9.0	2.7	**5.5**	**9.0**	**2.7**
21-Mar-00									5.9	9.0	1.4	**5.9**	**9.0**	**1.4**
22-Mar-00									8.2	13.8	2.2	**8.2**	**13.8**	**2.2**
23-Mar-00									9.2	17.2	2.7	**9.2**	**17.2**	**2.7**
24-Mar-00									7.6	14.4	0.6	**7.6**	**14.4**	**0.6**
25-Mar-00									11.7	19.8	5.5	**11.7**	**19.8**	**5.5**
26-Mar-00									6.1	10.2	0.4	**6.1**	**10.2**	**0.4**
27-Mar-00									3.3	7.8	-1.0	**3.3**	**7.8**	**-1.0**
28-Mar-00									3.1	7.8	-1.4	**3.1**	**7.8**	**-1.4**
29-Mar-00									2.1	4.9	0.5	**2.1**	**4.9**	**0.5**
30-Mar-00									3.7	8.2	0.3	**3.7**	**8.2**	**0.3**
31-Mar-00									5.3	12.6	-0.7	**5.3**	**12.6**	**-0.7**
01-Apr-00									8.1	15.8	-1.9	**8.1**	**15.8**	**-1.9**
02-Apr-00									8.4	10.7	6.0	**8.4**	**10.7**	**6.0**
03-Apr-00									6.8	8.9	5.1	**6.8**	**8.9**	**5.1**
04-Apr-00									4.5	8.3	-0.9	**4.5**	**8.3**	**-0.9**
05-Apr-00									0.1	3.1	-2.2	**0.1**	**3.1**	**-2.2**
06-Apr-00									5.1	9.8	-0.8	**5.1**	**9.8**	**-0.8**
07-Apr-00									4.2	8.0	-0.5	**4.2**	**8.0**	**-0.5**
08-Apr-00									-0.3	1.9	-2.4	**-0.3**	**1.9**	**-2.4**
09-Apr-00									-0.9	3.7	-5.3	**-0.9**	**3.7**	**-5.3**
10-Apr-00									-0.3	1.5	-2.4	**-0.3**	**1.5**	**-2.4**

Date	**Temperature Gauge**													
	Stouffville					**Pearson**			**Buttonville**			**Selected Temperatures in Analysis**		
	Calc Daily (from hr)	Daily Values	Processed (Daily if avail or Calc daily)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min
11-Apr-00									-1.7	0.8	-3.9	**-1.7**	**0.8**	**-3.9**
12-Apr-00									-0.5	5.1	-5.9	**-0.5**	**5.1**	**-5.9**
13-Apr-00									1.4	7.1	-5.7	**1.4**	**7.1**	**-5.7**
14-Apr-00									9.0	18.7	-2.4	**9.0**	**18.7**	**-2.4**
15-Apr-00									15.5	22.3	10.0	**15.5**	**22.3**	**10.0**
16-Apr-00									6.8	10.6	5.3	**6.8**	**10.6**	**5.3**
17-Apr-00									4.0	5.8	2.6	**4.0**	**5.8**	**2.6**
18-Apr-00									3.8	5.4	1.2	**3.8**	**5.4**	**1.2**
19-Apr-00									8.5	14.2	3.6	**8.5**	**14.2**	**3.6**
20-Apr-00									8.0	8.6	7.2	**8.0**	**8.6**	**7.2**
21-Apr-00									7.1	8.8	6.1	**7.1**	**8.8**	**6.1**
22-Apr-00									6.5	7.9	5.3	**6.5**	**7.9**	**5.3**
23-Apr-00									9.5	17.1	3.3	**9.5**	**17.1**	**3.3**
24-Apr-00									10.1	15.6	5.9	**10.1**	**15.6**	**5.9**
25-Apr-00									8.0	13.9	1.3	**8.0**	**13.9**	**1.3**
26-Apr-00									6.0	11.2	-1.0	**6.0**	**11.2**	**-1.0**
27-Apr-00									7.2	11.2	2.8	**7.2**	**11.2**	**2.8**
28-Apr-00									10.2	19.0	0.0	**10.2**	**19.0**	**0**
29-Apr-00									10.7	18.8	2.6	**10.7**	**18.8**	**2.6**
30-Apr-00									8.7	15.7	1.2	**8.7**	**15.7**	**1.2**
01-May-00									8.0	12.4	3.7	**8.0**	**12.4**	**3.7**
02-May-00									9.7	14.8	5.1	**9.7**	**14.8**	**5.1**
03-May-00									10.5	18.0	0.9	**10.5**	**18.0**	**0.9**
04-May-00									14.1	21.2	2.9	**14.1**	**21.2**	**2.9**
05-May-00									22.3	27.4	16.4	**22.3**	**27.4**	**16.4**
06-May-00									23.9	29.8	16.5	**23.9**	**29.8**	**16.5**

Date	**Temperature Gauge**													
	Stouffville					**Pearson**			**Buttonville**			**Selected Temperatures in Analysis**		
	Calc Daily (from hr)	Daily Values	Processed (Daily if avail or Calc daily)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min
07-May-00									24.1	29.2	19.0	**24.1**	**29.2**	**19.0**
08-May-00									22.1	25.2	17.1	**22.1**	**25.2**	**17.1**
09-May-00									20.6	25.4	13.4	**20.6**	**25.4**	**13.4**
10-May-00									13.0	19.4	8.8	**13.0**	**19.4**	**8.8**
11-May-00									12.5	19.4	6.1	**12.5**	**19.4**	**6.1**
12-May-00									12.1	15.3	8.8	**12.1**	**15.3**	**8.8**
13-May-00									15.9	20.8	9.2	**15.9**	**20.8**	**9.2**
14-May-00									9.5	10.9	7.4	**9.5**	**10.9**	**7.4**
15-May-00									10.1	15.1	4.8	**10.1**	**15.1**	**4.8**
16-May-00									8.7	14.4	1.9	**8.7**	**14.4**	**1.9**
17-May-00									12.7	17.4	7.7	**12.7**	**17.4**	**7.7**
18-May-00									11.6	13.0	8.7	**11.6**	**13.0**	**8.7**
19-May-00									7.1	11.8	3.7	**7.1**	**11.8**	**3.7**
20-May-00									8.4	11.2	6.5	**8.4**	**11.2**	**6.5**
21-May-00									11.4	16.6	6.4	**11.4**	**16.6**	**6.4**
22-May-00									11.4	16.7	7.2	**11.4**	**16.7**	**7.2**
23-May-00									10.7	13.8	7.5	**10.7**	**13.8**	**7.5**
24-May-00									16.9	23.5	11.2	**16.9**	**23.5**	**11.2**
25-May-00									12.1	14.7	8.3	**12.1**	**14.7**	**8.3**
26-May-00									11.7	17.7	6.0	**11.7**	**17.7**	**6.0**
27-May-00									13.4	19.6	5.8	**13.4**	**19.6**	**5.8**
28-May-00									11.0	14.8	7.7	**11.0**	**14.8**	**7.7**
29-May-00									12.7	17.9	7.2	**12.7**	**17.9**	**7.2**
30-May-00									15.1	21.8	7.6	**15.1**	**21.8**	**7.6**
31-May-00									18.4	22.9	13.0	**18.4**	**22.9**	**13.0**
01-Jun-00									16.7	19.7	13.1	**16.7**	**19.7**	**13.1**

Date	**Temperature Gauge**													
	Stouffville					**Pearson**			**Buttonville**			**Selected Temperatures in Analysis**		
	Calc Daily (from hr)	Daily Values	Processed (Daily if avail or Calc daily)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min
02-Jun-00									16.1	24.0	11.1	**16.1**	**24.0**	**11.1**
03-Jun-00									13.9	19.9	8.1	**13.9**	**19.9**	**8.1**
04-Jun-00									14.1	20.1	7.4	**14.1**	**20.1**	**7.4**
05-Jun-00									11.4	15.3	6.5	**11.4**	**15.3**	**6.5**
06-Jun-00									13.0	17.6	9.6	**13.0**	**17.6**	**9.6**
07-Jun-00									16.9	24.3	7.7	**16.9**	**24.3**	**7.7**
08-Jun-00									20.9	26.7	13.7	**20.9**	**26.7**	**13.7**
09-Jun-00									17.2	20.8	12.2	**17.2**	**20.8**	**12.2**
10-Jun-00									22.7	31.0	10.5	**22.7**	**31.0**	**10.5**
11-Jun-00									17.4	26.0	10.2	**17.4**	**26.0**	**10.2**
12-Jun-00									14.1	18.6	10.3	**14.1**	**18.6**	**10.3**
13-Jun-00									13.3	16.0	10.6	**13.3**	**16.0**	**10.6**
14-Jun-00									18.0	23.6	13.7	**18.0**	**23.6**	**13.7**
15-Jun-00									21.8	25.6	18.6	**21.8**	**25.6**	**18.6**
16-Jun-00									25.3	28.5	20.4	**25.3**	**28.5**	**20.4**
17-Jun-00									18.0	20.6	10.7	**18.0**	**20.6**	**10.7**
18-Jun-00									12.4	16.8	9.8	**12.4**	**16.8**	**9.8**
19-Jun-00									16.7	22.3	9.4	**16.7**	**22.3**	**9.4**
20-Jun-00									18.6	21.9	14.0	**18.6**	**21.9**	**14.0**
21-Jun-00									21.8	27.1	16.5	**21.8**	**27.1**	**16.5**
22-Jun-00									19.4	23.6	14.8	**19.4**	**23.6**	**14.8**
23-Jun-00									18.8	23.8	13.4	**18.8**	**23.8**	**13.4**
24-Jun-00									18.2	21.2	14.7	**18.2**	**21.2**	**14.7**
25-Jun-00									22.1	27.9	18.0	**22.1**	**27.9**	**18.0**
26-Jun-00									21.6	27.3	13.4	**21.6**	**27.3**	**13.4**
27-Jun-00									18.8	24.1	13.5	**18.8**	**24.1**	**13.5**

Date	Temperature Gauge													
	Stouffville					**Pearson**			**Buttonville**			**Selected Temperatures in Analysis**		
	Calc Daily (from hr)	Daily Values	Processed (Daily if avail or Calc daily)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min
28-Jun-00									17.1	21.3	11.1	**17.1**	**21.3**	**11.1**
29-Jun-00									14.8	16.8	13.1	**14.8**	**16.8**	**13.1**
30-Jun-00									18.0	23.6	11.0	**18.0**	**23.6**	**11.0**
01-Jul-00									22.1	27.4	15.4	**22.1**	**27.4**	**15.4**
02-Jul-00									23.0	28.4	17.6	**23.0**	**28.4**	**17.6**
03-Jul-00									19.4	22.2	17.9	**19.4**	**22.2**	**17.9**
04-Jul-00									20.7	25.9	16.0	**20.7**	**25.9**	**16.0**
05-Jul-00									18.5	23.4	13.9	**18.5**	**23.4**	**13.9**
06-Jul-00									17.3	22.7	13.2	**17.3**	**22.7**	**13.2**
07-Jul-00									16.7	21.6	11.3	**16.7**	**21.6**	**11.3**
08-Jul-00									19.1	24.8	13.1	**19.1**	**24.8**	**13.1**
09-Jul-00									19.5	23.4	16.4	**19.5**	**23.4**	**16.4**
10-Jul-00									20.7	24.1	16.8	**20.7**	**24.1**	**16.8**
11-Jul-00									19.6	24.4	13.9	**19.6**	**24.4**	**13.9**
12-Jul-00									19.8	25.2	13.4	**19.8**	**25.2**	**13.4**
13-Jul-00									19.4	24.7	13.5	**19.4**	**24.7**	**13.5**
14-Jul-00									18.3	21.0	15.0	**18.3**	**21.0**	**15.0**
15-Jul-00									18.7	22.2	16.0	**18.7**	**22.2**	**16.0**
16-Jul-00									18.6	21.5	16.6	**18.6**	**21.5**	**16.6**
17-Jul-00									20.2	25.6	17.0	**20.2**	**25.6**	**17.0**
18-Jul-00									16.0	19.4	12.7	**16.0**	**19.4**	**12.7**
19-Jul-00									16.0	21.0	12.4	**16.0**	**21.0**	**12.4**
20-Jul-00									17.5	23.5	8.8	**17.5**	**23.5**	**8.8**
21-Jul-00									18.0	21.5	13.3	**18.0**	**21.5**	**13.3**
22-Jul-00									15.6	20.4	11.3	**15.6**	**20.4**	**11.3**
23-Jul-00									16.2	22.6	10.1	**16.2**	**22.6**	**10.1**

Date	**Temperature Gauge**													
	Stouffville					**Pearson**			**Buttonville**			**Selected Temperatures in Analysis**		
	Calc Daily (from hr)	Daily Values	Processed (Daily if avail or Calc daily)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min
24-Jul-00									17.4	22.8	11.4	**17.4**	**22.8**	**11.4**
25-Jul-00									19.1	25.1	12.0	**19.1**	**25.1**	**12.0**
26-Jul-00									21.1	25.7	14.4	**21.1**	**25.7**	**14.4**
27-Jul-00									20.7	24.4	17.8	**20.7**	**24.4**	**17.8**
28-Jul-00									20.4	24.4	16.8	**20.4**	**24.4**	**16.8**
29-Jul-00									21.1	24.6	17.4	**21.1**	**24.6**	**17.4**
30-Jul-00									20.3	22.2	18.4	**20.3**	**22.2**	**18.4**
31-Jul-00									22.0	24.5	20.4	**22.0**	**24.5**	**20.4**
01-Aug-00									21.8	24.7	19.2	**21.8**	**24.7**	**19.2**
02-Aug-00									23.1	27.2	20.2	**23.1**	**27.2**	**20.2**
03-Aug-00									17.7	20.5	12.1	**17.7**	**20.5**	**12.1**
04-Aug-00									17.1	23.4	10.2	**17.1**	**23.4**	**10.2**
05-Aug-00									19.3	25.2	11.3	**19.3**	**25.2**	**11.3**
06-Aug-00									17.7	19.3	14.8	**17.7**	**19.3**	**14.8**
07-Aug-00									23.2	28.4	18.4	**23.2**	**28.4**	**18.4**
08-Aug-00									22.8	29.5	18.2	**22.8**	**29.5**	**18.2**
09-Aug-00									22.1	26.6	17.9	**22.1**	**26.6**	**17.9**
10-Aug-00									20.7	26.4	16.6	**20.7**	**26.4**	**16.6**
11-Aug-00									20.3	24.8	16.8	**20.3**	**24.8**	**16.8**
12-Aug-00									18.9	24.1	14.2	**18.9**	**24.1**	**14.2**
13-Aug-00									19.8	24.8	13.7	**19.8**	**24.8**	**13.7**
14-Aug-00									21.7	27.5	15.8	**21.7**	**27.5**	**15.8**
15-Aug-00									23.1	28.7	16.9	**23.1**	**28.7**	**16.9**
16-Aug-00									17.5	20.3	12.8	**17.5**	**20.3**	**12.8**
17-Aug-00									15.3	20.7	9.2	**15.3**	**20.7**	**9.2**
18-Aug-00									15.1	20.0	10.0	**15.1**	**20.0**	**10.0**

Date	Temperature Gauge														
	Stouffville					**Pearson**			**Buttonville**			**Selected Temperatures in Analysis**		
	Calc Daily (from hr)	Daily Values	Processed (Daily if avail or Calc daily)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min
19-Aug-00									14.3	18.6	9.3	**14.3**	**18.6**	**9.3**
20-Aug-00									12.5	18.0	7.2	**12.5**	**18.0**	**7.2**
21-Aug-00									15.1	20.3	8.9	**15.1**	**20.3**	**8.9**
22-Aug-00									16.8	22.5	8.7	**16.8**	**22.5**	**8.7**
23-Aug-00									19.1	25.1	15.5	**19.1**	**25.1**	**15.5**
24-Aug-00									18.8	24.5	14.0	**18.8**	**24.5**	**14.0**
25-Aug-00									19.3	26.0	11.8	**19.3**	**26.0**	**11.8**
26-Aug-00									19.5	24.0	13.4	**19.5**	**24.0**	**13.4**
27-Aug-00									19.0	22.0	16.4	**19.0**	**22.0**	**16.4**
28-Aug-00									18.7	22.5	13.1	**18.7**	**22.5**	**13.1**
29-Aug-00									21.3	26.7	14.6	**21.3**	**26.7**	**14.6**
30-Aug-00									23.0	25.9	20.7	**23.0**	**25.9**	**20.7**
31-Aug-00									22.9	27.9	18.4	**22.9**	**27.9**	**18.4**
01-Sep-00									23.5	29.0	17.7	**23.5**	**29.0**	**17.7**
02-Sep-00									19.7	21.2	18.0	**19.7**	**21.2**	**18.0**
03-Sep-00									18.7	20.8	17.4	**18.7**	**20.8**	**17.4**
04-Sep-00									15.1	18.9	9.2	**15.1**	**18.9**	**9.2**
05-Sep-00									10.9	17.0	6.0	**10.9**	**17.0**	**6.0**
06-Sep-00									12.0	17.7	5.4	**12.0**	**17.7**	**5.4**
07-Sep-00									16.2	22.8	8.1	**16.2**	**22.8**	**8.1**
08-Sep-00									20.2	24.0	15.6	**20.2**	**24.0**	**15.6**
09-Sep-00									19.5	25.1	12.6	**19.5**	**25.1**	**12.6**
10-Sep-00									20.7	23.8	18.3	**20.7**	**23.8**	**18.3**
11-Sep-00									23.0	26.4	19.4	**23.0**	**26.4**	**19.4**
12-Sep-00									20.4	24.0	13.2	**20.4**	**24.0**	**13.2**
13-Sep-00									16.0	21.6	8.0	**16.0**	**21.6**	**8.0**

Date	Temperature Gauge													
	Stouffville					**Pearson**			**Buttonville**			**Selected Temperatures in Analysis**		
	Calc Daily (from hr)	Daily Values	Processed (Daily if avail or Calc daily)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min
14-Sep-00									14.1	17.2	11.0	**14.1**	**17.2**	**11.0**
15-Sep-00									13.1	16.9	9.6	**13.1**	**16.9**	**9.6**
16-Sep-00									10.0	13.5	6.2	**10.0**	**13.5**	**6.2**
17-Sep-00									15.4	22.0	9.7	**15.4**	**22.0**	**9.7**
18-Sep-00									16.0	21.8	9.1	**16.0**	**21.8**	**9.1**
19-Sep-00									19.0	24.2	14.3	**19.0**	**24.2**	**14.3**
20-Sep-00									20.4	25.7	14.4	**20.4**	**25.7**	**14.4**
21-Sep-00									12.2	13.5	8.9	**12.2**	**13.5**	**8.9**
22-Sep-00									9.4	13.2	3.7	**9.4**	**13.2**	**3.7**
23-Sep-00									14.6	21.4	8.4	**14.6**	**21.4**	**8.4**
24-Sep-00									10.4	13.4	5.1	**10.4**	**13.4**	**5.1**
25-Sep-00									7.5	13.0	2.2	**7.5**	**13.0**	**2.2**
26-Sep-00									9.8	16.3	3.1	**9.8**	**16.3**	**3.1**
27-Sep-00									12.0	19.6	6.6	**12.0**	**19.6**	**6.6**
28-Sep-00									4.0	8.6	0.2	**4.0**	**8.6**	**0.2**
29-Sep-00									7.4	14.7	-0.8	**7.4**	**14.7**	**-0.8**
30-Sep-00									11.7	19.9	2.9	**11.7**	**19.9**	**2.9**
01-Oct-00									13.6	21.2	5.7	**13.6**	**21.2**	**5.7**
02-Oct-00									15.8	20.5	8.1	**15.8**	**20.5**	**8.1**
03-Oct-00									16.0	20.6	11.9	**16.0**	**20.6**	**11.9**
04-Oct-00									12.3	17.2	8.2	**12.3**	**17.2**	**8.2**
05-Oct-00									7.3	9.6	3.3	**7.3**	**9.6**	**3.3**
06-Oct-00									7.9	11.9	3.8	**7.9**	**11.9**	**3.8**
07-Oct-00									4.7	8.8	2.1	**4.7**	**8.8**	**2.1**
08-Oct-00									2.8	6.3	-1.1	**2.8**	**6.3**	**-1.1**
09-Oct-00									3.0	6.6	-0.4	**3.0**	**6.6**	**-0.4**

Date	**Temperature Gauge**													
	Stouffville					**Pearson**			**Buttonville**			**Selected Temperatures in Analysis**		
	Calc Daily (from hr)	Daily Values	Processed (Daily if avail or Calc daily)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min
10-Oct-00									6.4	14.2	-1.2	**6.4**	**14.2**	**-1.2**
11-Oct-00									11.7	18.5	6.2	**11.7**	**18.5**	**6.2**
12-Oct-00									11.7	20.2	2.2	**11.7**	**20.2**	**2.2**
13-Oct-00									14.7	19.5	6.8	**14.7**	**19.5**	**6.8**
14-Oct-00									17.7	23.5	13.6	**17.7**	**23.5**	**13.6**
15-Oct-00									11.2	14.2	8.7	**11.2**	**14.2**	**8.7**
16-Oct-00									8.2	9.6	6.8	**8.2**	**9.6**	**6.8**
17-Oct-00									9.9	11.2	7.5	**9.9**	**11.2**	**7.5**
18-Oct-00									11.7	16.2	8.9	**11.7**	**16.2**	**8.9**
19-Oct-00									9.8	15.4	3.2	**9.8**	**15.4**	**3.2**
20-Oct-00									11.8	22.3	1.1	**11.8**	**22.3**	**1.1**
21-Oct-00									12.8	16.7	7.5	**12.8**	**16.7**	**7.5**
22-Oct-00									4.5	10.0	0.5	**4.5**	**10.0**	**0.5**
23-Oct-00									6.9	13.9	-0.9	**6.9**	**13.9**	**-0.9**
24-Oct-00									12.9	17.3	9.3	**12.9**	**17.3**	**9.3**
25-Oct-00									12.7	15.0	10.2	**12.7**	**15.0**	**10.2**
26-Oct-00									12.7	18.3	9.3	**12.7**	**18.3**	**9.3**
27-Oct-00									13.2	21.9	6.6	**13.2**	**21.9**	**6.6**
28-Oct-00									3.8	6.8	1.1	**3.8**	**6.8**	**1.1**
29-Oct-00									4.1	9.8	-0.8	**4.1**	**9.8**	**-0.8**
30-Oct-00									5.5	13.0	-0.3	**5.5**	**13.0**	**-0.3**
31-Oct-00									5.4	12.0	0.0	**5.4**	**12.0**	**0**
01-Nov-00									6.2	15.5	-0.5	**6.2**	**15.5**	**-0.5**
02-Nov-00									7.2	15.5	-0.5	**7.2**	**15.5**	**-0.5**
03-Nov-00									11.5	19.2	6.8	**11.5**	**19.2**	**6.8**
04-Nov-00									6.7	9.7	4.1	**6.7**	**9.7**	**4.1**

Date	**Temperature Gauge**													
	Stouffville					**Pearson**			**Buttonville**			**Selected Temperatures in Analysis**		
	Calc Daily (from hr)	Daily Values	Processed (Daily if avail or Calc daily)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min
05-Nov-00									3.7	8.0	-1.3	**3.7**	**8.0**	**-1.3**
06-Nov-00									1.7	9.2	-4.2	**1.7**	**9.2**	**-4.2**
07-Nov-00									5.3	9.4	-2.1	**5.3**	**9.4**	**-2.1**
08-Nov-00									9.1	10.3	7.5	**9.1**	**10.3**	**7.5**
09-Nov-00									11.1	13.2	9.1	**11.1**	**13.2**	**9.1**
10-Nov-00									9.9	13.3	5.4	**9.9**	**13.3**	**5.4**
11-Nov-00									3.4	6.0	-0.2	**3.4**	**6.0**	**-0.2**
12-Nov-00									1.1	5.2	-2.6	**1.1**	**5.2**	**-2.6**
13-Nov-00									4.8	7.0	2.9	**4.8**	**7.0**	**2.9**
14-Nov-00									3.1	4.9	2.0	**3.1**	**4.9**	**2.0**
15-Nov-00									2.4	5.0	0.5	**2.4**	**5.0**	**0.5**
16-Nov-00									2.8	6.0	-2.9	**2.8**	**6.0**	**-2.9**
17-Nov-00									2.1	4.0	-0.6	**2.1**	**4.0**	**-0.6**
18-Nov-00									0.1	2.2	-1.9	**0.1**	**2.2**	**-1.9**
19-Nov-00									-0.9	2.0	-5.1	**-0.9**	**2.0**	**-5.1**
20-Nov-00									0.2	1.9	-1.3	**0.2**	**1.9**	**-1.3**
21-Nov-00									-2.5	-0.2	-5.6	**-2.5**	**-0.2**	**-5.6**
22-Nov-00									-6.3	-2.9	-9.9	**-6.3**	**-2.9**	**-9.9**
23-Nov-00									-9.6	-4.8	-14.0	**-9.6**	**-4.8**	**-14.0**
24-Nov-00									-4.8	0.2	-12.3	**-4.8**	**0.2**	**-12.3**
25-Nov-00									-0.6	5.0	-7.3	**-0.6**	**5.0**	**-7.3**
26-Nov-00									3.3	4.6	2.3	**3.3**	**4.6**	**2.3**
27-Nov-00									4.2	5.4	3.2	**4.2**	**5.4**	**3.2**
28-Nov-00									2.6	3.5	0.9	**2.6**	**3.5**	**0.9**
29-Nov-00									0.9	3.4	-1.9	**0.9**	**3.4**	**-1.9**
30-Nov-00									-0.9	0.0	-2.6	**-0.9**	**0**	**-2.6**

Date	Temperature Gauge													
	Stouffville					**Pearson**			**Buttonville**			**Selected Temperatures in Analysis**		
	Calc Daily (from hr)	Daily Values	Processed (Daily if avail or Calc daily)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min
01-Dec-00									-4.4	-1.5	-7.4	**-4.4**	**-1.5**	**-7.4**
02-Dec-00									-7.3	-3.3	-10.8	**-7.3**	**-3.3**	**-10.8**
03-Dec-00									-4.4	1.8	-9.4	**-4.4**	**1.8**	**-9.4**
04-Dec-00									-1.6	2.9	-8.1	**-1.6**	**2.9**	**-8.1**
05-Dec-00									-2.8	0.6	-8.4	**-2.8**	**0.6**	**-8.4**
06-Dec-00									-7.7	-6.4	-9.7	**-7.7**	**-6.4**	**-9.7**
07-Dec-00									-10.1	-7.1	-12.3	**-10.1**	**-7.1**	**-12.3**
08-Dec-00									-9.8	-6.6	-12.7	**-9.8**	**-6.6**	**-12.7**
09-Dec-00									-11.0	-3.1	-19.3	**-11.0**	**-3.1**	**-19.3**
10-Dec-00									-1.7	1.6	-9.2	**-1.7**	**1.6**	**-9.2**
11-Dec-00									-4.4	-0.8	-6.6	**-4.4**	**-0.8**	**-6.6**
12-Dec-00									-10.6	-7.4	-16.2	**-10.6**	**-7.4**	**-16.2**
13-Dec-00									-9.2	-4.1	-16.5	**-9.2**	**-4.1**	**-16.5**
14-Dec-00									-5.6	-3.9	-11.0	**-5.6**	**-3.9**	**-11.0**
15-Dec-00									-8.4	-1.6	-16.2	**-8.4**	**-1.6**	**-16.2**
16-Dec-00									0.8	3.3	-1.4	**0.8**	**3.3**	**-1.4**
17-Dec-00									2.1	4.7	-1.8	**2.1**	**4.7**	**-1.8**
18-Dec-00									-5.8	-2.5	-8.2	**-5.8**	**-2.5**	**-8.2**
19-Dec-00									-6.0	-3.9	-7.8	**-6.0**	**-3.9**	**-7.8**
20-Dec-00									-10.6	-7.8	-17.0	**-10.6**	**-7.8**	**-17.0**
21-Dec-00									-7.3	-3.6	-16.3	**-7.3**	**-3.6**	**-16.3**
22-Dec-00									-12.6	-6.6	-15.8	**-12.6**	**-6.6**	**-15.8**
23-Dec-00									-10.8	-6.4	-17.8	**-10.8**	**-6.4**	**-17.8**
24-Dec-00									-7.7	-4.8	-14.9	**-7.7**	**-4.8**	**-14.9**
25-Dec-00									-15.9	-10.8	-20.4	**-15.9**	**-10.8**	**-20.4**
26-Dec-00									-8.0	-6.1	-10.5	**-8.0**	**-6.1**	**-10.5**

Date	**Temperature Gauge**													
	Stouffville					**Pearson**			**Buttonville**			**Selected Temperatures in Analysis**		
	Calc Daily (from hr)	Daily Values	Processed (Daily if avail or Calc daily)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min	Calc Daily (from hr)	Day Max	Day Min
27-Dec-00									-8.4	-4.9	-15.7	**-8.4**	**-4.9**	**-15.7**
28-Dec-00									-15.6	-11.3	-19.7	**-15.6**	**-11.3**	**-19.7**
29-Dec-00									-13.4	-10.4	-16.5	**-13.4**	**-10.4**	**-16.5**
30-Dec-00									-8.4	-5.9	-11.3	**-8.4**	**-5.9**	**-11.3**
31-Dec-00									-9.3	-6.6	-12.1	**-9.3**	**-6.6**	**-12.1**

Appendix J: Evaporation Input Data for Calibration

1997 - 2000

The following table presents the lake evaporation data used in the water balance analysis. This data was generated using a 'fitted' curve generated from measurements at the Hamilton RGB AES station.

Evaporation	
Date	**'Fitted' Hamilton RGB Data** [mm]
01-Jan-97	0.253
02-Jan-97	0.255
03-Jan-97	0.258
04-Jan-97	0.261
05-Jan-97	0.263
06-Jan-97	0.266
07-Jan-97	0.269
08-Jan-97	0.271
09-Jan-97	0.274
10-Jan-97	0.277
11-Jan-97	0.279
12-Jan-97	0.282
13-Jan-97	0.285
14-Jan-97	0.287
15-Jan-97	0.290
16-Jan-97	0.307
17-Jan-97	0.324
18-Jan-97	0.341
19-Jan-97	0.358
20-Jan-97	0.375
21-Jan-97	0.392
22-Jan-97	0.409
23-Jan-97	0.426
24-Jan-97	0.443
25-Jan-97	0.460
26-Jan-97	0.477
27-Jan-97	0.494
28-Jan-97	0.511
29-Jan-97	0.528
30-Jan-97	0.545
31-Jan-97	0.562
01-Feb-97	0.562
02-Feb-97	0.579
03-Feb-97	0.596
04-Feb-97	0.613
05-Feb-97	0.630

Evaporation	
Date	**'Fitted' Hamilton RGB Data**
	[mm]
06-Feb-97	0.647
07-Feb-97	0.664
08-Feb-97	0.681
09-Feb-97	0.698
10-Feb-97	0.715
11-Feb-97	0.732
12-Feb-97	0.749
13-Feb-97	0.766
14-Feb-97	0.783
15-Feb-97	0.800
16-Feb-97	0.828
17-Feb-97	0.857
18-Feb-97	0.885
19-Feb-97	0.913
20-Feb-97	0.942
21-Feb-97	0.970
22-Feb-97	0.998
23-Feb-97	1.027
24-Feb-97	1.055
25-Feb-97	1.083
26-Feb-97	1.112
27-Feb-97	1.140
28-Feb-97	1.168
01-Mar-97	1.253
02-Mar-97	1.282
03-Mar-97	1.310
04-Mar-97	1.338
05-Mar-97	1.367
06-Mar-97	1.395
07-Mar-97	1.423
08-Mar-97	1.452
09-Mar-97	1.480
10-Mar-97	1.508
11-Mar-97	1.537
12-Mar-97	1.565
13-Mar-97	1.593
14-Mar-97	1.622
15-Mar-97	1.650
16-Mar-97	1.681
17-Mar-97	1.713
18-Mar-97	1.744
19-Mar-97	1.776

Evaporation	
Date	**'Fitted' Hamilton RGB Data**
	[mm]
20-Mar-97	1.807
21-Mar-97	1.839
22-Mar-97	1.870
23-Mar-97	1.902
24-Mar-97	1.933
25-Mar-97	1.965
26-Mar-97	1.996
27-Mar-97	2.028
28-Mar-97	2.059
29-Mar-97	2.091
30-Mar-97	2.122
31-Mar-97	2.153
01-Apr-97	2.153
02-Apr-97	2.185
03-Apr-97	2.216
04-Apr-97	2.248
05-Apr-97	2.279
06-Apr-97	2.311
07-Apr-97	2.342
08-Apr-97	2.374
09-Apr-97	2.405
10-Apr-97	2.437
11-Apr-97	2.468
12-Apr-97	2.500
13-Apr-97	2.531
14-Apr-97	2.563
15-Apr-97	2.594
16-Apr-97	2.624
17-Apr-97	2.653
18-Apr-97	2.683
19-Apr-97	2.713
20-Apr-97	2.742
21-Apr-97	2.772
22-Apr-97	2.802
23-Apr-97	2.831
24-Apr-97	2.861
25-Apr-97	2.891
26-Apr-97	2.920
27-Apr-97	2.950
28-Apr-97	2.979
29-Apr-97	3.009
30-Apr-97	3.039

Evaporation	
Date	**'Fitted' Hamilton RGB Data** [mm]
01-May-97	3.068
02-May-97	3.098
03-May-97	3.128
04-May-97	3.157
05-May-97	3.187
06-May-97	3.217
07-May-97	3.246
08-May-97	3.276
09-May-97	3.306
10-May-97	3.335
11-May-97	3.365
12-May-97	3.395
13-May-97	3.424
14-May-97	3.454
15-May-97	3.484
16-May-97	3.508
17-May-97	3.532
18-May-97	3.557
19-May-97	3.581
20-May-97	3.606
21-May-97	3.630
22-May-97	3.655
23-May-97	3.679
24-May-97	3.703
25-May-97	3.728
26-May-97	3.752
27-May-97	3.777
28-May-97	3.801
29-May-97	3.826
30-May-97	3.850
31-May-97	3.874
01-Jun-97	3.874
02-Jun-97	3.899
03-Jun-97	3.923
04-Jun-97	3.948
05-Jun-97	3.972
06-Jun-97	3.997
07-Jun-97	4.021
08-Jun-97	4.045
09-Jun-97	4.070
10-Jun-97	4.094
11-Jun-97	4.119

Evaporation	
Date	**'Fitted' Hamilton RGB Data**
	[mm]
12-Jun-97	4.143
13-Jun-97	4.168
14-Jun-97	4.192
15-Jun-97	4.216
16-Jun-97	4.223
17-Jun-97	4.230
18-Jun-97	4.237
19-Jun-97	4.244
20-Jun-97	4.251
21-Jun-97	4.258
22-Jun-97	4.265
23-Jun-97	4.272
24-Jun-97	4.279
25-Jun-97	4.286
26-Jun-97	4.293
27-Jun-97	4.300
28-Jun-97	4.307
29-Jun-97	4.314
30-Jun-97	4.321
01-Jul-97	4.328
02-Jul-97	4.335
03-Jul-97	4.342
04-Jul-97	4.349
05-Jul-97	4.356
06-Jul-97	4.363
07-Jul-97	4.370
08-Jul-97	4.377
09-Jul-97	4.384
10-Jul-97	4.391
11-Jul-97	4.398
12-Jul-97	4.405
13-Jul-97	4.412
14-Jul-97	4.419
15-Jul-97	4.426
16-Jul-97	4.397
17-Jul-97	4.369
18-Jul-97	4.340
19-Jul-97	4.312
20-Jul-97	4.283
21-Jul-97	4.255
22-Jul-97	4.226
23-Jul-97	4.198

Evaporation	
Date	**'Fitted' Hamilton RGB Data**
	[mm]
24-Jul-97	4.169
25-Jul-97	4.141
26-Jul-97	4.112
27-Jul-97	4.084
28-Jul-97	4.055
29-Jul-97	4.027
30-Jul-97	3.998
31-Jul-97	3.970
01-Aug-97	3.970
02-Aug-97	3.941
03-Aug-97	3.912
04-Aug-97	3.884
05-Aug-97	3.855
06-Aug-97	3.827
07-Aug-97	3.798
08-Aug-97	3.770
09-Aug-97	3.741
10-Aug-97	3.713
11-Aug-97	3.684
12-Aug-97	3.656
13-Aug-97	3.627
14-Aug-97	3.599
15-Aug-97	3.570
16-Aug-97	3.527
17-Aug-97	3.485
18-Aug-97	3.442
19-Aug-97	3.399
20-Aug-97	3.356
21-Aug-97	3.313
22-Aug-97	3.270
23-Aug-97	3.228
24-Aug-97	3.185
25-Aug-97	3.142
26-Aug-97	3.099
27-Aug-97	3.056
28-Aug-97	3.013
29-Aug-97	2.971
30-Aug-97	2.928
31-Aug-97	2.885
01-Sep-97	2.885
02-Sep-97	2.842
03-Sep-97	2.799

Evaporation	
Date	'Fitted' Hamilton RGB Data
	[mm]
04-Sep-97	2.757
05-Sep-97	2.714
06-Sep-97	2.671
07-Sep-97	2.628
08-Sep-97	2.585
09-Sep-97	2.542
10-Sep-97	2.500
11-Sep-97	2.457
12-Sep-97	2.414
13-Sep-97	2.371
14-Sep-97	2.328
15-Sep-97	2.285
16-Sep-97	2.249
17-Sep-97	2.213
18-Sep-97	2.177
19-Sep-97	2.141
20-Sep-97	2.105
21-Sep-97	2.069
22-Sep-97	2.033
23-Sep-97	1.997
24-Sep-97	1.961
25-Sep-97	1.925
26-Sep-97	1.889
27-Sep-97	1.853
28-Sep-97	1.817
29-Sep-97	1.781
30-Sep-97	1.745
01-Oct-97	1.709
02-Oct-97	1.672
03-Oct-97	1.636
04-Oct-97	1.600
05-Oct-97	1.564
06-Oct-97	1.528
07-Oct-97	1.492
08-Oct-97	1.456
09-Oct-97	1.420
10-Oct-97	1.384
11-Oct-97	1.348
12-Oct-97	1.312
13-Oct-97	1.276
14-Oct-97	1.240
15-Oct-97	1.204

Evaporation	
Date	**'Fitted' Hamilton RGB Data**
	[mm]
16-Oct-97	1.182
17-Oct-97	1.160
18-Oct-97	1.138
19-Oct-97	1.116
20-Oct-97	1.094
21-Oct-97	1.072
22-Oct-97	1.050
23-Oct-97	1.028
24-Oct-97	1.006
25-Oct-97	0.984
26-Oct-97	0.962
27-Oct-97	0.940
28-Oct-97	0.918
29-Oct-97	0.896
30-Oct-97	0.874
31-Oct-97	0.852
01-Nov-97	0.852
02-Nov-97	0.830
03-Nov-97	0.808
04-Nov-97	0.786
05-Nov-97	0.764
06-Nov-97	0.742
07-Nov-97	0.720
08-Nov-97	0.698
09-Nov-97	0.676
10-Nov-97	0.654
11-Nov-97	0.632
12-Nov-97	0.610
13-Nov-97	0.588
14-Nov-97	0.566
15-Nov-97	0.544
16-Nov-97	0.533
17-Nov-97	0.522
18-Nov-97	0.510
19-Nov-97	0.499
20-Nov-97	0.488
21-Nov-97	0.477
22-Nov-97	0.466
23-Nov-97	0.455
24-Nov-97	0.444
25-Nov-97	0.433
26-Nov-97	0.421

Evaporation	
Date	**'Fitted' Hamilton RGB Data** [mm]
27-Nov-97	0.410
28-Nov-97	0.399
29-Nov-97	0.388
30-Nov-97	0.377
01-Dec-97	0.366
02-Dec-97	0.355
03-Dec-97	0.344
04-Dec-97	0.332
05-Dec-97	0.321
06-Dec-97	0.310
07-Dec-97	0.299
08-Dec-97	0.288
09-Dec-97	0.277
10-Dec-97	0.266
11-Dec-97	0.255
12-Dec-97	0.243
13-Dec-97	0.232
14-Dec-97	0.221
15-Dec-97	0.210
16-Dec-97	0.213
17-Dec-97	0.215
18-Dec-97	0.218
19-Dec-97	0.221
20-Dec-97	0.223
21-Dec-97	0.226
22-Dec-97	0.229
23-Dec-97	0.231
24-Dec-97	0.234
25-Dec-97	0.237
26-Dec-97	0.239
27-Dec-97	0.242
28-Dec-97	0.245
29-Dec-97	0.247
30-Dec-97	0.250
31-Dec-97	0.253
01-Jan-98	0.253
02-Jan-98	0.255
03-Jan-98	0.258
04-Jan-98	0.261
05-Jan-98	0.263
06-Jan-98	0.266
07-Jan-98	0.269

Evaporation	
Date	**'Fitted' Hamilton RGB Data**
	[mm]
08-Jan-98	0.271
09-Jan-98	0.274
10-Jan-98	0.277
11-Jan-98	0.279
12-Jan-98	0.282
13-Jan-98	0.285
14-Jan-98	0.287
15-Jan-98	0.290
16-Jan-98	0.307
17-Jan-98	0.324
18-Jan-98	0.341
19-Jan-98	0.358
20-Jan-98	0.375
21-Jan-98	0.392
22-Jan-98	0.409
23-Jan-98	0.426
24-Jan-98	0.443
25-Jan-98	0.460
26-Jan-98	0.477
27-Jan-98	0.494
28-Jan-98	0.511
29-Jan-98	0.528
30-Jan-98	0.545
31-Jan-98	0.562
01-Feb-98	0.562
02-Feb-98	0.579
03-Feb-98	0.596
04-Feb-98	0.613
05-Feb-98	0.630
06-Feb-98	0.647
07-Feb-98	0.664
08-Feb-98	0.681
09-Feb-98	0.698
10-Feb-98	0.715
11-Feb-98	0.732
12-Feb-98	0.749
13-Feb-98	0.766
14-Feb-98	0.783
15-Feb-98	0.800
16-Feb-98	0.828
17-Feb-98	0.857
18-Feb-98	0.885

Evaporation	
Date	**'Fitted' Hamilton RGB Data**
	[mm]
19-Feb-98	0.913
20-Feb-98	0.942
21-Feb-98	0.970
22-Feb-98	0.998
23-Feb-98	1.027
24-Feb-98	1.055
25-Feb-98	1.083
26-Feb-98	1.112
27-Feb-98	1.140
28-Feb-98	1.168
01-Mar-98	1.253
02-Mar-98	1.282
03-Mar-98	1.310
04-Mar-98	1.338
05-Mar-98	1.367
06-Mar-98	1.395
07-Mar-98	1.423
08-Mar-98	1.452
09-Mar-98	1.480
10-Mar-98	1.508
11-Mar-98	1.537
12-Mar-98	1.565
13-Mar-98	1.593
14-Mar-98	1.622
15-Mar-98	1.650
16-Mar-98	1.681
17-Mar-98	1.713
18-Mar-98	1.744
19-Mar-98	1.776
20-Mar-98	1.807
21-Mar-98	1.839
22-Mar-98	1.870
23-Mar-98	1.902
24-Mar-98	1.933
25-Mar-98	1.965
26-Mar-98	1.996
27-Mar-98	2.028
28-Mar-98	2.059
29-Mar-98	2.091
30-Mar-98	2.122
31-Mar-98	2.153
01-Apr-98	2.153

Evaporation	
Date	**'Fitted' Hamilton RGB Data** [mm]
02-Apr-98	2.185
03-Apr-98	2.216
04-Apr-98	2.248
05-Apr-98	2.279
06-Apr-98	2.311
07-Apr-98	2.342
08-Apr-98	2.374
09-Apr-98	2.405
10-Apr-98	2.437
11-Apr-98	2.468
12-Apr-98	2.500
13-Apr-98	2.531
14-Apr-98	2.563
15-Apr-98	2.594
16-Apr-98	2.624
17-Apr-98	2.653
18-Apr-98	2.683
19-Apr-98	2.713
20-Apr-98	2.742
21-Apr-98	2.772
22-Apr-98	2.802
23-Apr-98	2.831
24-Apr-98	2.861
25-Apr-98	2.891
26-Apr-98	2.920
27-Apr-98	2.950
28-Apr-98	2.979
29-Apr-98	3.009
30-Apr-98	3.039
01-May-98	3.068
02-May-98	3.098
03-May-98	3.128
04-May-98	3.157
05-May-98	3.187
06-May-98	3.217
07-May-98	3.246
08-May-98	3.276
09-May-98	3.306
10-May-98	3.335
11-May-98	3.365
12-May-98	3.395
13-May-98	3.424

Evaporation	
Date	**'Fitted' Hamilton RGB Data**
	[mm]
14-May-98	3.454
15-May-98	3.484
16-May-98	3.508
17-May-98	3.532
18-May-98	3.557
19-May-98	3.581
20-May-98	3.606
21-May-98	3.630
22-May-98	3.655
23-May-98	3.679
24-May-98	3.703
25-May-98	3.728
26-May-98	3.752
27-May-98	3.777
28-May-98	3.801
29-May-98	3.826
30-May-98	3.850
31-May-98	3.874
01-Jun-98	3.874
02-Jun-98	3.899
03-Jun-98	3.923
04-Jun-98	3.948
05-Jun-98	3.972
06-Jun-98	3.997
07-Jun-98	4.021
08-Jun-98	4.045
09-Jun-98	4.070
10-Jun-98	4.094
11-Jun-98	4.119
12-Jun-98	4.143
13-Jun-98	4.168
14-Jun-98	4.192
15-Jun-98	4.216
16-Jun-98	4.223
17-Jun-98	4.230
18-Jun-98	4.237
19-Jun-98	4.244
20-Jun-98	4.251
21-Jun-98	4.258
22-Jun-98	4.265
23-Jun-98	4.272
24-Jun-98	4.279

Evaporation	
Date	**'Fitted' Hamilton RGB Data**
	[mm]
25-Jun-98	4.286
26-Jun-98	4.293
27-Jun-98	4.300
28-Jun-98	4.307
29-Jun-98	4.314
30-Jun-98	4.321
01-Jul-98	4.328
02-Jul-98	4.335
03-Jul-98	4.342
04-Jul-98	4.349
05-Jul-98	4.356
06-Jul-98	4.363
07-Jul-98	4.370
08-Jul-98	4.377
09-Jul-98	4.384
10-Jul-98	4.391
11-Jul-98	4.398
12-Jul-98	4.405
13-Jul-98	4.412
14-Jul-98	4.419
15-Jul-98	4.426
16-Jul-98	4.397
17-Jul-98	4.369
18-Jul-98	4.340
19-Jul-98	4.312
20-Jul-98	4.283
21-Jul-98	4.255
22-Jul-98	4.226
23-Jul-98	4.198
24-Jul-98	4.169
25-Jul-98	4.141
26-Jul-98	4.112
27-Jul-98	4.084
28-Jul-98	4.055
29-Jul-98	4.027
30-Jul-98	3.998
31-Jul-98	3.970
01-Aug-98	3.970
02-Aug-98	3.941
03-Aug-98	3.912
04-Aug-98	3.884
05-Aug-98	3.855

Evaporation	
Date	**'Fitted' Hamilton RGB Data** [mm]
06-Aug-98	3.827
07-Aug-98	3.798
08-Aug-98	3.770
09-Aug-98	3.741
10-Aug-98	3.713
11-Aug-98	3.684
12-Aug-98	3.656
13-Aug-98	3.627
14-Aug-98	3.599
15-Aug-98	3.570
16-Aug-98	3.527
17-Aug-98	3.485
18-Aug-98	3.442
19-Aug-98	3.399
20-Aug-98	3.356
21-Aug-98	3.313
22-Aug-98	3.270
23-Aug-98	3.228
24-Aug-98	3.185
25-Aug-98	3.142
26-Aug-98	3.099
27-Aug-98	3.056
28-Aug-98	3.013
29-Aug-98	2.971
30-Aug-98	2.928
31-Aug-98	2.885
01-Sep-98	2.885
02-Sep-98	2.842
03-Sep-98	2.799
04-Sep-98	2.757
05-Sep-98	2.714
06-Sep-98	2.671
07-Sep-98	2.628
08-Sep-98	2.585
09-Sep-98	2.542
10-Sep-98	2.500
11-Sep-98	2.457
12-Sep-98	2.414
13-Sep-98	2.371
14-Sep-98	2.328
15-Sep-98	2.285
16-Sep-98	2.249

Evaporation	
Date	**'Fitted' Hamilton RGB Data**
	[mm]
17-Sep-98	2.213
18-Sep-98	2.177
19-Sep-98	2.141
20-Sep-98	2.105
21-Sep-98	2.069
22-Sep-98	2.033
23-Sep-98	1.997
24-Sep-98	1.961
25-Sep-98	1.925
26-Sep-98	1.889
27-Sep-98	1.853
28-Sep-98	1.817
29-Sep-98	1.781
30-Sep-98	1.745
01-Oct-98	1.709
02-Oct-98	1.672
03-Oct-98	1.636
04-Oct-98	1.600
05-Oct-98	1.564
06-Oct-98	1.528
07-Oct-98	1.492
08-Oct-98	1.456
09-Oct-98	1.420
10-Oct-98	1.384
11-Oct-98	1.348
12-Oct-98	1.312
13-Oct-98	1.276
14-Oct-98	1.240
15-Oct-98	1.204
16-Oct-98	1.182
17-Oct-98	1.160
18-Oct-98	1.138
19-Oct-98	1.116
20-Oct-98	1.094
21-Oct-98	1.072
22-Oct-98	1.050
23-Oct-98	1.028
24-Oct-98	1.006
25-Oct-98	0.984
26-Oct-98	0.962
27-Oct-98	0.940
28-Oct-98	0.918

Evaporation	
Date	**'Fitted' Hamilton RGB Data** [mm]
29-Oct-98	0.896
30-Oct-98	0.874
31-Oct-98	0.852
01-Nov-98	0.852
02-Nov-98	0.830
03-Nov-98	0.808
04-Nov-98	0.786
05-Nov-98	0.764
06-Nov-98	0.742
07-Nov-98	0.720
08-Nov-98	0.698
09-Nov-98	0.676
10-Nov-98	0.654
11-Nov-98	0.632
12-Nov-98	0.610
13-Nov-98	0.588
14-Nov-98	0.566
15-Nov-98	0.544
16-Nov-98	0.533
17-Nov-98	0.522
18-Nov-98	0.510
19-Nov-98	0.499
20-Nov-98	0.488
21-Nov-98	0.477
22-Nov-98	0.466
23-Nov-98	0.455
24-Nov-98	0.444
25-Nov-98	0.433
26-Nov-98	0.421
27-Nov-98	0.410
28-Nov-98	0.399
29-Nov-98	0.388
30-Nov-98	0.377
01-Dec-98	0.366
02-Dec-98	0.355
03-Dec-98	0.344
04-Dec-98	0.332
05-Dec-98	0.321
06-Dec-98	0.310
07-Dec-98	0.299
08-Dec-98	0.288
09-Dec-98	0.277

Evaporation	
Date	'Fitted' Hamilton RGB Data [mm]
10-Dec-98	0.266
11-Dec-98	0.255
12-Dec-98	0.243
13-Dec-98	0.232
14-Dec-98	0.221
15-Dec-98	0.210
16-Dec-98	0.213
17-Dec-98	0.215
18-Dec-98	0.218
19-Dec-98	0.221
20-Dec-98	0.223
21-Dec-98	0.226
22-Dec-98	0.229
23-Dec-98	0.231
24-Dec-98	0.234
25-Dec-98	0.237
26-Dec-98	0.239
27-Dec-98	0.242
28-Dec-98	0.245
29-Dec-98	0.247
30-Dec-98	0.250
31-Dec-98	0.253
01-Jan-99	0.253
02-Jan-99	0.255
03-Jan-99	0.258
04-Jan-99	0.261
05-Jan-99	0.263
06-Jan-99	0.266
07-Jan-99	0.269
08-Jan-99	0.271
09-Jan-99	0.274
10-Jan-99	0.277
11-Jan-99	0.279
12-Jan-99	0.282
13-Jan-99	0.285
14-Jan-99	0.287
15-Jan-99	0.290
16-Jan-99	0.307
17-Jan-99	0.324
18-Jan-99	0.341
19-Jan-99	0.358
20-Jan-99	0.375

Evaporation	
Date	**'Fitted' Hamilton RGB Data**
	[mm]
21-Jan-99	0.392
22-Jan-99	0.409
23-Jan-99	0.426
24-Jan-99	0.443
25-Jan-99	0.460
26-Jan-99	0.477
27-Jan-99	0.494
28-Jan-99	0.511
29-Jan-99	0.528
30-Jan-99	0.545
31-Jan-99	0.562
01-Feb-99	0.562
02-Feb-99	0.579
03-Feb-99	0.596
04-Feb-99	0.613
05-Feb-99	0.630
06-Feb-99	0.647
07-Feb-99	0.664
08-Feb-99	0.681
09-Feb-99	0.698
10-Feb-99	0.715
11-Feb-99	0.732
12-Feb-99	0.749
13-Feb-99	0.766
14-Feb-99	0.783
15-Feb-99	0.800
16-Feb-99	0.828
17-Feb-99	0.857
18-Feb-99	0.885
19-Feb-99	0.913
20-Feb-99	0.942
21-Feb-99	0.970
22-Feb-99	0.998
23-Feb-99	1.027
24-Feb-99	1.055
25-Feb-99	1.083
26-Feb-99	1.112
27-Feb-99	1.140
28-Feb-99	1.168
01-Mar-99	1.253
02-Mar-99	1.282
03-Mar-99	1.310

Evaporation	
Date	**'Fitted' Hamilton RGB Data** [mm]
04-Mar-99	1.338
05-Mar-99	1.367
06-Mar-99	1.395
07-Mar-99	1.423
08-Mar-99	1.452
09-Mar-99	1.480
10-Mar-99	1.508
11-Mar-99	1.537
12-Mar-99	1.565
13-Mar-99	1.593
14-Mar-99	1.622
15-Mar-99	1.650
16-Mar-99	1.681
17-Mar-99	1.713
18-Mar-99	1.744
19-Mar-99	1.776
20-Mar-99	1.807
21-Mar-99	1.839
22-Mar-99	1.870
23-Mar-99	1.902
24-Mar-99	1.933
25-Mar-99	1.965
26-Mar-99	1.996
27-Mar-99	2.028
28-Mar-99	2.059
29-Mar-99	2.091
30-Mar-99	2.122
31-Mar-99	2.153
01-Apr-99	2.153
02-Apr-99	2.185
03-Apr-99	2.216
04-Apr-99	2.248
05-Apr-99	2.279
06-Apr-99	2.311
07-Apr-99	2.342
08-Apr-99	2.374
09-Apr-99	2.405
10-Apr-99	2.437
11-Apr-99	2.468
12-Apr-99	2.500
13-Apr-99	2.531
14-Apr-99	2.563

Evaporation	
Date	**'Fitted' Hamilton RGB Data**
	[mm]
15-Apr-99	2.594
16-Apr-99	2.624
17-Apr-99	2.653
18-Apr-99	2.683
19-Apr-99	2.713
20-Apr-99	2.742
21-Apr-99	2.772
22-Apr-99	2.802
23-Apr-99	2.831
24-Apr-99	2.861
25-Apr-99	2.891
26-Apr-99	2.920
27-Apr-99	2.950
28-Apr-99	2.979
29-Apr-99	3.009
30-Apr-99	3.039
01-May-99	3.068
02-May-99	3.098
03-May-99	3.128
04-May-99	3.157
05-May-99	3.187
06-May-99	3.217
07-May-99	3.246
08-May-99	3.276
09-May-99	3.306
10-May-99	3.335
11-May-99	3.365
12-May-99	3.395
13-May-99	3.424
14-May-99	3.454
15-May-99	3.484
16-May-99	3.508
17-May-99	3.532
18-May-99	3.557
19-May-99	3.581
20-May-99	3.606
21-May-99	3.630
22-May-99	3.655
23-May-99	3.679
24-May-99	3.703
25-May-99	3.728
26-May-99	3.752

Evaporation	
Date	**'Fitted' Hamilton RGB Data**
	[mm]
27-May-99	3.777
28-May-99	3.801
29-May-99	3.826
30-May-99	3.850
31-May-99	3.874
01-Jun-99	3.874
02-Jun-99	3.899
03-Jun-99	3.923
04-Jun-99	3.948
05-Jun-99	3.972
06-Jun-99	3.997
07-Jun-99	4.021
08-Jun-99	4.045
09-Jun-99	4.070
10-Jun-99	4.094
11-Jun-99	4.119
12-Jun-99	4.143
13-Jun-99	4.168
14-Jun-99	4.192
15-Jun-99	4.216
16-Jun-99	4.223
17-Jun-99	4.230
18-Jun-99	4.237
19-Jun-99	4.244
20-Jun-99	4.251
21-Jun-99	4.258
22-Jun-99	4.265
23-Jun-99	4.272
24-Jun-99	4.279
25-Jun-99	4.286
26-Jun-99	4.293
27-Jun-99	4.300
28-Jun-99	4.307
29-Jun-99	4.314
30-Jun-99	4.321
01-Jul-99	4.328
02-Jul-99	4.335
03-Jul-99	4.342
04-Jul-99	4.349
05-Jul-99	4.356
06-Jul-99	4.363
07-Jul-99	4.370

Evaporation	
Date	'Fitted' Hamilton RGB Data
	[mm]
08-Jul-99	4.377
09-Jul-99	4.384
10-Jul-99	4.391
11-Jul-99	4.398
12-Jul-99	4.405
13-Jul-99	4.412
14-Jul-99	4.419
15-Jul-99	4.426
16-Jul-99	4.397
17-Jul-99	4.369
18-Jul-99	4.340
19-Jul-99	4.312
20-Jul-99	4.283
21-Jul-99	4.255
22-Jul-99	4.226
23-Jul-99	4.198
24-Jul-99	4.169
25-Jul-99	4.141
26-Jul-99	4.112
27-Jul-99	4.084
28-Jul-99	4.055
29-Jul-99	4.027
30-Jul-99	3.998
31-Jul-99	3.970
01-Aug-99	3.970
02-Aug-99	3.941
03-Aug-99	3.912
04-Aug-99	3.884
05-Aug-99	3.855
06-Aug-99	3.827
07-Aug-99	3.798
08-Aug-99	3.770
09-Aug-99	3.741
10-Aug-99	3.713
11-Aug-99	3.684
12-Aug-99	3.656
13-Aug-99	3.627
14-Aug-99	3.599
15-Aug-99	3.570
16-Aug-99	3.527
17-Aug-99	3.485
18-Aug-99	3.442

Evaporation	
Date	**'Fitted' Hamilton RGB Data** [mm]
19-Aug-99	3.399
20-Aug-99	3.356
21-Aug-99	3.313
22-Aug-99	3.270
23-Aug-99	3.228
24-Aug-99	3.185
25-Aug-99	3.142
26-Aug-99	3.099
27-Aug-99	3.056
28-Aug-99	3.013
29-Aug-99	2.971
30-Aug-99	2.928
31-Aug-99	2.885
01-Sep-99	2.885
02-Sep-99	2.842
03-Sep-99	2.799
04-Sep-99	2.757
05-Sep-99	2.714
06-Sep-99	2.671
07-Sep-99	2.628
08-Sep-99	2.585
09-Sep-99	2.542
10-Sep-99	2.500
11-Sep-99	2.457
12-Sep-99	2.414
13-Sep-99	2.371
14-Sep-99	2.328
15-Sep-99	2.285
16-Sep-99	2.249
17-Sep-99	2.213
18-Sep-99	2.177
19-Sep-99	2.141
20-Sep-99	2.105
21-Sep-99	2.069
22-Sep-99	2.033
23-Sep-99	1.997
24-Sep-99	1.961
25-Sep-99	1.925
26-Sep-99	1.889
27-Sep-99	1.853
28-Sep-99	1.817
29-Sep-99	1.781

Evaporation	
Date	**'Fitted' Hamilton RGB Data**
	[mm]
30-Sep-99	1.745
01-Oct-99	1.709
02-Oct-99	1.672
03-Oct-99	1.636
04-Oct-99	1.600
05-Oct-99	1.564
06-Oct-99	1.528
07-Oct-99	1.492
08-Oct-99	1.456
09-Oct-99	1.420
10-Oct-99	1.384
11-Oct-99	1.348
12-Oct-99	1.312
13-Oct-99	1.276
14-Oct-99	1.240
15-Oct-99	1.204
16-Oct-99	1.182
17-Oct-99	1.160
18-Oct-99	1.138
19-Oct-99	1.116
20-Oct-99	1.094
21-Oct-99	1.072
22-Oct-99	1.050
23-Oct-99	1.028
24-Oct-99	1.006
25-Oct-99	0.984
26-Oct-99	0.962
27-Oct-99	0.940
28-Oct-99	0.918
29-Oct-99	0.896
30-Oct-99	0.874
31-Oct-99	0.852
01-Nov-99	0.852
02-Nov-99	0.830
03-Nov-99	0.808
04-Nov-99	0.786
05-Nov-99	0.764
06-Nov-99	0.742
07-Nov-99	0.720
08-Nov-99	0.698
09-Nov-99	0.676
10-Nov-99	0.654

Evaporation	
Date	**'Fitted' Hamilton RGB Data** [mm]
11-Nov-99	0.632
12-Nov-99	0.610
13-Nov-99	0.588
14-Nov-99	0.566
15-Nov-99	0.544
16-Nov-99	0.533
17-Nov-99	0.522
18-Nov-99	0.510
19-Nov-99	0.499
20-Nov-99	0.488
21-Nov-99	0.477
22-Nov-99	0.466
23-Nov-99	0.455
24-Nov-99	0.444
25-Nov-99	0.433
26-Nov-99	0.421
27-Nov-99	0.410
28-Nov-99	0.399
29-Nov-99	0.388
30-Nov-99	0.377
01-Dec-99	0.366
02-Dec-99	0.355
03-Dec-99	0.344
04-Dec-99	0.332
05-Dec-99	0.321
06-Dec-99	0.310
07-Dec-99	0.299
08-Dec-99	0.288
09-Dec-99	0.277
10-Dec-99	0.266
11-Dec-99	0.255
12-Dec-99	0.243
13-Dec-99	0.232
14-Dec-99	0.221
15-Dec-99	0.210
16-Dec-99	0.213
17-Dec-99	0.215
18-Dec-99	0.218
19-Dec-99	0.221
20-Dec-99	0.223
21-Dec-99	0.226
22-Dec-99	0.229

Evaporation	
Date	'Fitted' Hamilton RGB Data [mm]
23-Dec-99	0.231
24-Dec-99	0.234
25-Dec-99	0.237
26-Dec-99	0.239
27-Dec-99	0.242
28-Dec-99	0.245
29-Dec-99	0.247
30-Dec-99	0.250
31-Dec-99	0.253
01-Jan-00	0.253
02-Jan-00	0.255
03-Jan-00	0.258
04-Jan-00	0.261
05-Jan-00	0.263
06-Jan-00	0.266
07-Jan-00	0.269
08-Jan-00	0.271
09-Jan-00	0.274
10-Jan-00	0.277
11-Jan-00	0.279
12-Jan-00	0.282
13-Jan-00	0.285
14-Jan-00	0.287
15-Jan-00	0.290
16-Jan-00	0.307
17-Jan-00	0.324
18-Jan-00	0.341
19-Jan-00	0.358
20-Jan-00	0.375
21-Jan-00	0.392
22-Jan-00	0.409
23-Jan-00	0.426
24-Jan-00	0.443
25-Jan-00	0.460
26-Jan-00	0.477
27-Jan-00	0.494
28-Jan-00	0.511
29-Jan-00	0.528
30-Jan-00	0.545
31-Jan-00	0.562
01-Feb-00	0.562
02-Feb-00	0.579

Evaporation	
Date	**'Fitted' Hamilton RGB Data**
	[mm]
03-Feb-00	0.596
04-Feb-00	0.613
05-Feb-00	0.630
06-Feb-00	0.647
07-Feb-00	0.664
08-Feb-00	0.681
09-Feb-00	0.698
10-Feb-00	0.715
11-Feb-00	0.732
12-Feb-00	0.749
13-Feb-00	0.766
14-Feb-00	0.783
15-Feb-00	0.800
16-Feb-00	0.828
17-Feb-00	0.857
18-Feb-00	0.885
19-Feb-00	0.913
20-Feb-00	0.942
21-Feb-00	0.970
22-Feb-00	0.998
23-Feb-00	1.027
24-Feb-00	1.055
25-Feb-00	1.083
26-Feb-00	1.112
27-Feb-00	1.140
28-Feb-00	1.168
29-Feb-00	1.197
01-Mar-00	1.253
02-Mar-00	1.282
03-Mar-00	1.310
04-Mar-00	1.338
05-Mar-00	1.367
06-Mar-00	1.395
07-Mar-00	1.423
08-Mar-00	1.452
09-Mar-00	1.480
10-Mar-00	1.508
11-Mar-00	1.537
12-Mar-00	1.565
13-Mar-00	1.593
14-Mar-00	1.622
15-Mar-00	1.650

Evaporation	
Date	**'Fitted' Hamilton RGB Data** [mm]
16-Mar-00	1.681
17-Mar-00	1.713
18-Mar-00	1.744
19-Mar-00	1.776
20-Mar-00	1.807
21-Mar-00	1.839
22-Mar-00	1.870
23-Mar-00	1.902
24-Mar-00	1.933
25-Mar-00	1.965
26-Mar-00	1.996
27-Mar-00	2.028
28-Mar-00	2.059
29-Mar-00	2.091
30-Mar-00	2.122
31-Mar-00	2.153
01-Apr-00	2.153
02-Apr-00	2.185
03-Apr-00	2.216
04-Apr-00	2.248
05-Apr-00	2.279
06-Apr-00	2.311
07-Apr-00	2.342
08-Apr-00	2.374
09-Apr-00	2.405
10-Apr-00	2.437
11-Apr-00	2.468
12-Apr-00	2.500
13-Apr-00	2.531
14-Apr-00	2.563
15-Apr-00	2.594
16-Apr-00	2.624
17-Apr-00	2.653
18-Apr-00	2.683
19-Apr-00	2.713
20-Apr-00	2.742
21-Apr-00	2.772
22-Apr-00	2.802
23-Apr-00	2.831
24-Apr-00	2.861
25-Apr-00	2.891
26-Apr-00	2.920

Evaporation	
Date	**'Fitted' Hamilton RGB Data**
	[mm]
27-Apr-00	2.950
28-Apr-00	2.979
29-Apr-00	3.009
30-Apr-00	3.039
01-May-00	3.068
02-May-00	3.098
03-May-00	3.128
04-May-00	3.157
05-May-00	3.187
06-May-00	3.217
07-May-00	3.246
08-May-00	3.276
09-May-00	3.306
10-May-00	3.335
11-May-00	3.365
12-May-00	3.395
13-May-00	3.424
14-May-00	3.454
15-May-00	3.484
16-May-00	3.508
17-May-00	3.532
18-May-00	3.557
19-May-00	3.581
20-May-00	3.606
21-May-00	3.630
22-May-00	3.655
23-May-00	3.679
24-May-00	3.703
25-May-00	3.728
26-May-00	3.752
27-May-00	3.777
28-May-00	3.801
29-May-00	3.826
30-May-00	3.850
31-May-00	3.874
01-Jun-00	3.874
02-Jun-00	3.899
03-Jun-00	3.923
04-Jun-00	3.948
05-Jun-00	3.972
06-Jun-00	3.997
07-Jun-00	4.021

Evaporation	
Date	**'Fitted' Hamilton RGB Data**
	[mm]
08-Jun-00	4.045
09-Jun-00	4.070
10-Jun-00	4.094
11-Jun-00	4.119
12-Jun-00	4.143
13-Jun-00	4.168
14-Jun-00	4.192
15-Jun-00	4.216
16-Jun-00	4.223
17-Jun-00	4.230
18-Jun-00	4.237
19-Jun-00	4.244
20-Jun-00	4.251
21-Jun-00	4.258
22-Jun-00	4.265
23-Jun-00	4.272
24-Jun-00	4.279
25-Jun-00	4.286
26-Jun-00	4.293
27-Jun-00	4.300
28-Jun-00	4.307
29-Jun-00	4.314
30-Jun-00	4.321
01-Jul-00	4.328
02-Jul-00	4.335
03-Jul-00	4.342
04-Jul-00	4.349
05-Jul-00	4.356
06-Jul-00	4.363
07-Jul-00	4.370
08-Jul-00	4.377
09-Jul-00	4.384
10-Jul-00	4.391
11-Jul-00	4.398
12-Jul-00	4.405
13-Jul-00	4.412
14-Jul-00	4.419
15-Jul-00	4.426
16-Jul-00	4.397
17-Jul-00	4.369
18-Jul-00	4.340
19-Jul-00	4.312

Evaporation	
Date	**'Fitted' Hamilton RGB Data**
	[mm]
20-Jul-00	4.283
21-Jul-00	4.255
22-Jul-00	4.226
23-Jul-00	4.198
24-Jul-00	4.169
25-Jul-00	4.141
26-Jul-00	4.112
27-Jul-00	4.084
28-Jul-00	4.055
29-Jul-00	4.027
30-Jul-00	3.998
31-Jul-00	3.970
01-Aug-00	3.970
02-Aug-00	3.941
03-Aug-00	3.912
04-Aug-00	3.884
05-Aug-00	3.855
06-Aug-00	3.827
07-Aug-00	3.798
08-Aug-00	3.770
09-Aug-00	3.741
10-Aug-00	3.713
11-Aug-00	3.684
12-Aug-00	3.656
13-Aug-00	3.627
14-Aug-00	3.599
15-Aug-00	3.570
16-Aug-00	3.527
17-Aug-00	3.485
18-Aug-00	3.442
19-Aug-00	3.399
20-Aug-00	3.356
21-Aug-00	3.313
22-Aug-00	3.270
23-Aug-00	3.228
24-Aug-00	3.185
25-Aug-00	3.142
26-Aug-00	3.099
27-Aug-00	3.056
28-Aug-00	3.013
29-Aug-00	2.971
30-Aug-00	2.928

Evaporation	
Date	**'Fitted' Hamilton RGB Data** [mm]
31-Aug-00	2.885
01-Sep-00	2.885
02-Sep-00	2.842
03-Sep-00	2.799
04-Sep-00	2.757
05-Sep-00	2.714
06-Sep-00	2.671
07-Sep-00	2.628
08-Sep-00	2.585
09-Sep-00	2.542
10-Sep-00	2.500
11-Sep-00	2.457
12-Sep-00	2.414
13-Sep-00	2.371
14-Sep-00	2.328
15-Sep-00	2.285
16-Sep-00	2.249
17-Sep-00	2.213
18-Sep-00	2.177
19-Sep-00	2.141
20-Sep-00	2.105
21-Sep-00	2.069
22-Sep-00	2.033
23-Sep-00	1.997
24-Sep-00	1.961
25-Sep-00	1.925
26-Sep-00	1.889
27-Sep-00	1.853
28-Sep-00	1.817
29-Sep-00	1.781
30-Sep-00	1.745
01-Oct-00	1.709
02-Oct-00	1.672
03-Oct-00	1.636
04-Oct-00	1.600
05-Oct-00	1.564
06-Oct-00	1.528
07-Oct-00	1.492
08-Oct-00	1.456
09-Oct-00	1.420
10-Oct-00	1.384
11-Oct-00	1.348

Evaporation	
Date	'Fitted' Hamilton RGB Data
	[mm]
12-Oct-00	1.312
13-Oct-00	1.276
14-Oct-00	1.240
15-Oct-00	1.204
16-Oct-00	1.182
17-Oct-00	1.160
18-Oct-00	1.138
19-Oct-00	1.116
20-Oct-00	1.094
21-Oct-00	1.072
22-Oct-00	1.050
23-Oct-00	1.028
24-Oct-00	1.006
25-Oct-00	0.984
26-Oct-00	0.962
27-Oct-00	0.940
28-Oct-00	0.918
29-Oct-00	0.896
30-Oct-00	0.874
31-Oct-00	0.852
01-Nov-00	0.852
02-Nov-00	0.830
03-Nov-00	0.808
04-Nov-00	0.786
05-Nov-00	0.764
06-Nov-00	0.742
07-Nov-00	0.720
08-Nov-00	0.698
09-Nov-00	0.676
10-Nov-00	0.654
11-Nov-00	0.632
12-Nov-00	0.610
13-Nov-00	0.588
14-Nov-00	0.566
15-Nov-00	0.544
16-Nov-00	0.533
17-Nov-00	0.522
18-Nov-00	0.510
19-Nov-00	0.499
20-Nov-00	0.488
21-Nov-00	0.477
22-Nov-00	0.466

Evaporation	
Date	'Fitted' Hamilton RGB Data
	[mm]
23-Nov-00	0.455
24-Nov-00	0.444
25-Nov-00	0.433
26-Nov-00	0.421
27-Nov-00	0.410
28-Nov-00	0.399
29-Nov-00	0.388
30-Nov-00	0.377
01-Dec-00	0.366
02-Dec-00	0.355
03-Dec-00	0.344
04-Dec-00	0.332
05-Dec-00	0.321
06-Dec-00	0.310
07-Dec-00	0.299
08-Dec-00	0.288
09-Dec-00	0.277
10-Dec-00	0.266
11-Dec-00	0.255
12-Dec-00	0.243
13-Dec-00	0.232
14-Dec-00	0.221
15-Dec-00	0.210
16-Dec-00	0.213
17-Dec-00	0.215
18-Dec-00	0.218
19-Dec-00	0.221
20-Dec-00	0.223
21-Dec-00	0.226
22-Dec-00	0.229
23-Dec-00	0.231
24-Dec-00	0.234
25-Dec-00	0.237
26-Dec-00	0.239
27-Dec-00	0.242
28-Dec-00	0.245
29-Dec-00	0.247
30-Dec-00	0.250
31-Dec-00	0.253

TECHNICAL ANALYSIS AND INTEGRATION PROCESS SUMMARY REPORT

DUFFINS AND CARRUTHERS CREEK WATERSHED PLAN

August, 2003

Prepared by

Toronto and Region Conservation

in cooperation with

Aquafor Beech Ltd.
Clarifica Inc.
Gerber Geosciences Inc.
Stantec Consulting Ltd.

For the Duffins and Carruthers Creek Watershed Task Forces

Preface

This report contains an overview of the individual technical studies carried out in support of the Duffins and Carruthers Creek Watershed Plan. It is intended to serve those readers who wish to understand the general scope of technical work and rationale behind management strategy recommendations, but who do not require full copies of all technical background reports. All supporting documents are listed at the back of the report, and may be obtained from the TRCA.

NOTE: In this report, figures are found at the end of each chapter.

TECHNICAL ANALYSIS AND INTEGRATION PROCESS
SUMMARY REPORT FOR THE
DUFFINS AND CARRUTHERS CREEK WATERSHED PLAN

August, 2003

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1.0 INTRODUCTION

1.1 Duffins and Carruthers Creek Watershed Planning Process

In 1999, the Toronto and Region Conservation Authority (TRCA) began the process of developing a watershed management plan for the Duffins and Carruthers Creek watersheds. This initiative continued the Authority's commitment, under its 1989 Greenspace Strategy, to prepare a watershed strategy for each of the nine watersheds within its jurisdiction. The Duffins Creek watershed, draining an area of 283 km^2, and Carruthers Creek watershed, draining 38 km^2, form the eastern end of the TRCA jurisdiction **(Figure 1-1)**. This planning initiative represented the sixth and seventh management strategies to be completed out of the nine TRCA watersheds, and as such was designed to build upon the successes and lessons learned from past experience.

The purpose of the Duffins and Carruthers Creek watershed planning process was to: undertake a thorough study of natural features and functions, human heritage, and public use and the interdependencies among these elements; evaluate the potential effects of current and future watershed activities; and identify management actions needed for watershed protection and enhancement.

The planning process was divided into three phases **(Figure 1-2)**. The Characterization phase involved the assessment of current watershed conditions and issues, which were documented in State of the Watershed Reports produced for each watershed (TRCA, 2002). Management goals, objectives, and associated indicators and working targets were also developed in this phase and were used to guide the technical analysis. The Technical Analysis and Integration phase involved an evaluation of the watershed's response to alternative land use and management scenarios. The final phase, Plan Development, focused on preparation of the watershed plan, including management recommendations, implementation strategies, roles and responsibilities. Recognizing the importance of involving watershed residents and other stakeholders, an extensive and broad-based public and stakeholder involvement program was conducted throughout the process.

This report documents the process, methodologies, and key findings associated with the Technical Analysis and Integration phase of the Duffins and Carruthers Watershed Planning Process. As such, it is a background report supporting the Watershed Plan and other associated technical reports and implementation plans.

1.2 Toward an Integrated Analysis

From the 1980s to the present, watershed management practices in Ontario and internationally have evolved significantly toward an integrated approach.

> *"Integration is the study of the complete system (the watershed, its components, and their interrelationships). Integration in watershed planning is both a process and an evolving discipline - a science that is cross-disciplinary in nature. As a discipline, integration is a very young science.*
>
> (Snodgrass *et. al.*, 1996)

Table 1-1 describes several of the trends and characteristics associated with current practice. "State-of-the-art watershed management today not only addresses a broader range of resource and environmental protection issues than previous initiatives, but also considers and evaluates the interrelationships among these issues" (CVC, GRCA, and TRCA, 2002).

Table 1-1: Trends in Watershed Planning and Management Approaches

SHIFT FROM		***TO***
Single media focus (e.g. flood management)	➜	Trans media, cumulative approaches (e.g. hydrology, aquatic and terrestrial natural heritage, human heritage, etc.)
Natural science focus	➜	Ecosystem approaches addressing natural watershed systems and the human communities in them
Single disciplinary led	➜	Interdisciplinary
Government led	➜	Multi-stakeholder involvement and empowerment
Regulated and reactive approaches	➜	Shared responsibilities, proactive approaches

(Heathcote, 1998; Executive Resource Group, 2001; Conservation Ontario, 2001)

In order to take a proactive approach, watershed managers must anticipate future activities that will take place within the watershed and quantitatively predict the watershed response to these activities to the extent possible. The evaluation should be carried out within each technical discipline and address linkages between the disciplines and within the system as a whole. The degree to which the scientific relationships are understood and the availability of predictive models, necessary to quantify these linkages, varies from one science to another.

A 1997 study by a committee of the provincial government identified ten essential scientific components of watershed management: aquatics, terrestrial, hydrology, stream morphology, water quality, groundwater/hydrogeology, economics, social, mapping and data management, and integration. Following a review of current practice, the committee reported that the components of aquatics, hydrology, and water quality generally reflect state-of-the-art science, however applications within the remaining components are generally lagging behind state-of-the-art (WPIPMC, 1997).

Integrated watershed management is still a relatively new concept. Although the management of water on a watershed basis is reasonably well accepted, Heathcote (1998) acknowledges that water management activities are less frequently integrated with other resource management activities affecting or affected by water. Even where practitioners express an interest in analysing the effects of resource management decisions on watershed systems, Snodgrass *et.al.* (1996) have noted *"...the field is at least half a decade away from being able to quantify the 'stress-response' relationships as a predictive tool for impact assessment, and the immediate future will depend upon relationships and synthesis of models and experience".* While predictive models and tools have been widely available in the fields of hydrology, hydrogeology and water quality, similar tools are still being developed in the fields of aquatic and terrestrial ecology, human heritage, and in the overall science of integrated watershed planning.

Given the relatively rich information base existing within the Duffins and Carruthers Creek watersheds and TRCA's extensive experience with broad-based watershed planning, the Watershed Task Forces were in a good position to not only employ, but advance, the state-of-the-art in integrated watershed planning.

1.3 Purpose

The overall goal of the technical work was to provide a defensible, scientific knowledge base that could be used to set management policies and recommendations that will contribute to the long term protection and enhancement of the health of the Duffins and Carruthers Creek watersheds and their communities. A key aspect of the approach to this work was the attempt to advance the state-of-the-art practice in predicting the response of watershed systems to alternative land use and management scenarios and interpreting the interdependencies among watershed systems.

The studies addressed three primary objectives:

1. To develop benchmarks of watershed condition in response to selected alternative land use and management scenarios;

2. To identify key management issues and effective management approaches; and

3. To develop and test an improved integration model for TRCA watershed and subwatershed planning.

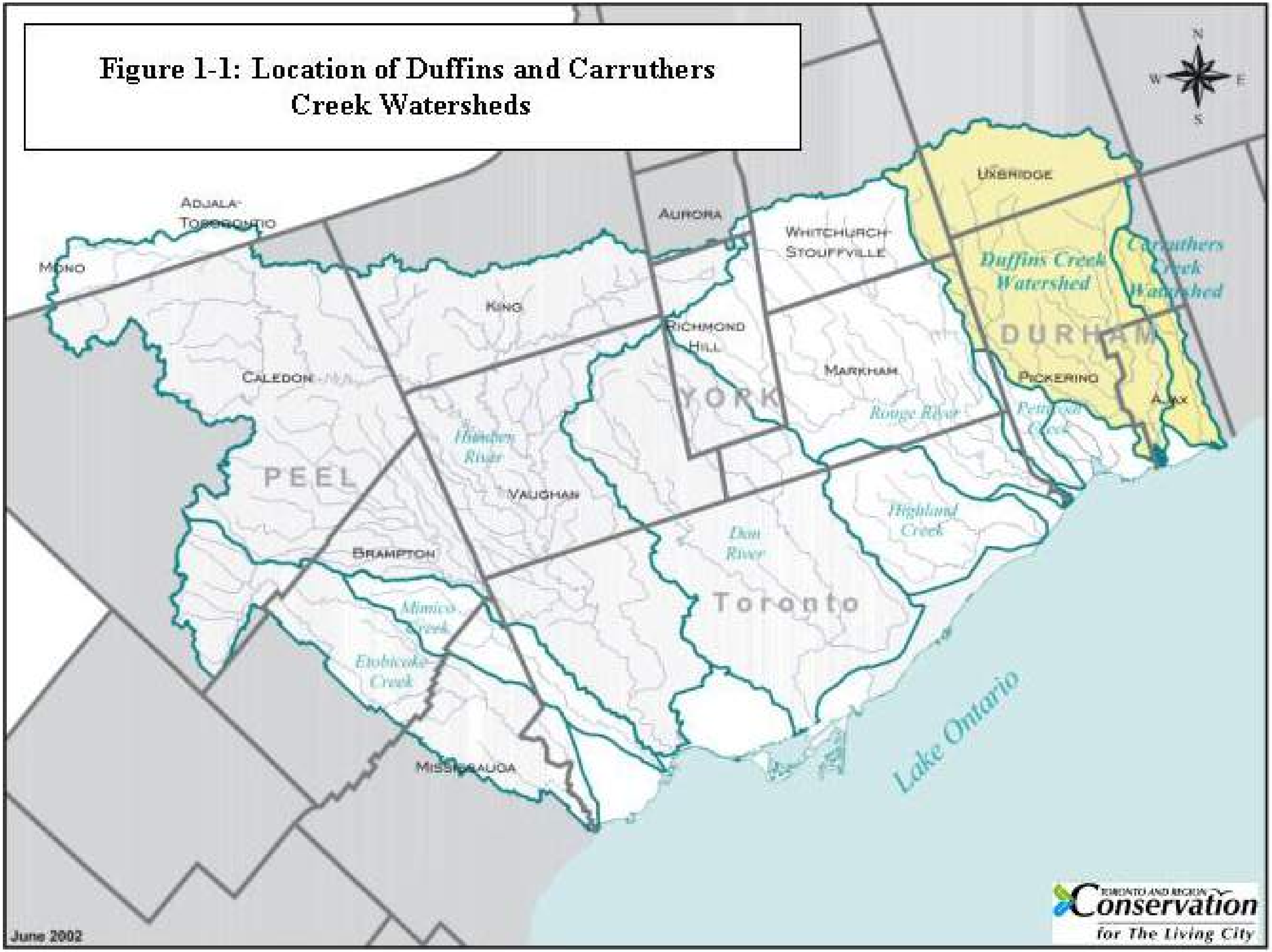
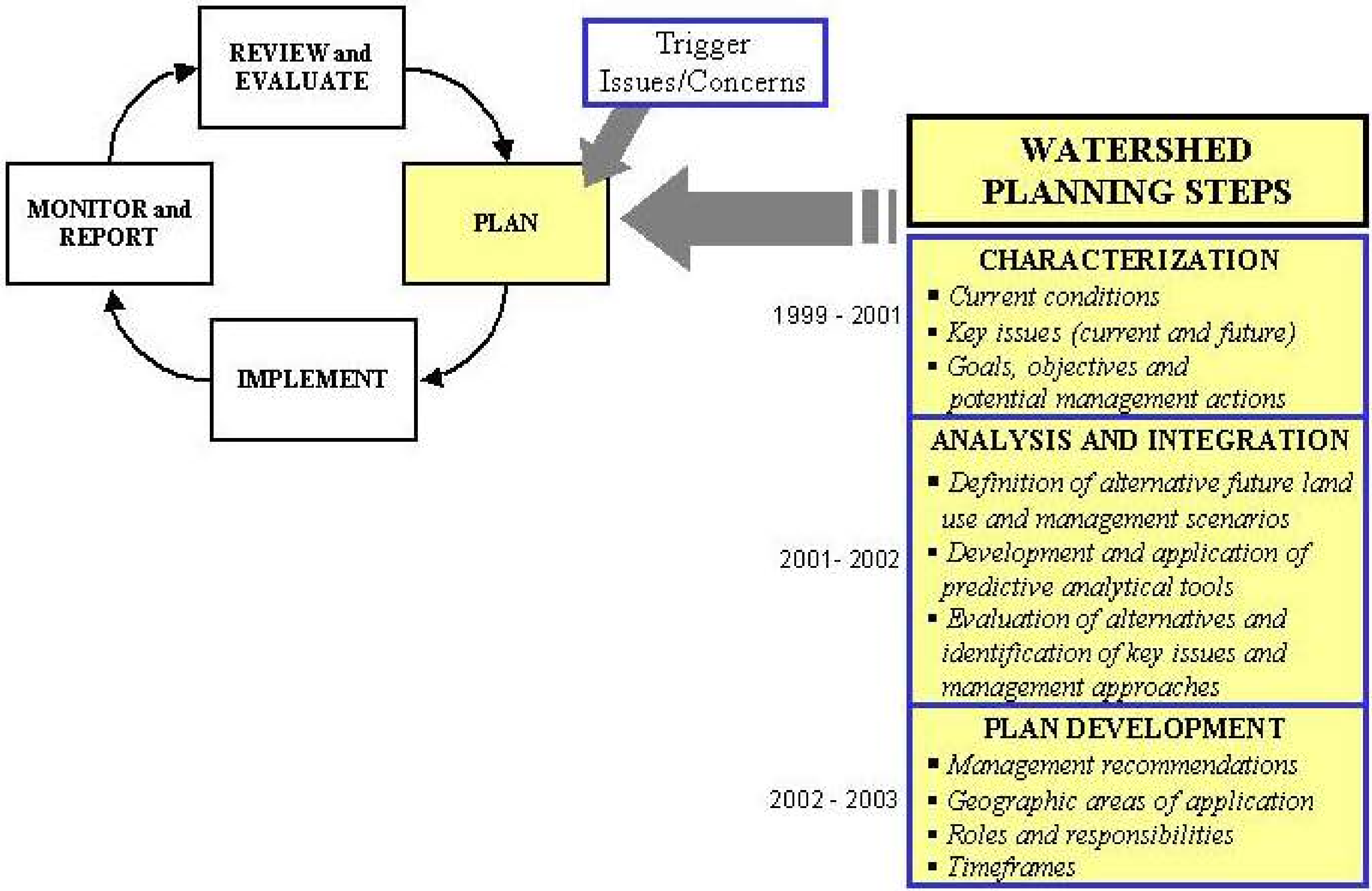


Figure 1-1: Location of Duffins and Carruthers Creek Watersheds

Figure: 1-2 Duffins/Carruthers Watershed Management Process



2.0 AN INTEGRATED APPROACH

2.1 Setting the Stage for Technical Integration

Application of an integrated analysis must be considered at the earliest stages of the technical work, because the foundations for this approach need to be inherent in the design of the work program components, scheduling, and in decisions about the specific parameters and scope of work to be completed. Without this early coordination of work, there may be information gaps or inconsistencies in the presentation of findings from each of the technical components. These problems create weaknesses in understanding watershed function and in the overall strength of the results.

The importance of this coordination was discovered shortly after several of the technical studies had been initiated, such that there was time to modify the workplans and improve consistency. It was also found that coordination among technical teams was necessary throughout the process so that any modifications in workplans could be discussed and understood by other teams that may have been reliant on the information.

Sections 2.2 to 2.7 discuss critical aspects of the integrated approach used in the technical work for the Duffins and Carruthers Creek Watersheds. Due to the lack of certain data and resultant lag in technical studies for the Carruthers Creek watershed, a modified approach was necessary for that watershed (see Section 2.8).

2.2 Technical Study Components

Recognizing that the watershed ecosystem is a complex network of inter-related features and functions, it was necessary to take it apart and reduce it to a set of simpler component systems in order to understand each one and its contribution to the whole.

For the purpose of the Duffins and Carruthers Watershed studies, the following technical components were defined **(Figure 2-1)**:

1. Surface Water Quantity (including surface water budget, hydrology, flooding, stream morphology, base flow, and water taking issues);

2. Groundwater Quantity and Quality (including recharge, water levels, discharge, water taking, and contaminant issues);

3. Surface Water Quality (including pollutant loading issues associated with rural and urban runoff, construction activity, and wastewater discharges);

4. Aquatic Habitat and Species (addressing issues associated with fish and benthic invertebrate species and communities, instream and riparian habitat);

5. Terrestrial Habitat and Species (addressing forest, wetland and meadow habitats, plant and animal communities and species);

6. Human Heritage (archaeological and built heritage); and

7. Recreational Use (primarily trails and other passive use opportunities).

Although not identified as separate components of study, watershed geomorphology (landforms, topography, soils) and land use data were assembled and used as input data to other study components. An integrated analysis of all of these components constitutes an ecosystem approach and provides the foundation for sustainable watershed management.

A complementary study effort looked at state-of-the-art approaches to sustainable development and provided assistance in the formulation of management recommendations for sustainability.

Air quality, climate, and stream geomorphology information for the two watersheds was documented in the State of the Watershed Reports, but no further technical analyses were carried out for these components as part of the initial watershed plan development process. Air quality in the watersheds is relatively good, and therefore the Task Force felt strongly that work should focus on other more critical issues. TRCA was aware that future climate change scenarios were to be defined under a larger Environment Canada study of climate change in the Toronto to Niagara area, although not in the timeframe needed for the local watershed work. This factor, coupled with inadequate funding, led to the decision to postpone work on evaluating climate change implications and possible strategies. Recognizing that the primary threats to natural stream stability were limited to a few subwatersheds expected to undergo urban development, a decision was made to conduct the potential erosion analysis and associated studies at the subwatershed scale. These studies were initiated concurrent with the Task Force's plan development process, but were not intended to be completed within that timeframe.

Identifying and understanding the linkages between technical components was an important aspect of the integrated analysis, and these concepts are addressed at greater length in the following sections.

2.3 Watershed Response Model

Within the Duffins and Carruthers Creek Watersheds, the predominant drivers of future change are associated with urban development pressures, the proposed development of an airport, and the opportunity to protect and enhance an extensive terrestrial natural heritage system afforded by the provincial Oak Ridges Moraine Conservation Act, significant government land holdings, and willing landowners. The potential impacts of urban development on a watershed ecosystem are well-documented (e.g. Ministry of the Environment, 1994; Toronto and Region RAP, 1994) and include such changes as increased runoff to streams, degraded water quality, and loss of habitat. Likewise, there is a growing renewal of understanding of the benefits of vegetation in not only providing habitat, but also serving hydrological functions, preventing erosion, protecting water quality, and enhancing recreation and quality of life. This concept was recognized by conservationists in the last century, as early as the 1940s (Richardson, 1974).

A set of three alternative land use and management scenarios were defined by the technical team, to foster a consistent analysis within and between each technical discipline. Each land use scenario represented a different proportion of natural, rural and urban land cover characteristics. These alternative scenarios are described in Chapter 3.

In order to analyse the response of the watershed ecosystem to each of the three scenarios, a simplified model/procedure was defined, which identified the relationship between each watershed system and the order in which changes would occur. **Figure 2-2** illustrates the Watershed Response Model used by TRCA in this work. The model describes the sequential order in which changes occur in the condition of each watershed system in response to a given stress, such as a change in land cover. The pathways of change include direct "footprint" effects (such as the loss of forest habitat or destruction of a human heritage site due to resource development); indirect "flow related" effects (such as increased flooding and stream erosion potential due to increased runoff associated with urban development); and cumulative effects (such as changes in aquatic community composition arising from a combination of hydrological, chemical, and physical habitat effects from upstream areas). The procedure guided the integration and exchange of information among separate technical staff teams.

The model was adapted from an initial model developed by Snodgrass *et. al.* (1996), which focussed on impacts on aquatic ecosystems contained within streams and rivers, and on a later adaptation of that work by Credit Valley Conservation in a subwatershed study (CVC, 2001), which also focussed on flow related impacts to the aquatic system. TRCA has expanded the model to address terrestrial natural heritage, human heritage, and recreational use components.

2.4 Predictive Tools

Currently, there is not a comprehensive computer model that is designed to predict all of the effects of a watershed activity on all of the various ecosystem components (i.e. ecological, human heritage and recreation). Therefore, for the purposes of this analysis, a combination of computerized mathematical models, empirical relationships, and professional judgement were used to assess changes within each technical study component. By specifying common standards for the scale of analysis, units, and presentation of results, the input and output data could be shared from one model to another, within the context of the overall watershed response model (after Snodgrass *et. al.*, 1996).

Figure 2-3 identifies the predictive tool or assessment methodology used in each theme area. A more detailed description of each methodology is found in Chapter 3.

2.5 Objectives, Indicators, Measures, and Targets

To analyse and evaluate the results generated by the predictive models, a set of management objectives and an associated set of meaningful indicators and measures of change were specified. Management recommendations for the Duffins and Carruthers Creek Watersheds were defined, with input from the Watershed Task Forces, for each of the eight technical theme areas, using a framework of Goals, Objectives, Indicators, Measures, Targets, and Management Actions.

Goals: identify the desired end points for each component that are necessary to achieve the watershed vision.

Objectives: identify the approaches necessary to address the key issues affecting that component.

Indicators: are facts or devices that provide specific information about the objective.

Measures: are quantitative or qualitative ways to measure the state of the indicator.

Targets: represent a numerical threshold or directional aim, associated with each measure, and were chosen as the minimum (or maximum) state necessary to achieve the desired objective.

Management Actions: are mechanisms recommended to achieve the objective and may include: policy, planning and regulatory tools, stewardship, regeneration, and education/awareness activities, land securement, monitoring, and/or further study needs.

Appendix A presents the goals, objectives, indicators, measures and targets that were established for the Duffins and Carruthers watersheds. Recommended management actions were finalized following the technical studies and are presented in the watershed plan.
This overall framework has evolved from and is consistent with frameworks used in TRCA's previous watershed report cards and strategies for the Don (TRCA, 1997 and 2001), Humber (1997 and 2000), and Etobicoke-Mimico (TRCA, 2002) Watersheds and the Regional Watershed Monitoring Network (TRCA, 2000). Indicators provide a useful means of summarizing complex information into understandable, relevant terms, and therefore they have also been widely used in other jurisdictions for state-of-the-environment reporting (eg. UTRCA and RVCA, 2002).

Most of the Duffins and Carruthers watershed management objectives, and subsequently the indicators, describe the desired watershed condition; several indicators provide information about stresses (of human or natural origin) on environmental quality or the status of management actions (response). A condition-stress-response framework of indicators has been widely accepted as a means of monitoring and reporting on watershed health (Environment Canada and US EPA, 1999; Campbell and MacLaren, 1995). Each of the three types of indicators provide different information, but they are linked by causal relationships. For the purposes of this technical analysis, the condition and stress indicators are of particular use.

Figure 2-4 identifies the specific indicators and measures that were the focus of the integrated analysis. These were chosen due to their ability to be quantitatively modelled and their established relationships with other indicators and measures of interest.

2.6 Watershed Study Area and Subwatershed Units

The State of the Watershed Reports provided a good understanding of key issues associated with the Duffins and Carruthers Creek Watersheds, and facilitated the development of technical work programs. An important management consideration within the Duffins Creek watershed is the degree to which the well-forested headwaters and the Oak Ridges Moraine geology contribute to the maintenance of a high quality river system. Significant areas of the Duffins Creek headwaters are already in public ownership or are protected under conservation easements and the remaining lands are afforded a level of protection under the Oak Ridges Moraine Act. Significant land areas off the Moraine are owned by the federal government, and are being held for a future airport development. Other lands, known as "Seaton", are owned by the provincial government, and are intended for future urban development. Less than one-third of the Carruthers Creek watershed is currently urbanized, although urban expansion is projected and will need to be managed in order to maintain and restore environmental conditions within this somewhat degraded system. The technical analyses were designed to provide guidance for the management of these and other issues.

In order to facilitate interpretation, the Duffins Creek Watershed was divided into six smaller subwatershed units, including the West Duffins Creek, East Duffins Creek, Ganatsekiagon Creek, Urfe Creek, Miller Creek, and the Lower Duffins Creek Subwatersheds **(Figure 2-5)**. Subwatershed units were defined with consideration for common physical characteristics and land use issues present within each and the desire for a manageable number of study units.

These subwatersheds, together with the Carruthers Creek watershed, provided a common basis for communication among the technical teams when presenting and interpreting study findings. This coordination was necessary, because individual technical studies discretized the watersheds into smaller or larger units, depending on the specific level of resolution needed for their work. For example, the hydrology and water budget exercises divided the Duffins Creek watershed into 31 sub-basins. The terrestrial natural heritage modelling and public recreational use studies were conducted on a watershed-wide scale, but results were qualitatively described for each subwatershed.

These subwatershed units also provided the basis for a more detailed assessment of management priorities and implementation requirements, that were identified in the watershed strategy.

2.7 Presentation and Interpretation of Findings

The preceding sections have described a number of steps taken to facilitate an integrated approach to studying the watersheds, including: definition of a common set of alternative land use and management scenarios for analysis by all disciplines; definition of the environmental pathways that describe the relationships between disciplines; identification of key indicators and associated standardized measures; and agreement on a common geographic scale for analysis. This groundwork provided for a level of integration that was embedded in the technical studies and assisted in ensuring that the findings were presented, discussed and interpreted in a consistent, integrated way.

Modelling results from individual studies were presented in a variety of ways, including tables and thematic maps. Overlay methods, using either a crude system of overhead transparencies or a more sophisticated Geographic Information System (GIS) on-line, were used to assist staff in identifying common patterns and interdependencies within the results. These techniques were used to identify areas within the watersheds that required special management considerations. Section 4.3.2 describes in more detail how a GIS-approach was used to integrate the key management recommendations and illustrate the multiple watershed management benefits of natural heritage cover.

A series of four technical team workshops were held at different stages throughout the study. At each workshop, each technical disciplinary group presented findings from their studies and received input and a broader base of interpretation from the overall team.

2.8 Carruthers Creek Watershed - Modified Integration Approach

Adequate stream flow data for the Carruthers Creek were not available at the outset of this study. These data are needed to calibrate a watershed hydrology, water budget, and groundwater flow models. Therefore, a decision was made to proceed with the installation of a stream gauge and, once adequate data are collected, undertake the modelling studies. Interim approaches were used to facilitate a similar technical evaluation of the alternative land use and management scenarios, as was carried out for the Duffins Creek watershed where information was unavailable. For example, in some cases the results of previous, simplified studies were used (e.g. hydrology and floodplain mapping) or surrogate information was applied (e.g. estimates of pollutant loads from similar neighbouring watersheds were pro-rated for the Carruthers watershed). These modified methods are noted with the technical study approaches and findings.

Figure 2-1 : Technical Study Components of the Duffins and Carruthers Watersheds Planning Process

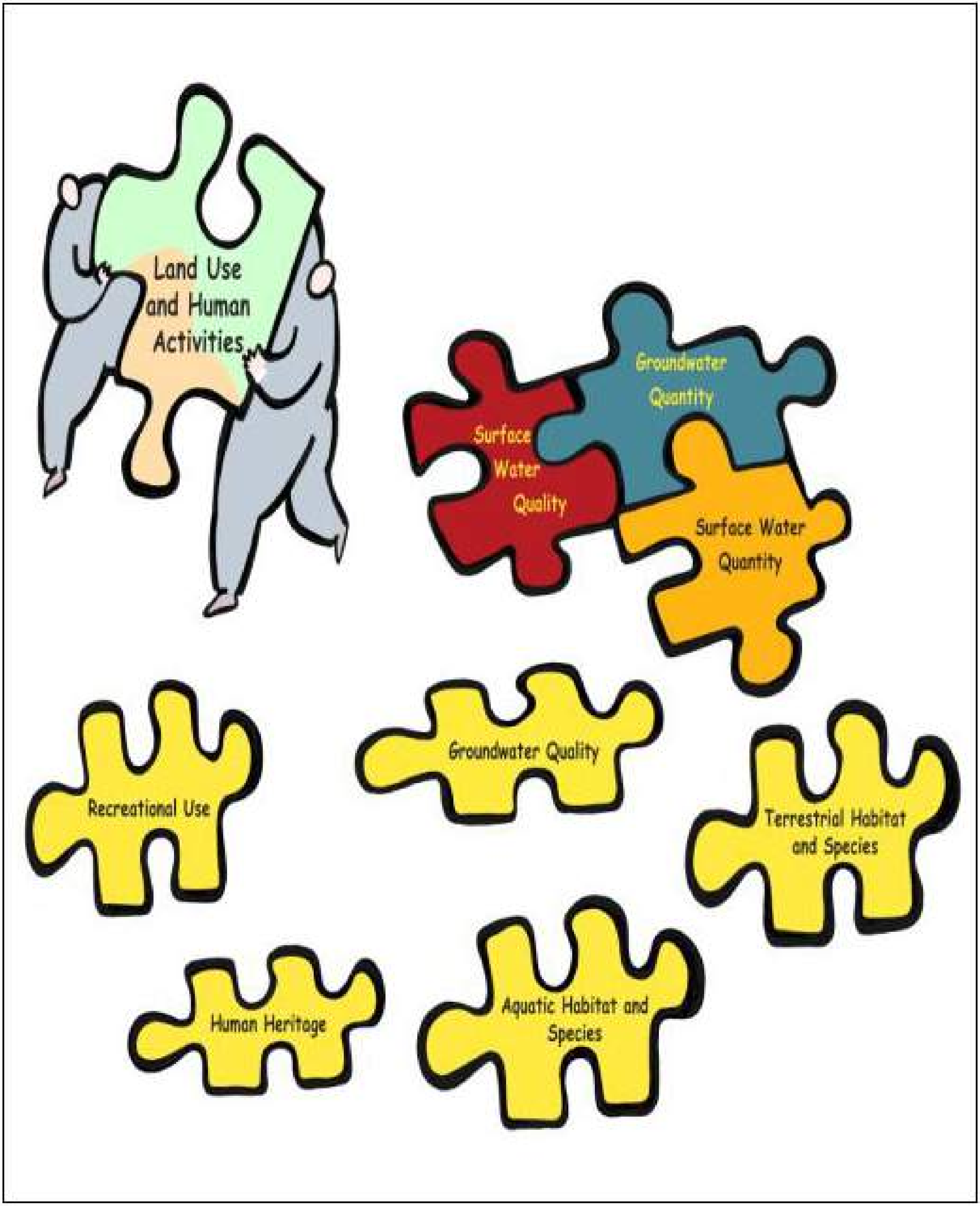


Figure 2-2: Watershed Response Model – Hierarchy of Change

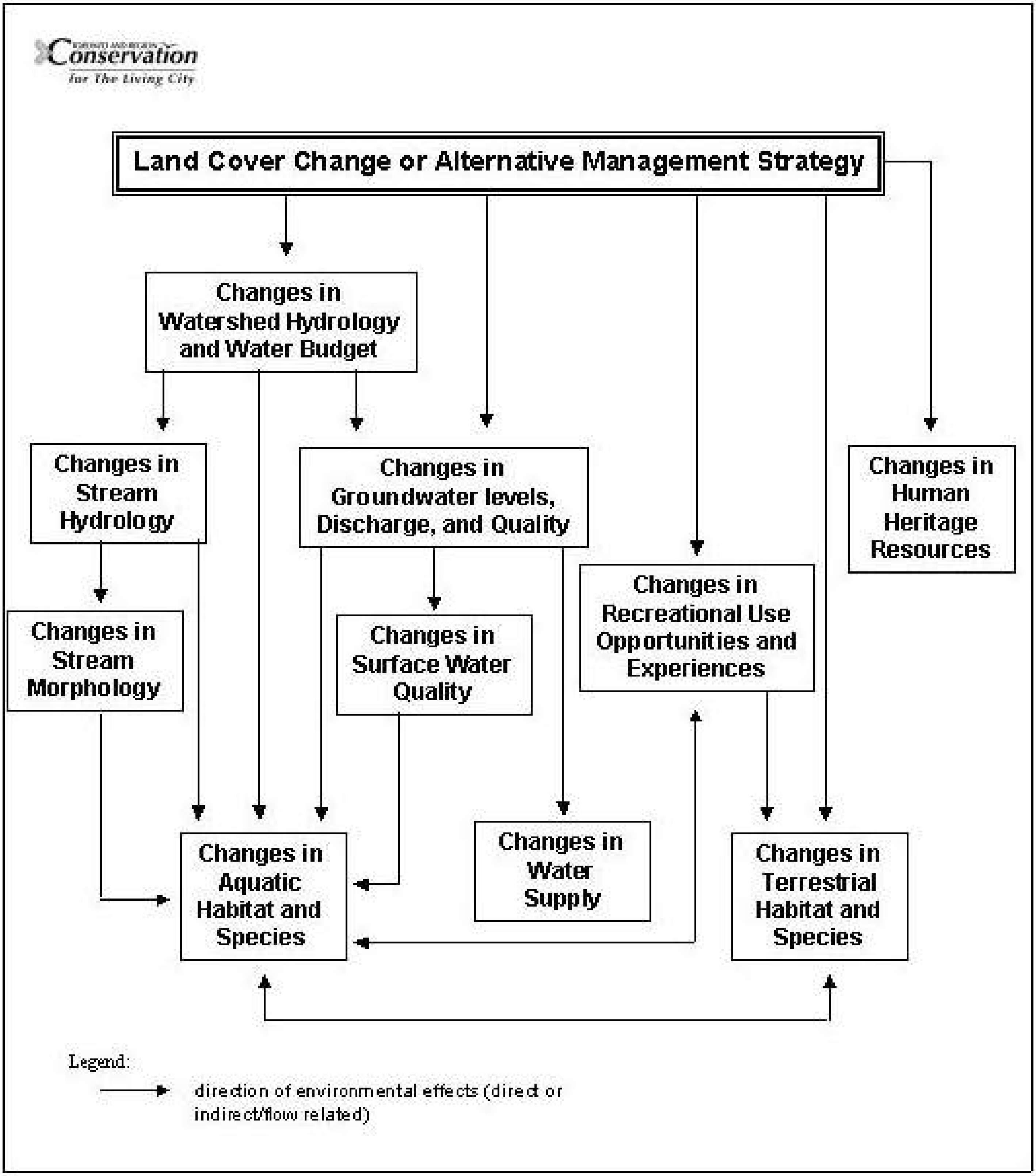


Figure 2-3: Predictive Tools Employed in the Duffins and Carruthers Watershed Planning Process

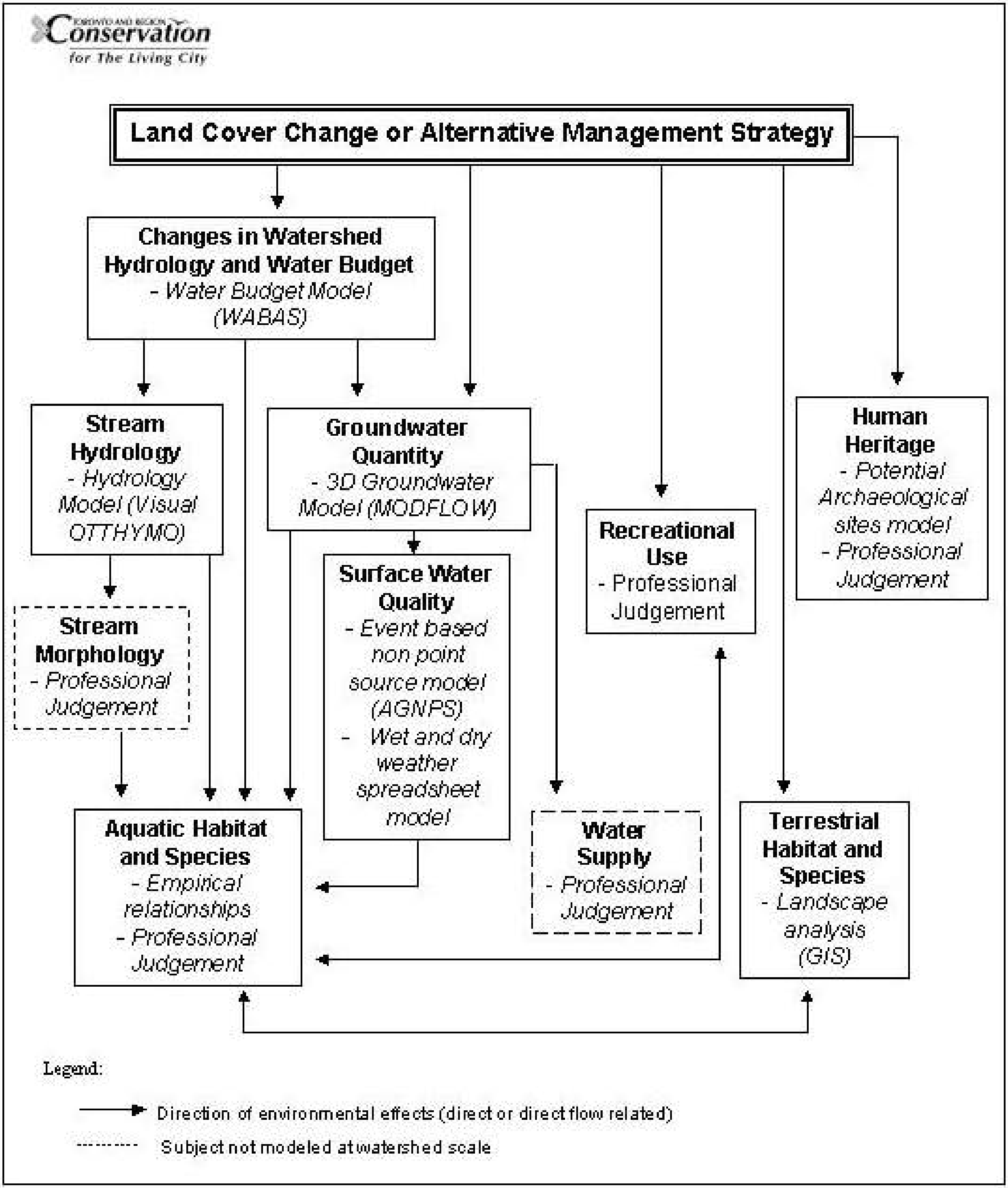


Figure 2-4: Primary Indicators of Change

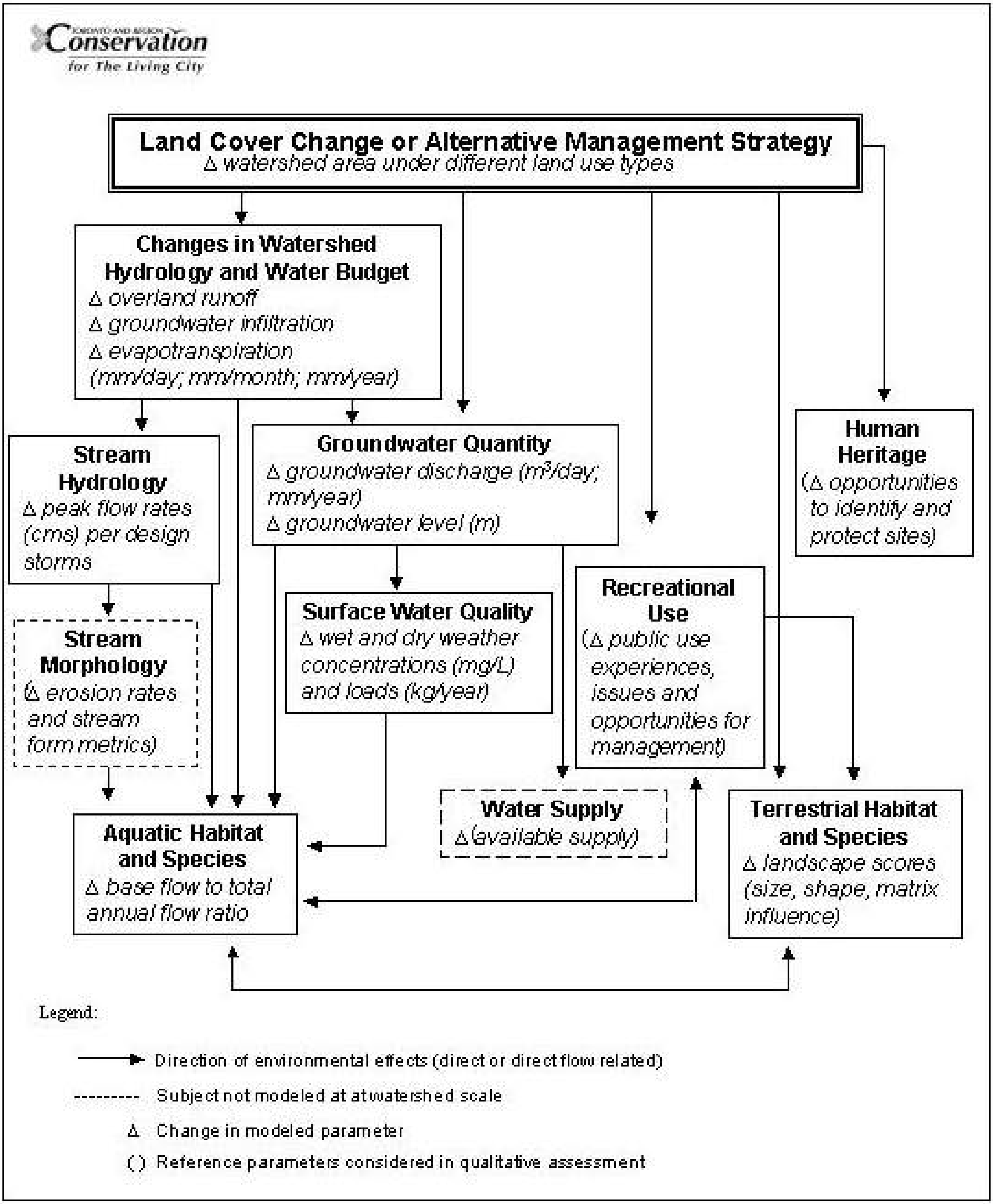
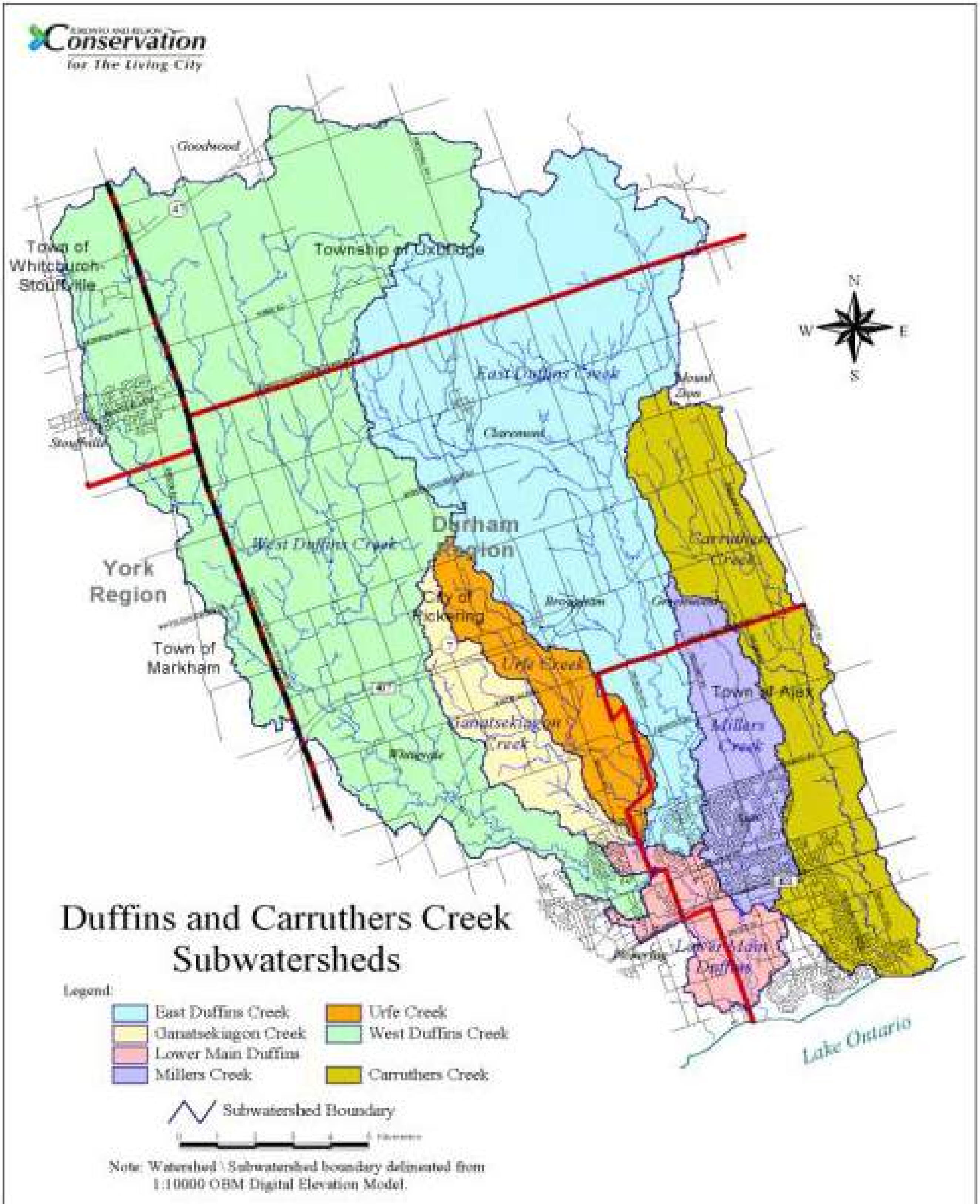


Figure 2-5: Watershed and Subwatershed Study Units



3.0 ANALYSIS OF ALTERNATIVE LAND USE AND MANAGEMENT SCENARIOS

3.1 Land Use and Management Scenarios

While the Duffins and Carruthers Creek Watersheds are in relatively good condition today, they are not static systems. Future pressures from urban growth, road widenings and construction (e.g. Hwy. 401 and 407), proposed airport development, and associated impacts are anticipated in these watersheds over the next 20 years. Although an infinite number of land use and management combinations could have been defined, it was felt that by identifying a few discrete future watershed states, the technical team would be able to generally benchmark the watershed's response along a continuum and use these alternative states as guidance in formulating a management strategy.

Considering the anticipated pressures and opportunities, three primary alternative land use and management scenarios were defined for common analysis by all technical disciplines:

1) Existing Land Use;
2) Future Land Use;
3) Future Land Use With Enhanced Natural Heritage Cover.

Additional land use and management approaches, tailored to individual technical issues, were also reviewed. The following sections describe the methods used to develop and depict the alternative scenarios.

Municipal land use maps were used as a primary basis for the scenario development, along with 1999 Digital Ortho Aerial Photography (1:4000) in the case of the Existing Land Use Scenario. Municipal ***land use*** classifications were interpreted and digitized in terms of their associated ***land cover*** characteristics. **Appendix B** presents the municipal land use maps used in this work and identifies the assumptions made in their interpretation. **Figures 3-1 (a,b,c) and 3-2 (a,b,c)** illustrate the three scenarios. **Table 3-1** summarizes the area of land under each land cover type within each subwatershed for the three scenarios. It should be noted that more detailed land cover classifications and mapping were tailored to the needs of individual technical studies. For example, golf courses were assigned runoff values similar to natural areas for surface and groundwater studies, while natural areas were further subdivided into areas of forest, wetland, meadow, and successional habitat for terrestrial natural heritage studies.

Table 3-1: The total area and percent land cover in the Duffins and Carruthers Creek watersheds and subwatersheds for three alternative land cover scenarios

	Size (ha.)	Existing Conditions (%)				Future Land Use -Official Plan (%)				Future Land Use (OP) + Natural Heritage (%)			
		Golf Course	Agri-culture	Natural Areas	Urban	Golf Course	Agri-culture	Natural Areas	Urban	Golf Course	Agri-culture	Natural Areas	Urban
West Duffins	13538	2	63	32	3	2	58	31	9	2	43	46	9
East Duffins	9202	1	50	45	4	2	48	45	5	1	30	64	5
Ganatsekiagon	1305	0	58	40	2	0	24	33	43	0	23	34	43
Urfe	1436	3	52	44	1	3	31	36	30	3	30	37	30
Millers	1698	0	38	24	38	0	16	23	61	0	16	23	61
Lower Main	1124	6	0	49	45	6	0	36	58	6	0	36	58
Whole Duffins	28303	2	54	37	7	2	47	36	15	2	34	49	15
Whole Carruthers	3812	5	49	29	17	4	34	25	37	5	28	30	37

3.1.1 Existing Land Use

The "Existing Land Use" scenario (**Figures 3-1a and 3-2a**)assumed maintenance of existing land use conditions and associated land cover characteristics (i.e. areas of imperviousness, vegetation, etc.). Mapping was developed by interpreting 1999 Digital Ortho Aerial Photography at a scale of 1:4000. Analysis of this scenario would essentially provide a benchmark for current watershed conditions and identify healthy elements to be protected and existing problems to be remedied.

As shown in **Table 3-1**, the Duffins Creek watershed supports predominantly agricultural/rural (54%) and natural (37%) land cover. Forests make up a significant proportion of the natural area. There is about three times as much of the natural area in forest cover as compared to meadow. Wetlands make up only 2% of the watershed area. About 49% of the Carruthers Creek watershed is under agricultural/rural land cover. The area in natural cover represents about 29%. In the case of the Carruthers Creek watershed, this natural area is made up of roughly half meadow and half forest cover. Wetlands form a small percentage of the watershed area.

3.1.2 Future Land Use

The "Future Land Use" scenario assumed full build out of the approved Regional and Local Municipal Official Plans, which projected watershed land use up to the year 2020. Under this scenario, urban land cover in the Duffins watershed would increase from 7% (existing) to 15% of the watershed area. In the Carruthers Creek watershed, the urban area would expand from 17% (existing) to 37%. Mapping was developed by digitizing municipal official planning schedules. When applying the land cover classifications, associated with future designated urban growth areas, it was assumed that the TRCA's Valley and Stream Corridor Policies would be implemented, and therefore vegetated land cover was applied to all valley and stream corridors, as defined under the TRCA program. Modelling exercises assumed no best management practices would be incorporated with the urban development, in order to demonstrate the response of watershed systems under a "worst case" scenario.

The Durham Region Official Plan assumes urban development within the provincially-owned Seaton lands, so results of the modelling exercises provided some indication of the potential impacts associated with the development of "Seaton", although the exact density and type of the future urban land cover is not known. This information is especially timely, in consideration of an April 2002 provincial government decision to facilitate a "land swap" in the Seaton area with private land owners in Richmond Hill and Uxbridge, in order to remove sensitive Oak Ridges Moraine lands from development in that area (MMAH, 2002). Under the agreement, these lands will be brought into public ownership for the creation of a park and the landowners will be compensated with land more suitable for development in Seaton.

Durham Region’s Official Plan identified a future regional airport, but did not show any details with respect to an airport on the federal lands. Even the future prospect of an airport was questionable when this watershed study began. Therefore, the federal lands were classified as rural and assigned the same land cover classifications as in the Existing scenario.

3.1.3 Future Land Use with Enhanced Natural Heritage Cover

The "Future Land Use with Enhanced Natural Heritage Cover" scenario assumed full build out of the approved Regional and Local Official Plans, as in the previous scenario, but also assumed revegetation of lands, where such opportunities were expected to exist and where other watershed management objectives were likely to be realized. The resulting scenario represented an increase in area of natural cover from 37% (existing) to 49% in the Duffins Watershed and from 29% (existing) to 30% natural cover in the Carruthers Creek Watershed.

This land use scenario inherently incorporates the Task Forces' "environment first" and “net gain” management approaches, which are premised on the understanding that natural systems provide a long term, sustainable first step in an integrated management strategy. It also recognizes that any management benefits derived from the protection/enhancement of natural systems would still need to be augmented by mitigative measures and best management practices associated with land use activities. However, for the purposes of the modelling, no BMPs were assumed in order to demonstrate the watershed response associated with the enhanced natural cover. The management philosophies represented by this scenario are consistent with trends in water management approaches from the early 1980s to late 1990s, as identified by Heathcote, 1998 and summarized in **Table 3-2.**

Table 3-2: Trends in Water Management Approaches

SHIFT FROM	***TO***
End of pipe	➜ Control at source
Remediation	➜ Prevention
Point source focus	➜ Point and Non Point source focus
Site focussed solutions	➜ Regional and watershed approaches
Trust of technology	➜ Understanding the limits of technology

Adapted from Heathcote, 1998

The formulation of this scenario preceded detailed terrestrial natural heritage modelling conducted by TRCA as part of its Terrestrial Natural Heritage Program, and thus applied a similar but alternative approach. The lands targeted for enhanced natural cover were delineated manually, according to the following considerations:

- opportunities to improve size, shape, and connectivity of existing habitat patches
- opportunities to rehabilitate riparian vegetation
- likelihood of benefitting other watershed management objectives (i.e. groundwater infiltration, floodwaters detention, recreational use enhancement, etc.)
- compatibility of adjacent land use and likelihood of implementing enhanced natural cover
- assumption that aggregate operations would be naturalized
- land ownership and expected willingness to implement enhanced natural cover (emphasis on public lands, areas of known private landowner interest in conservation

easements, Transport Canada's Greenspace Lands, Minister's Airport Zoning Control Order)

- provincially-owned Seaton lands were assumed to be urbanized according to the provisions of existing legislation and policies for natural heritage, and therefore, typical of privately developed lands, no revegetation opportunities were assumed beyond the protection of existing natural heritage features. It is expected that there will be opportunities for enhancing natural heritage cover as planning for these lands proceeds.

It should be emphasized that these considerations went beyond those factors that might solely be associated with terrestrial habitat management objectives, in recognition of the other benefits of natural cover, such as hydrological benefits and enhanced public recreational use experiences. Most of the opportunities for enhanced natural cover were concentrated in the headwater areas, particularly in the East Duffins Creek subwatershed.

The development of this scenario preceded the release of the Oak Ridges Moraine Conservation Plan (ORMCP) and its protective land use designations. When compared, the TRCA enhanced natural heritage cover scenario would address all of the lands protected under the ORMCP, and go further in a few areas.

The resulting scenario, representing 49% natural cover in the Duffins Watershed and 30% natural cover in the Carruthers Watershed, was intended for study purposes and was not intended to limit revegetation to these specific geographic areas.

3.1.4 Other Land Use and Management Alternatives

Additional land use and management scenarios were defined and evaluated for several of the individual technical components, in order to provide more direction to the management of specific issues.

<u>Watershed Hydrology, Water Balance, Groundwater, and Aquatic Resources</u>

In an effort to define an ultimate benchmark of water quantity response in the Duffins Creek watershed, a land use scenario was analysed involving build out of the approved Official Plans plus an additional 50% impervious cover on the remaining non-urbanized lands. Results of this analysis are published in the component technical reports. Results were used to help demonstrate the watershed's sensitivity to change.

<u>Flooding Concerns</u>

In addition to modelling the watershed's hydrological response to the three land use scenarios, the hydrological modelling exercise evaluated alternative stormwater management strategies for peak flow control for each land use scenario. The alternative stormwater management strategies included: no control; control of flows from the 2 year to 100 year return period storms; and control of flows from the Regional Storm.

<u>Surface Water Quality</u>

The modelling exercises that were undertaken to identify the primary source areas of rural pollution, specifically sediments and nutrients, incorporated one additional management scenario. The "Priority Management Areas Revegetation" scenario was based on the "Existing" land use scenario, but simulated the effects that increased forest cover would have on pollutant loads, if selectively applied to areas identified as predominant sources of sediment load. Predominant source areas were defined as those 1 km^2 grid cells, which together contribute over 65% of the total sediment load. Percent forest cover within each cell was increased to a total of 60% of the grid area to form the "Priority Management Area Revegetation" scenario. This cover would equate to a forested area of 300 x 500 m across the grid cell and might be achieved through such best management practices as riparian plantings, vegetated buffer strips, and reforestation.

3.1.5 Existing Water Use

Data regarding existing surface and ground water takings, as recorded in the Ministry of the Environment's Permit to Take Water database, were obtained and reviewed in the context of the groundwater management and low flow management issues.

3.2 Predictive Tools and Methodologies

A combination of computerized mathematical models, empirical relationships, and professional judgement were used to assess the watersheds' response to the alternative land use scenarios. The following sections identify the methods used within each technical theme.

3.2.1 Surface Water Quantity

3.2.1.1 Water Balance

A water balance analysis has increasingly been recognized as one of the most integral indicators of change in many watershed functions. The Oak Ridges Moraine Conservation Plan (Government of Ontario, 2002) has in fact made the development of a water balance a requirement, prior to consideration of major development approvals. Based on the components of the hydrologic cycle, the purpose of the water balance analysis in this study was to estimate changes in overland runoff, infiltration, and evapotranspiration values due to land cover changes associated with the three land use scenarios. Typically, urbanization causes an increased volume of runoff and reduced infiltration, due to the hardening of surfaces, removal of depression storage, and reduced evapotranspiration associated with the loss of vegetation.

A water balance analysis tool was developed for the Duffins Creek Watershed to quantify the current and future water balance according to the alternative scenarios. A similar study was not possible for the Carruthers Creek Watershed due to the lack of stream flow data needed for calibration. Monitoring is underway to address this deficiency. For the purposes of the technical analysis, qualitative estimates of water balance changes were made for the Carruthers Creek Watershed.

Details of the water balance study are included in the technical report *Water Budget in Urbanizing Watersheds: Duffins Creek Watershed* (Clarifica Inc., May 2002)

The water balance analysis methodology calculates the water balance component of the basin using the “WABAS” system. WABAS (Water Balance Analysis System) was developed by Clarifica Inc. to analyze the hydrologic water balance of rural and urbanizing watersheds. WABAS was designed to use the data from other surface hydrology analysis techniques including SCS CN runoff method, snowmelt methodology (GAWSER), unsaturated groundwater infiltration and evaporation techniques. The model operates from an ‘EXCEL’ worksheet platform. It requires a time series input of daily precipitation, average or maximum-minimum temperature, and measured evaporation. It outputs a time series of runoff, infiltration, evaporation, and storage conditions within each water balance reservoir (pervious and impervious interception storage, surficial soil storage, snowpack storage).

Input includes climate, hydrometric (measured flows), and physical basin parameters. Local climate data and measured flows are used for surface runoff calibration. Physical basin parameters define the surface and surficial properties of each basin affecting the storage and movement of water from one stage to another including imperviousness, interception abstractions, vegetation, and surficial soil characteristics. These parameters are collected directly or indirectly based on typical land-use or surrogate soil and vegetation parameters. Because the model outputs daily time step volumetric results, it does not require routing coefficients. However, for the Duffins watershed, a three-day unit hydrograph lag was found suitable for calibrating observed daily average in-stream flows following rainfall events and this was incorporated as part of the surface runoff response.

This water balance tool provides advantages over other existing hydrologic modelling tools because it:

- Explicitly calculates evapotranspiration as a function of vegetation cover and soil moisture availability. Therefore, it can be used to assess impacts of urbanization as well as natural heritage (reforestation) strategies.
- Utilizes daily time step to account for consecutive rainfall events and antecedent soil moisture conditions and tracks available storage such as in stormwater management infiltration facilities.
- It links evaporation and groundwater infiltration with surficial soil moisture when accounting for antecedent soil moisture conditions.
- Has been adapted from accepted and practised SCS CN surface approach in use in Southern Ontario.
- Determines urbanization effects such as directly and indirectly connected impervious areas.
- Incorporates winter snow and snowmelt processes.
- Can be utilized at the site plan and sub-division level to size stormwater management infiltration practices to mitigate potential reductions in groundwater infiltration.
- Can be readily used to conduct sensitivity analysis such as short or long-term precipitation changes (ie. climate changes).
- It can be made user-friendly and adapted for wide spread distribution.

Model Calibration

Model calibration is the process by which modelled and measured runoff flows are matched by varying ‘calibration’ parameters. The calibration process involves collection, screening and analysis of measured flows and climate data, as well as the systematic evaluation of the response of runoff to variations of calibration parameters. Specifically, the following steps were taken during calibration:

1. Collection and evaluation of measured flow data at several locations in the watershed.
2. Baseflow separation. The process requires the analysis and quantification of low flow patterns and separation from the total observed stream flow. The difference between total stream flow and baseflow is assumed to be the wet-weather response.
3. Isolate and quantify the physical watershed parameters upstream of each flow gauge.
4. Set-up basin model with the physical watershed information at each gauging station and with climate data corresponding to the measured flow period. Include additional years of climate data prior to calibration to provide a 'warm-up' period to estimate 'initial' conditions.
5. Execute model while varying calibration parameters within physical limits to best match wet-weather hydrograph obtained in Step 2.
6. Adjust individual basin calibration parameter to match gauge calibration results.

The water balance analysis has been calibrated using measured flows from 1997 to 2000 from six stream gauges located throughout the watershed. The long term water balance analysis was completed using 15 years of climate data and the alternative land use scenarios for each of 30 sub basins in the Duffins watershed.

The findings from the water balance study are presented in section 3.3.1.1.

3.2.1.2 Watershed Hydrology and Hydraulics

The primary purpose of watershed based hydrological modelling is to estimate peak flow rates arising from differently sized storm events, as an indication of where changes in flooding risk may occur under the various land use scenarios, and to evaluate the effectiveness of alternative stormwater management approaches. Typically, urban development causes an increase in the magnitude and frequency of severe flood events. Flood control strategies from the 1940s have demonstrated the moderating effects of headwaters reforestation programs.

Duffins Creek Watershed

Aquafor Beech Limited was retained by the Toronto and Region Conservation Authority to complete an update of the hydrologic model for Duffins Creek. The existing watershed model was created in 1991, also by Aquafor Beech Limited.

The software selected for the Duffins hydrology update was VISUAL OTTHYMO, Version 1.06. This model is a HYMO-based model and was selected for this application given that it has essentially the same operating characteristics as the model used for the original, 1991 model with some additional interface upgrades. VISUAL OTTHYMO is a mathematical model that uses the unit hydrograph theory to simulate a watershed response to simulated or actual rainfall events.

In order to carry out the hydrologic analysis, the Duffins Creek Watershed was discretized into 31 subcatchments based on physical characteristics. A number of parameters were then calculated for each of the subcatchments for input into the model. The model output identified peak flow estimates for specified locations in the watershed for three land use scenarios. A comparison of the results was carried out to determine the hydrologic impact of proposed future land use, to identify the effectiveness of runoff controls and to quantify the benefit assuming an expanded natural heritage system.

The hydrologic model was calibrated using local hydrometric data (i.e. stream flow) collected at six locations throughout the watershed. In addition, precipitation data, collected and archived by the Region of York was also used for calibration purposes. In total, six events, occurring between 1999 and 2000 were selected for the calibration exercise. Details of this work are described in *Duffins Creek Hydrology Update* (Aquafor Beech Limited, May 2002).

For the purposes of the watershed planning process, a qualitative assessment was carried out to summarize the anticipated changes to the existing hydraulic conditions throughout the watershed given the results of the hydrology update. An update to the existing hydraulic model and associated floodplain mapping for the Duffins Watershed is underway and will continue over the next 2 years. This update will be carried out to define the limits of the Regional Floodplain given the updated flow information. Corresponding updates to the Flood Vulnerable Areas (FVA) and Flood Vulnerable Roads (FVR) database will be carried out as required.

The results of the hydrology study are summarized in section 3.3.1.2.

Carruthers Creek Watershed

The Carruthers Creek hydrology model was last updated in 1999 by Totten Simms Hubicki Limited and further updated by Cosburn Patterson Mather Limited in 2000 through the A8 Secondary Plan process. The watershed model was developed using the OTTHYMO 89 computer model. OTTHYMO 89 is a mathematical model that uses the unit hydrograph theory to simulate watershed response to simulated or actual rainfall events.

In order to carry out the hydrologic analysis, the consultants discretized the watershed into 3 subcatchments based on physical characteristics. A number of parameters were then calculated for each of the subcatchments for input into the model. The model output identified peak flow estimates for specified locations in the watershed for three land use scenarios, including existing conditions, approved future land use and future forseeable land use.

For the purposes of the watershed planning process, results from the earlier modelling work were used for assessment purposes. TRCA plans to recalibrate and update the Carruthers Creek hydrology model in 2003, once adequate streamflow data have been collected from the gauge installed in 2002.

3.2.1.3 Stream Morphology/Erosion Assessment

Stream channel form is a function of the hydrologic flow regime and the erodibility of the channel sediments. The typical impacts of urbanization on the flow regime and stream morphology have been well documented and include: increased frequency of erosive flow events, increased stream cross-sectional area by widening or down-cutting, increased sediment loads and altered riffle-pool-run sequences and a shift toward finer grain sizes in streambed sediments (MOE, 1999; MacRae and Rowney, 1992). To predict the location and severity of adjustments in the stream channel, in response to altered flow regimes, it is necessary to determine the erosion potential of stream banks and bed sediments, based on field measurements. This level of effort was not possible throughout the watershed during the planning timeframe so, for the purposes of watershed plan development, it was assumed that erosion rates will increase downstream of urbanized areas under the Future Land Use scenario (assuming no erosion control) given the extent of proposed development. Erosion rates are also expected to increase downstream of urbanized areas, under the Enhanced Natural Heritage scenario (assuming no erosion control); however, the rate of increase will be smaller than experienced under the Future Land Use scenario, due to the moderating effects of vegetative cover on runoff and streamflows.

Further work in Duffins Watershed

An erosion assessment for portions of the Duffins Creek watershed was carried out in 2002 and will be finalized in 2003. The assessment was carried out for those subwatersheds where future development is proposed, and included: field work to determine baseline conditions and erosion thresholds. Results of the erosion analysis will be used by development proponents and their consultants to determine criteria for future development in terms of release rates (L/s/ha) and storage volumes (m^3/imp.ha).

Available Erosion Criteria in Carruthers Watershed

In 1997 an erosion and fluvial geomorphology assessment was carried out as part of the Secondary Planning process for the A8 area in the Town of Ajax. The A8 area is bounded by Taunton Road in the north, Audley Road in the east, and Kingston Road in the South. The western boundary, south of Rossland Road is approximately half way between Harwood Ave. and Audley Rd. North of Rossland Road, the western boundary varies from east and west of Salem Road. The A8 area encompasses the majority of the remaining future development area, within the existing Official Plan, in the Carruthers Creek Watershed. As part of the A8 study, erosion thresholds were determined and the corresponding stormwater pond volumes and release rates were also calculated.

In addition to the criteria set for the A8 area, erosion thresholds have also been determined for Carruthers Creek from Kingston Road, south to Bayly Street. These thresholds will be used to calculate the appropriate erosion control volumes and release rates for new stormwater ponds associated with new development applications in this area.

3.2.1.4 Baseflow Measurements and Modelling

Baseflow monitoring and mapping was undertaken to provide an indication of stream reaches receiving groundwater discharge or flow losses, through either natural processes (i.e. recharge) or human induced water withdrawals. This observed baseline data, under existing land use conditions, was used as a reference in interpreting the predicted changes from future land use scenarios and evaluating the impacts of water withdrawals.

Baseflow Measurements

Baseflow measurements were undertaken by Authority staff on the Carruthers Creek watershed in 2000, based upon Water Survey of Canada flow measurement standards and a sampling protocol originally developed by the Geologic Survey of Canada (GSC) during its sampling program on the Duffins Creek watershed in 1995 and 1996. The GSC sampling protocol was used by TRCA, to ensure that a baseflow condition existed following any precipitation event.

Given the hydrologic response of the TRCA watersheds, a 72 hour period was established as the minimum time to wait following any rainfall event, prior to beginning any sampling.

Sampling sites were chosen from headwaters to mouth on topographic maps prior to field reconnaisance at major and minor road crossings. Locations were chosen with consideration for accessibility to field staff and opportunity to develop a stage-discharge relationship (eg. at road crossings). Once a transect location was chosen, the channel was broken into 20 panels. These panels were measured for depth, width, and water velocity. The collected measurements were recorded and calculated to give a total discharge of the stream segment sampled. The final discharge figure was then referenced with the closest upstream discharge and compared for accuracy and continuity.

Using TRCA's baseflow measurements at a total of 19 sites on Carruthers Creek (2000 data) and GSC's 1995-96 data for 93 sites on Duffins Creek, a set of maps were developed to show the existing baseflow distribution within the two watersheds. An assessment of the distribution, at watershed and subwatershed scales was undertaken to better understand the existing system in terms of significant discharge areas and potential recharge areas. The maps also provided an understanding of the relative local subwatershed inputs on a reach basis. An understanding was also developed of the stressors that exist, including natural processes, such as losses or gains due to geologic features (i.e. Lake Iroquois shoreline) and water takings (i.e. known withdrawals as per the Ministry of the Environment's Permit to Take Water (PTTW) data base.

Results of the baseflow monitoring work are presented in section 3.3.1.3.

Modelling of Future Scenarios

Predicted impacts to the groundwater discharge components of the stream baseflow, in response to the projected land use changes within these watersheds, were also estimated. This assessment was undertaken by reviewing the relative changes in ground water infiltration (GWI; i.e. recharge) predicted by the water budget model under various land use scenarios. The relative changes in recharge amounts were used as input data to run the groundwater flow model, which in turn was used to predict changes in the volume of groundwater discharge to watercourses. The distribution of measured baseflow was evaluated at reach, subwatershed and watershed scales, and used in verifying the groundwater model outputs. Impact assessments of changes in groundwater discharge from the modelling exercise were analysed at subwatershed and watershed scales. Results are found in section 3.3.1.3.

3.2.1.5 Surface Water Use

The significance of existing surface water withdrawals was evaluated with reference to the existing PTTW data base and an online database of permit applications produced under the Environmental Bill of Rights (http://204.40.253.254/samples/search/Ebrquery_REG.htm). Data records from these sources include days of pumping per year, maximum daily taking amounts, and hours of pumping per day. With this information and the measured baseflow data, approximate water budgets could be calculated. As the PTTW data base had several records with missing data, several assumptions had to be made. Estimates of these missing data were based on a review of other similar use permits and the minimum pumping amount at which a PTTW is required (ie: >50,000 litres/day). Expired permits were, for the most part, included in all calculations. It was noted many permits were issued in the 1960s and '70s, and upon expiry the client had not re-applied. It was assumed that the water is still being actively pumped if the land use had not changed. The only permits omitted from all calculations were those listed as temporary (ie. road construction), or permits cancelled by the user.

The assessment of surface water withdrawals is discussed in section 3.3.1.4.

3.2.2 Groundwater Quantity and Quality

The groundwater quantity assessment was designed to establish an understanding of groundwater flow directions, water levels, and discharge areas, and to predict the changes that would occur in these parameters in response to an altered water balance (specifically infiltration rates) associated with future land use scenarios. Typically, urbanization is expected to reduce infiltration volumes, lower the water table elevation, and reduce discharge volumes, however these impacts depend on scale, location in the watershed, and local geology. Groundwater chemistry under the existing land use scenario was considered.

3.2.2.1 Groundwater Flow Model

The scope of work for the groundwater component of the study included:

- Review of existing data regarding the regional and local geology and hydrogeology of the Duffins Creek watershed;
- Update of the conceptual geological model of the Duffins Creek watershed;
- Update of the three dimensional groundwater flow model using MODFLOW;
- Updated calibration of the groundwater flow model to the observed conditions in the flow system and baseflow in the various reaches of Duffins Creek
- Comparison of the modelled groundwater infiltration to infiltration calculated by Clarifica Inc.; and
- Assessment of potential effects of land use change with the calibrated model.

There is an extensive existing knowledge base of the geology and hydrogeology of the Duffins Creek watershed. This information includes water well records, intensive subsurface investigations for the Durham component of the Interim Waste Authority landfill search (IWA, 1994-c), regional geologic data compiled by the Geological Survey of Canada (Sharpe *et. al.*, 1997) and the Ontario Geological Survey (Barnett *et. al.*, 1998), and a three dimensional flow model of the watershed (Gerber and Howard, 2000). To maximize the benefit of this existing data, TRCA assessed the documentation and used the information to update the conceptual hydrogeological model of the watershed.

The calibrated numerical flow model for the study area (Duffins, Petticoat and Frenchman's Bay watersheds) is described in detail in Gerber and Howard (2000). The model was constructed using Visual MODFLOW (Waterloo Hydrogeologic Inc. 1996) which provides a graphical user interface for the three-dimensional finite-difference code MODFLOW (MacDonald and Harbaugh 1988). The model encapsulates the three-dimensional framework of the geologic deposits using nine model layers with a grid discretization of 200 x 200 m cells (110 columns and 150 rows).

The configuration of the geologic layers in the model was prepared using borehole data extracted from approximately 7000 Ontario Ministry of the Environment (MOE) water well records, supplemented by borehole data collected from landfill (M.M. Dillon Limited 1990; IWA 1994a-e), regional water resource (Sibul et al. 1977) and aquitard investigations (Gerber and Howard 1996; Boyce 1997; Gerber 1999).

Other inputs to the steady-state model include recharge and hydraulic conductivity estimates for the various hydrogeologic units. Recharge estimates used were obtained from streamflow separation and soil moisture balance methods (Gerber 1994; IWA 1994e; Gerber and Howard 1997), and regional groundwater flow modeling (M.M.Dillon Limited 1990; Smart 1994; IWA 1994e), and more recently from Clarifica Inc (May, 2002) who estimate recharge for various land use scenarios. Hydraulic conductivity (K) estimates for all hydrogeologic units were obtained from slug tests, pump tests and specific capacity analysis. Hydraulic conductivity anisotropy for all layers was set as $K_x = K_y$ and K_h (K_{xy}) = 10 times K_v (K_z), consistent with values for similar deposits to the west of the study area near Waterloo (Martin and Frind 1998).

The model was calibrated to observed hydraulic heads (112 monitoring wells at 38 locations) and estimates of groundwater discharge to streams at seventeen locations. Model calculated hydraulic head distributions were also calibrated to hydraulic head distributions produced from MOE water well records in areas where monitoring wells were not available. The calibration was achieved by trial and error and involved varying recharge and hydraulic conductivity values independently within the range of estimated values, until the observed heads and groundwater discharge to streams were reproduced. The root mean square (RMS) error for the calibrated heads within all three aquifers is 3.5 m. Although not calibration targets, the model spatial distribution of groundwater discharge to streams proved to be consistent with field observations of low streamflow in the summer (Hinton 1996; Kenney et al. 1996); also model estimates of spring and aquifer discharge to Lake Ontario (700 m^3/d) compared favourably with estimates from Haefeli (1972) and Ostry (1979)(600 m^3/d).

Although the model was calibrated at steady state to the estimated annual average groundwater discharge to streams and the average annual values of hydraulic head for the period of record, it is recognized that both groundwater recharge and groundwater discharge to streams vary seasonally and from year to year depending on climatic and antecedent conditions. For the study area, groundwater recharge occurs mainly in the spring during snow melt and in the late fall when soil moisture deficits are satisfied and evapotranspiration rates are low. It is during these seasons that the water table and aquifer hydraulic head values are highest, hydraulic gradients are greatest and groundwater discharge to streams reaches a maximum. Groundwater discharge to streams is at a minimum when the water table and hydraulic head configuration are at their lowest. The calibration for the Duffins model is to an “average” groundwater flow system condition, or to an average basin saturated state of mean water levels in aquifers and long-term mean groundwater discharge to streams.

Hydrogeologic Modelling of Land Use Scenarios

The groundwater infiltration values (GWI) from the water balance analysis (Clarifica Inc., 2002), described in section 3.2.1.1, were incorporated into the numerical groundwater flow model (MODFLOW) which exists for the Duffins basin, as a means of estimating the effects of future land use scenarios on recharge and the groundwater system.

As previously described, the groundwater model was calibrated to an average watershed saturation condition and discretized the study area into 200 m cell sizes. The Clarifica water balance estimates provide an average groundwater infiltration rate for each of the 30 subcatchments within the Duffins watershed (Figure 3-4). The different characteristics relating to soil conditions and land use have been averaged or lumped for each subcatchment area. The groundwater flow model was not re-calibrated to the Clarifica GWI values because these estimates represent an average value for the subcatchment. For example, for a sub-catchment containing both surficial sand and till deposits, calibrating to an average GWI will lead to a model calculated water table that is too low for the sand area and too high for the till area because the actual recharge value over the sand will be higher than the till.

The emphasis of this exercise was to estimate the potential changes to the groundwater flow system based on the estimated changes in recharge due to land use change. The Existing calibration scenario of Gerber and Howard (2000) was compared to the GWI values for the Existing land use conditions as estimated by Clarifica for the 30 subcatchments shown on Figure 3-4. Results from Clarifica's evaluation of the other land use scenarios were then compared to the Existing land use scenario to address the estimated changes to the groundwater flow system due to land use changes.

It should be noted that river cells within the groundwater flow model were given a recharge value of zero to reflect the fact that they are potential discharge, or 100% runoff zones. The remaining land not covered by river cells within the subcatchment was given the GWI value of Clarifica. In other words the GWI values of Clarifica were used but just over a smaller area within the model. Therefore, the recharge area in the Duffins basin within the model is 24,720 ha as compared to the total basin area used in the Clarifica water balance of 28,301 ha. This has the effect of reducing the total recharge in the model to 139,000 m^3/d compared to the total recharge (GWI) of 159,500 m^3/d reported in the Clarifica water balance. In general, the water table configuration using the Clarifica GWI estimates is lower on the Oak Ridges Moraine and higher over some parts of the South Slope and Glacial Lake Iroquois areas, than the model calculated water table of Gerber and Howard (2000) and the observed water table.

The calculation methodology of the Clarifica water balance assumed that all runoff (RO) and recharge (GWI) calculated for each subcatchment was received by the stream by the outlet of each of the subcatchments. In reality, some recharge which occurs over the northern parts of the flow system moves to the deeper aquifer system and is not realized as groundwater discharge until areas within the southern parts of the flow system where the river valleys intersect these deposits. Most of the groundwater recharge within the basin has been realized as groundwater discharge to streams prior to the mouth of the river at Lake Ontario. Total streamflow measured at gauging station 02HC006/049 can then be considered to be representative of all of the groundwater runoff and recharge components for the basin. The RO and GWI estimates for 28 of the 30 (#1 to 26) subcatchments can then be compared to the observations at 02HC006/049 (subcatchment locations are shown on **Figure 3-4**). Subcatchments #27 and #28 do not contribute to Duffins Creek upstream of this gauge and were not included. A comparison of the Clarifica RO plus GWI estimates for the 28 subcatchments was compared to total streamflow at this gauge for the period 1986 to 1997. This showed that the water balance estimates for some years were much higher than observed total streamflow. This could be due to a number of factors relating to meteorological data, streamflow observations, and/or calculation procedures that do not incorporate all of the physical processes that are occurring within the basin. The Clarifica water balance numbers for the existing scenario are considered to represent a slightly higher than average saturation state for the watershed.

Findings of the groundwater flow modelling are summarized in section 3.3.2.1.

3.2.2.2 Groundwater Use

Gerber Geosciences, on behalf of TRCA, reviewed the active permits to take water (PTTW) on file with the MOE (Gerber, 2003) as well as pumping data provided by the Regional Municipality of York. The study team's assessment of these data is provided in section 3.3.2.2.

3.2.2.3 Groundwater Quality

Gerber Geosciences, on behalf of the TRCA reviewed the available chemical data for groundwater within the Duffins Creek and Carruthers Creek Watersheds. These data included:

- 44 groundwater samples collected by the MOE from the Duffins and Rouge River watersheds in 1970 and 1974 (Sibul et al., 1977);
- 260 groundwater samples collected in the Duffins and Rouge watersheds between 1982 and 1984 (Howard and Beck, 1986);
- 79 groundwater samples collected on behalf of The Regional Municipality of Durham for a regional landfill site search (M.M. Dillon Limited, 1990); and
- 205 groundwater samples collected on behalf of the Interim Waste Authority for the Metro Toronto/York and Durham landfill site searches (IWA, 1994a-e).
- 9 samples from research projects at the University of Toronto.

The study team's assessment of these data is provided in Section 3.3.2.3.

3.2.3 Surface Water Quality

The surface water quality assessment evaluated the changes in in-stream water chemistry and the relative predominance of pollutant sources in response to predicted changes in watershed hydrology (i.e. overland runoff, groundwater discharge to streams) and pollutant availability associated with the various land use scenarios. Several methods were used in this analysis, and they are described in sections 3.2.3.1 to 3.2.3.5.

3.2.3.1 Agricultural Non Point Source (AGNPS) Model

The AGNPS model is a distributed water quality model, designed to predict water quality and hydrologic response conditions in agricultural watersheds for the purpose of evaluating different land cover scenarios and Best Management Practices (BMPs). Developed by the U.S. Department of Agriculture, the AGNPS model is an event-based model, simulating conditions based on a single precipitation event, uniformly distributed across the catchment (Young *et. al.* 1988.). The model is widely used in the United States and is considered by practitioners to be a robust, practical model for decision support purposes (Leon *et. al.*, 2002).

The model considers a wide range of factors affecting water quality, including local hydrology, soils, nutrient and sediment loading, land use practices, land slope, precipitation, drainage, erosion and existing water quality. Hydrology outputs in the model are calculated using the Soil

Conservation Service (SCS) curve number approach. According to this method, runoff is calculated simply by subtracting the infiltration volume from the amount of precipitation. The AGNPS model simulates soil loss and sediment yield in a two step process. The Universal Soil Loss Equation (USLE) is used to predict soil erosion for five particle sizes (silts, clays, sand small and large aggregates). Eroded sediments are then transported in the receiving channel using a steady state continuity equation. The pollutant transport part of the model estimates chemical oxygen demand, soluble and sediment bound nitrogen, phosphorous concentrations and loads.

Model set-up and calibration

For the purposes of this study, the AGNPS model runs for the Duffins Creek watershed and East and West Branches employed a 1.2 x 1.2 km grid size. For smaller subwatersheds in the Duffins Creek, grid sizes of 600 x 600 m (Urfe, Millers) and 900 x 900 m (Ganatsekiagon, Reesor) were used. The grid size for the Carruthers Creek watershed was 900 x 900 m. For each grid cell, inputs from GIS mapping of soils, land cover and topography (DEM) are automatically extracted using an interface developed by Leon (1997). All user defined inputs to the model followed procedures established in the calibration study (Leon, 1997; Leon, 2002).

The hydrological response of the watershed was calibrated from eight events monitored in 1995 and, at the subwatershed scale, from 17 events monitored between 1997 and 1999. Peak flows calculated by the model matched the measured peak flows reasonably well for both data sets. The coefficient of efficiency (CE) - a dimensionless number from less than 0 to 1 - was used to indicate the goodness of fit between calculated and measured values. The CE for peak flows ranged from 0.75 to 0.92 among modelled events.

As noted above, the model computes deposition based on sediment transport of five particle size classes: clay, silt, sand, small and large aggregates. The size class or classes of particles permitted to scour within a particular cell was the only option selected during the calibration process. For each event, the model was run twice; the first allowing all particle size classes to be scoured, and the second allowing none of them to be scoured. The model produced a relatively small difference between values for full or no scouring and both produced a satisfactory match with measured sediment yield (CE range from 0.86 to 0.87).

Fertilizer applications rates and suggested availability factors were based on the results of a survey conducted for the Duffins Creek watershed in 1997 (JDE Ventures, 1998). Rates were propogated as a function of landuse coverage. Decay factors were the only parameters modified in the calibration of nutrient concentrations. These values were obtained by trial and error until the model produced a good match with field data. The ranges used in the model for nitrogen decay were between 5 and 12%, and for phosphorus, between 20 and 30%. These decay ranges produced a satisfactory fit between calculated and measured concentrations and loads for both nitrogen and phosphorus (CE values ranging from 0.58 to 0.64 for nitrogen, and from 0.96 to 0.99 for phosphorus).

Results of the AGNPS Modelling are shown in section 3.3.3.1.

3.2.3.2 Spreadsheet Model

A simple spreadsheet model was developed to estimate annual dry and wet weather loads and pollutant concentrations under the following three alternative land use scenarios:

1) existing land cover;
2) future land cover under the Official Plan; and
3) future land cover under the Official Plan with enhanced natural heritage cover.

This work, together with the Agricultural Non-point Source (AGNPS) modelling, serves as a tool for evaluating the water quality impacts associated with different land use scenarios. A full analysis of available stream water chemistry data from the Provincial Water Quality Monitoring Network (PWQMN) and other sources in the Duffins and Carruthers Creek Watersheds was dcoumented in the State of the Watershed Reports (TRCA, 2002). This assessment provided a broader basis for discussing water quality under the existing land use scenario.

The following data were used in the spreadsheet calculation of annual loads for TSS, Phosphorous, and Chloride under the three alternative land use scenarios discussed above:

(i) percent area in rural, wooded, and urban land use;
(ii) total wet / dry weather flow (runoff / baseflow) volumes for each study area;
(iii) mean concentrations for three pollutants under each of the three land use categories (rural, wooded, and urban) during wet and dry weather.

The mean wet weather concentrations for rural, wooded, and urban land uses in the Duffins Creek watershed represent an average of annual land use specific event mean concentration (EMC) data from several studies of stormwater quality, most of which were conducted in the City of Toronto (Aquafor Beech, 2001). Dry weather concentrations were derived from observed baseflow concentrations for monitoring stations with similar upstream land cover types in the Duffins Creek watershed and other Southern Ontario watersheds (Hinton, 1996; Beak, 1993). The wet and dry weather concentrations used in this study for each land use category were as follows:

Table 3-3: **Phosphorus, TSS, and chloride concentrations under three land use scenarios during wet and dry weather.**

	Rural	Wooded	Urban
Wet weather			
Phosphorus (mg/L)	0.20	0.12	0.30
TSS (mg/L)	100	70	170
Chloride (mg/L)	30	5	98
Dry weather			
Phosphorus (mg/L)	0.020	0.016	0.015
TSS (mg/L)	6	6	6
Chloride (mg/L)	17	5	32

Note: Rural land use includes both open space and agricultural land, and wooded areas include wetlands, meadows and forests. Wet weather event mean concentrations represent an average concentration from several studies for specific land uses. (Aquafor Beech, 2001).

Estimates of annual loads for TSS, Phosphorus, and Chloride were calculated as:

$$\text{Annual load}_i = \text{runoff} [LU^r * C^r_i + LU^w * C^w_i + LU^u * C^u_i]$$

where: LU = percent land use
C= wet or dry weather event mean concentrations
runoff = total runoff volume or total baseflow for the sub-watershed
subscript i represents the individual pollutant listed above; and
superscripts r,w and u represent rural, wooded, and urban land uses, respectively.

A detailed description of how the land use percentages were determined is provided in Chapter 3. Wet weather runoff was determined from water budget model outputs for each watershed / sub-watershed and each scenario (Clarifica Inc., 2002). Dry weather runoff was determined for the same watershed / sub-watershed and scenarios from discharge rates generated by a groundwater model, MODFLOW (Gerber, 2003).

Annual runoff and baseflow volumes were not available for the Carruthers Creek watershed. Hence, Carruthers Creek runoff volumes were calculated from Millers Creek sub-watershed runoff volumes, as follows:

Carruthers Creek runoff (m^3) = C * Millers Creek runoff (m^3)

where: C = Carruthers Creek area (3810 ha)/Millers Creek area (1698 ha)

Millers Creek was chosen for this purpose because it is immediately adjacent to Carruthers Creek and has similar physical characteristics (e.g. slope, soils, land use).

Calculations were completed for each of the 31 subbasins, defined in the hydrologic and water balance models. Results were consolidated and presented for watershed and subwatershed units.

Findings from the spreadsheet modelling are shown in section 3.3.3.2.

3.2.3.3 Wastewater Discharge Assessment

An assessment of discharges from the Stouffville Water Pollution Control Plant (WPCP) was undertaken in 2001 to estimate downstream phosphorus concentrations in the Reesor and West Duffins Creeks attributed to discharges from the plant. These estimates, together with measurements of WPCP discharge volumes, help to characterize existing conditions and generally indicate the magnitude of water quality improvement that may be expected following decommissioning of the plant, which is scheduled to occur in 2003.

The influence of the WPCP on phosphorus concentrations in the creeks was determined from the average phosphorus concentration in the WPCP effluent from 1993 to 2001 (0.17 mg/L) and dilution ratios at various points within the creeks, where the dilution ratio is:

$$\frac{\text{Average monthly streamflow volume}}{\text{Average monthly WPCP effluent volume}}$$

Average monthly streamflow volumes were calculated over the period of record for each stream gauging station. The data were ranked and dilution ratios were calculated for observations that fall at or below a range of percentiles. Where possible, the dilution ratio was also calculated for the minimum 7 day flow over a 20 year recurrence interval (the 7Q20 flow), which is the most frequently used criterion for assimilative capacity assessments.

The phosphorus concentration in the creek attributable to the WPCP at a given location and for a range of dilution ratios was subsequently calculated as:

$$\frac{\text{Average WPCP effluent phosphorus concentration (0.17 mg/L)}}{\text{Dilution ratio}}$$

Section 3.3.3.3 presents the findings from the wastewater discharge assessment.

3.2.3.4 Stormwater Management Assessment

The water quality impacts associated with urban stormwater runoff were recognized in the 1980s, and since 1990 all new developments have been required to install stormwater quality control measures. The quality of stormwater runoff is controlled through the provision of best management practices at the lot level, along the conveyance route and at the end of pipe. Currently, TRCA requires Level 1 water quality control (i.e. 80 % total suspended solids removal) for all new development areas. A review of the existing status of stormwater control within the watershed was carried out to identify areas where improvement was needed. Three levels of control were quantified: percent of developed area with quality and quantity control, percent of developed area with quantity control only (i.e. areas developed in the 1980s), and percent of developed area with no control (i.e. areas developed prior to the 1980s).

In an effort to improve the level of stormwater control within the Duffins, TRCA and area municipalities are undertaking stormwater retrofit studies for the watershed. The studies will identify opportunities to upgrade existing facilities (i.e. quantity facilities upgraded to incorporate quality and erosion control as well) and will also identify opportunities for new facilities (i.e. in areas where there currently is no control).

3.2.3.5 Erosion and Sediment Control for Urban Construction

For the purposes of the watershed plan development, it was assumed that in-stream, total suspended solid (TSS) concentrations would increase and that the duration of these elevated levels would also increase, under future development, without effective erosion and sediment control measures in place.

Recently, TRCA completed two important initiatives designed to improve the quality and effectiveness of erosion and sediment control measures being implemented on urban construction sites. The first initiative involved the development of a “model” by-law for control of erosion and sediment, mud tracking, litter, debris, and dust. This model by-law will assist in implementing the recommendations of the watershed plan.
The second initiative was to carry out a background study which included a literature review

relating to in-stream sediment and the effects on aquatic ecosystems. The study also included the development of a modelling framework to simulate erosion and sediment transport on construction sites and to effectively evaluate treatment facility performance. Over the next two to three years, TRCA will be monitoring a sediment and erosion control facility in the Town of Richmond Hill. Data collected from this exercise will be used to calibrate the modelling component. It is anticipated that a new sizing criteria will be developed using this information. In the interim, TRCA has adopted a revised, more stringent criteria that requires both a permanent pool and an active storage component. The revised criteria will be a requirement for new development applications until the new criteria has been established.

3.2.4 Aquatic Habitat and Species

The analysis of aquatic data has been an important component of assessing the health of watercourses within the TRCA's jurisdiction for many years. Previous watershed strategies for the Don and Humber Rivers and the Etobicoke and Mimico Creeks provide background information and rationale for many of the measures and indicators used in this document. These strategies relied on analysis done as part of the Fisheries Management Plans (FMP) prepared for each of these watersheds. Similarly, the information contained in the aquatic habitat sections of the Duffins and Carruthers Watershed Plan is presented in more detail in the Fisheries Management Plan (TRCA, 2003) prepared for the watersheds under present day or "existing land use" conditions.

Tools for assessing aquatic habitat and species are identified in the following discussion. Of these tools, the only one available at this time that could provide a basis for predicting aquatic habitat impacts from future land use scenarios is an empirical relationship between fish community type and the baseflow to total annual flow ratio. This empirical relationship and its use in predictive modelling is described under "Instream Habitat".

A summary of results from the aquatic system analyses is shown in section 3.3.4.

Tools for Assessing Aquatic Habitat and Species

Starting with the Don River Fisheries Management Plan in 1997, a similar approach has been used to characterize the aquatic system and to set future management direction for TRCA's watersheds. Using physical and biological information, an assessment of how the watershed would have functioned historically is prepared. Human factors such as barriers, land use change, and user input is applied as an additional level of analysis to help set management direction.

The process used in the Duffins and Carruthers watersheds, however, was slightly different. Analysis of the watershed response to future land use scenarios, particularly through the completion a water budget and groundwater flow modelling allowed for the assessment of potential impacts on the aquatic system, and the formulation of recommendations for reducing potential impacts.
A total of six indicators and associated measures and targets were developed to assess the health of the aquatic community. These are summarized in **Table 3-4.**

Table 3-4: Indicators of Aquatic Community Health

INDICATOR	MEASURES	TARGETS
Fish and Invertebrate Community Makeup	• invertebrate indices • IBI • indicator species and abundance	• To be determined • minimum IBI of good • maintain/achieve historical distribution of targeted indicator species as specified in the FMP
Instream habitat	• % instream woody cover • % riffle substrate • baseflow as a per cent of total annual flow	• to be determined • to be determined • as specified in FMP
Water chemistry	• water temperature • TSS • phosphorus • chlorides	• as specified in FMP • as specified in FMP • as specified in FMP • as specified in FMP
Fish passage to critical habitat (breeding, rearing, foraging grounds)	• presence of instream barriers	• only strategic barriers for fisheries management to remain
Riparian zone	• extent of woody vegetation along stream length	• minimum of 75% of stream length
Stream hydrograph	• flow events (timing, duration, frequency, and rate of change) • baseflow to average annual flow ratio • seasonal baseflow ratio	• to be determined with consideration or restoring historical hydrograph as specified in FMP; consideration for timing of low flows with respect to sensitive life cycle requirements of fish community

Fish and Invertebrate Community Makeup

Sampling was done in 2000 at six stations in the Carruthers Creek and 32 in Duffins Creek. At each of these stations, benthic invertebrate, fish, algae, and instream habitat data were collected. It is this information that provides much of the recent information on the status of the aquatic community within both watersheds.

Invertebrate Indices

Benthic invertebrates were collected, preserved and identified to the species level in the lab for the 2000 data. However, no detailed analysis was done. Some initial calculations of Hilsenhoff index was done for some of the data. Very little historical benthic invertebrate data was found.

Based on the lack of historical information and level of analysis done on the 2000 data, no targets or ratings have yet been set for the benthic invertebrate community.

Indicator Species and Abundance

Historical fish collection information was gathered from many sources including the Ontario Ministry of Natural Resources, Royal Ontario Museum, Highway 407 baseline reports, TRCA, and North Pickering Development Corporation Lands reports. Some of this information dates back to the early 1950s and provides a detailed picture of the fish community throughout the watershed over a period of more than 50 years.

Recent fish species information was collected in 2000 from six stations in Carruthers Creek and 32 in Duffins Creek. This information allowed a comparison between current and historic fish distribution across both watersheds. It was also one of the components used to determine fisheries potential in the watersheds.

Index of Biotic Integrity

The presence or absence of aquatic communities and/or indicator species are considered to be good indicators of aquatic ecosystem health as they are integrators of a variety of disturbances to their environment. An example of this methodology of evaluating aquatic ecosystem health is seen in the Index of Biotic Integrity (IBI). IBI is a measure of fish community associations that is used to identify the general health of the broader stream ecosystem. It was first developed to assess small to moderate sized warmwater rivers in the United States (Karr, 1981). Steedman's (1987) adaptation of this method for streams in southern Ontario includes two local indicators: *Salvelinus fontinalis* (brook trout) and *Rhynichthys* species (Longnose and blacknose dace). In general terms, the presence of brook trout is an indicator of a healthy coldwater system, while a high abundance of *Rhynichthys* species, generally indicates a degraded system. Steedman uses 10 measures of fish community composition to determine an IBI on a scale from 10 (poor) to 50 (very good) grouped into four general categories: species richness, local indicator species, trophic composition and fish abundance. A detailed explanation of these indices can be found in Steedman, 1987. **Table 3-5** shows the measures used in the Duffins/Carruthers application, as adapted from Steedman.

Table 3-5: Nine sub-indices used in calculation of the Index of Biotic Integrity

SPECIES RICHNESS	
1.	number of native species
2.	number of darter and /or sculpin species
3.	number of sunfish and/or trout species
4.	number of sucker and/or catfish species
LOCAL INDICATOR SPECIES	
5.	presence or absence of brook trout (only in streams designated as coldwater)
6.	percent of sample as *Rhinichthys* species
TROPHIC COMPOSITION	
7.	percent of sample as omnivorous species
8.	percent of sample as piscivorous species
FISH ABUNDANCE	
9.	catch per minute of sampling

Two modifications of Steedman's work were necessary for the application of IBI using the data for the Duffins Creek data set. The presence/absence of blackspot (a parasite of fish) was eliminated from the IBI because the information was not available for all surveys. The second modification related to the brook trout indicator. Steedman assumed that brook trout should be present in all streams and their absence was, therefore, a sign of degradation. However, there are numerous streams in the Greater Toronto Area that due to low groundwater input, would not have historically supported brook trout. For this reason, IBI scores in streams where it is felt brook trout would not have been found historically (ie. warmwater streams) were calculated using eight sub-indices, rather than nine. These scores out of 40 were then transformed to a score out of 45 to allow comparison with the remaining stations (ie. coldwater streams).

The modified IBI scores ranges from a low of nine (scoring one for each index) to a high of 45 (scoring five for each index). Four ranges of IBI scores have been designated to reflect stream quality.

Instream Habitat

Percent Instream Woody Cover
Only data for 2000 were available and it was felt they did not provide enough of a basis for setting targets and establishing ratings of current condition. It is anticipated that this will be done in a future update.

Percent Riffle Substrate
Only data for 2000 were available and it was felt they did not provide enough of a basis for setting targets and establishing ratings of current condition. It is anticipated that this will be done in a future update.

Baseflow As A Percent of Total Annual Flow
Due to their interconnectedness, surficial geology, baseflow and the water budget are described together in this section.

One of the roles surficial geology plays in stream morphology is determining infiltration of precipitation. The type and percentage of soils within a subwatershed will control the amount and rate of run-off to the streams versus infiltration to the ground. Since groundwater discharge is critical to maintaining baseflows, determining the type and extent of surficial materials is key to understanding areas of potential groundwater recharge and discharge.

Digital surficial geology data for the both watersheds was used in this assessment. Surficial geology types with similar infiltration characteristics, were grouped together. The resulting map provided a general assessment of potential areas of high and low infiltration and discharge rates. This information was used as one component of establishing habitat potential. An infiltration map was also produce by Gerber (2000) which provided an additional layer of analysis.

Groundwater is defined as subsurface flow that occurs in fully saturated soils and geologic formations (Freeze and Cherry, 1979). Where these saturated soils or geologic formations intersect the surface, groundwater discharge occurs. Groundwater discharge to a stream forms baseflow and is critical for maintaining water flows, especially during the drier, summer months. In the Greater Toronto Area, groundwater temperatures are in the range of 8-10^{0}C. The more groundwater discharge to a stream the lower and more stable are the water temperatures, which is important to temperature sensitive species like brook trout. Groundwater is also relatively sediment free as it discharges into a stream. This is very important for brook trout spawning since they often spawn upon locations of groundwater discharge. Decreases in the amount of groundwater entering a watercourse may result in increased water temperatures or even cause a stream to dry up completely. This is particularly harmful in coldwater streams. Bowlby and Roff (1986) indicate that groundwater discharge is one of the major characteristics that determines the presence of a cold or warmwater fish community. Understanding the influence of baseflow on aquatic habitat is, therefore, of critical importance in protecting and rehabilitating aquatic communities.

Habitat Suitability Indices developed in the United States utilize annual baseflow as a percent of average annual daily flow to determine habitat suitability for certain trout species (Raleigh, 1982, Raleigh et al., 1984; Raleigh et al. 1986). This ratio is useful in determining flow fluctuations, providing an indication of flow stability. This research suggests that ratios greater than 50% are excellent for trout production, between 25-50% are good for trout production, and less than 25% is poor for trout production. The higher the ratio, the more stable the flow and the more likely the habitat is suitable for sensitive coldwater species.

The water budget and groundwater flow modelling evaluations of the future land use scenarios enabled the calculation of baseflow as a percent of total annual and total monthly flows.

Water Chemistry

A target setting approach developed as part of the Toronto Wet Weather Flow Management Master Plan (WWFMMP) provided the basis for assessing the aquatic habitat and species targets and ratings for this indicator. Current water quality conditions are as reported in the Duffins and Carruthers State of the Watershed Reports (TRCA, 2002). Refer to the water quality section (3.2.3.2) for more information on how water quality was analysed in response to the future land use scenarios.

Water Temperature
Some water temperature information was collected in 2001. This information provides some insight into a few locations of both watersheds and, therefore, does not allow for a full assessment of current conditions.

Total Suspended Solids

A literature review used in the WWFMMP suggests that for most fish communities, except the most tolerant, a maximum TSS concentration should not be more than 100mg/L.

Phosphorus
A literature review used in the WWFMMP suggests that for the least tolerant fish communities, a phosphorus concentrations should not exceed 0.03 mg/l under dry conditions and 0.1 mg/l under wet conditions 80% of the time.

Chlorides
The Government of Canada has recently published a report on the toxicity of road salt (Environment Canada and Health Canada, 2001). They establish a maximum concentration of approximately 250 mg/l.

Fish Passage

Some previous work had already identified instream barriers in the headwater areas of Duffins Creek. Using 1999 air photos, additional instream barriers were identified. Beaver dams and log jams were not included since they tend to be relatively short term in nature. Initially, road and rail crossings were not identified but were added later. Due to limitations in resolution of the air photos and tree cover, additional barriers may exist that were not identified.

Concern over competition between stream resident trout (native brook trout and naturalized brown trout) and migratory trout (rainbow trout and chinook salmon) necessitated that maintenance of a partition between these two fish communities. The existing barriers on the West Duffins at Whitevale and north of Highway 7 on the East Duffins were felt to fulfill this role and should be maintained as fisheries management structures.

While many barriers were identified in both watersheds, they did not limit fish movement as much as many of the other watersheds in TRCA's jurisdiction.

Riparian Zone

The riparian vegetation within these watersheds was mapped, measured, and categorized from interpretation of 1999 ortho photography. Riparian communities were divided into five categories: forest, wetland, meadow, successional, and bare. Although the targeted riparian zone would be delineated as being within 30 m of the digital watercourse, due to limitations of the GIS analysis, only the vegetation type found immediately adjacent to the watercourse was used for the purposes of classification and measurement. This evaluation also looked at the percent of total stream length having woody riparian vegetation. It should be recognized that the total riparian zone length was calculated by doubling the total stream length, because every stream has a left and right bank.

Stream Hydrograph

Flow Events
More detailed analysis will need to be done before an asessment of current conditions is undertaken with respect to the aquatic community.

Baseflow to Total Annual Flow Ratio
Refer to previous discussion, under "Instream Habitat".

Seasonal Baseflow Ratio
Some initial analysis from the three modelling scenarios shows that the potential increases in run-off and decreases in infiltration are also reflected monthly, as well as overall in the annual water budget. However, more detailed analysis will need to be done before and assessment of current conditions is completed.

3.2.5 Terrestrial Habitat and Species

Although natural cover has been increasing in the upper Duffins and Carruthers watersheds over the past 50 years, rapid growth in the Greater Toronto Area has generally led to the incremental loss of remaining forest fragments, local extirpation of sensitive species, and loss of ecosystem health. In an effort to identify the values of all remaining habitat patches, and to determine restoration potential, Toronto and Region Conservation, through its Terrestrial Natural Heritage

Program, has developed a landscape analysis of habitat patches using GIS. Applying landscape ecology principles, the analysis is able to predict the impact that small changes have on the overall terrestrial natural heritage system at a variety of geographic scales and so can direct both restoration and preservation efforts at the local level in order to improve the health of the regional system.

This analysis is built upon common principles from the scientific fields of conservation biology and landscape ecology, and all components of the program have been extensively peer reviewed by scientific experts. The analysis has been used by TRCA and the City of Toronto for a natural heritage study that was used to inform the City of Toronto's new Official Plan (City of Toronto, 2001). A version of the analysis has also been adopted by Lake Simcoe Region Conservation Authority for their study of the Town of Newmarket (LSRCA, 2002).

The landscape analysis goes beyond the short-term, local planning needs of the regional and local municipalities by demonstrating the long term cumulative impacts of local decisions at the regional level. It allows municipalities to develop and monitor their Official Plans in a way that builds in clear and specific biodiversity targets and provides a method for measuring progress against those targets. The program is also able to model results of decisions at the site level and thereby provides a robust planning tool which will be essential for restoring a healthy regional ecosystem.

TRCA, through literature review and consultation with the scientific community, has identified indicators that address six critical aspects of the terrestrial ecosystem. A set of twenty measures are used to report on the status of each of these indicators. Each of these measures covers a different component of the terrestrial ecosystem from landscape level, down to community level, and down again to species level.

The indicators and measures provide a scientifically valid, quantitative, defensible approach for evaluating conditions at a site through landscape scale. The use of these indicators and measures will allow the establishment of quantitative targets for the terrestrial ecosystem.

The indicators and measures used are:

Indicator	**Measure**	**Level of Detail**
Quantity	▪ Percent natural cover	▪ Landscape
	▪ Vegetation community proportion	▪ Community
	▪ Species population	▪ Species
Distribution	▪ Distribution of natural cover	▪ Landscape
	▪ Distribution of communities of concern	▪ Community
	▪ Distribution of species of concern	▪ Species
Matrix Influence	▪ Landscape matrix influence	▪ Landscape
	▪ Trail density	▪ Community
	▪ Sensitivity to development index	▪ Species
Size and Shape	▪ Average patch size	▪ Landscape
	▪ Average patch shape	▪ Landscape
	▪ Interior habitat	▪ Landscape
	▪ Area-sensitivity index	▪ Species

Connectivity	▪ Natural cover connectivity	▪ Landscape
	▪ Vegetation type connectivity	▪ Community
	▪ Mobility index	▪ Species
Biodiversity	▪ Vegetation type representation	▪ Community
	▪ Geophysical requirements index	▪ Community
	▪ Species representation	▪ Species
	▪ Habitat dependence index	▪ Species

Except for the matrix influence measure (which is an original measure developed by TRCA) the remaining landscape measures are commonly used in other ecological studies. The use and interpretation of these other measures by the TRCA Terrestrial Natural Heritage Program is consistent with many other studies. Sample studies are documented in Freemark (1988), Forman (1995), and Fahrig (1997). There is scientific support in the literature, the scientific community, and from TRCA field data for how the matrix influence measure has been employed and interpreted by the TRCA; however, beyond TRCA's (City of Toronto, 2001) and LSRCA's (LSCRA, 2002) reports, this exact measure has not yet been utilized in other studies.

The remote sensing to collect the landscape scale data has been completed. Major cover types mapped include forest, successional, wetland, meadow, urban and rural. The vegetation community and species data are more labour intensive to collect, requiring field surveys by biologists. The current health of the terrestrial ecosystem in the Duffins and Carruthers watersheds was assessed primarily using the landscape level measures and aided by the field data where these were collected. These results will be updated as new field-collected or remote-sensed information becomes available.

For each of the three land use scenarios, a map illustrating the resulting land cover was digitized. The Existing and Future Land Use with Enhanced Natural Cover scenario maps were then analysed for five selected measures: percent natural cover, distribution of natural cover, matrix influence, average patch size, and average patch shape. Percent of natural cover was measured by calculating the percent of the total watershed area that is under natural land cover, which includes forest, meadow, wetland and successional land cover types. The measure of "distance-to-centroid" was used to evaluate the distribution of natural cover over the watershed. For this measure, a GIS is used to determine the Cartesian coordinates of the centroid (the theoretical "centre of mass") of the mosaic of patches of natural cover that make-up the terrestrial system, and the Cartesian coordinates of the centroid of the watershed. The measure of "distance-to-centroid" is the distance that separates the two sets of coordinates. The ideal condition for this measure is a distance of zero, which occurs when the patches of natural cover that make up the terrestrial system are distributed evenly across the watershed.

The matrix influence score is a measure of the influence of surrounding land uses on the status of each individual patch as a viable natural habitat area. Scores consider land uses within 2 km of the edge of each natural cover patch and are based on a rating scale of 0 to 5 developed by TRCA. Patches that score high are considered to experience less negative impact from surrounding land uses than patches that score low. Using GIS, matrix influence scores are assigned to each natural land cover patch and an average score is calculated for each watershed.

The patch size and shape indicators were also evaluated using GIS to quantify the area of each patch of natural land cover (size indicator), and to establish the ratio of patch area to perimeter length (shape indicator) which provides a means of quantifying the extent to which each natural land cover patch is being influenced by “edge effects”. These values were transformed into patch size and shape scores which are based on a scale of 0 to 5. Patches that score high are considered to be quality habitats capable of supporting a variety of sensitive species, mid-scoring patches are considered to be in fair condition, and low scoring patches support only the most robust species.

In addition, the scores for matrix influence, average patch size, and average patch shape are also summed together to achieve a total patch score. The analysis is taken this extra step as it is at this more localized level where management plans and land use policies will have a visible effect on habitat quality. These total patch scores are used to compare changes at a patch level under each management scenario. Patches that score high are considered to be quality habitats capable of supporting a variety of sensitive species, mid-scoring patches are considered to be in fair condition, and low scoring patches support only the most robust species.

Results are used to compare the status of the terrestrial ecosystem at a landscape level under each scenario. The Future land use scenario was not analysed, because it represented only limited, localized changes in the natural heritage system, which would not likely be reflected in the landscape level analysis.

It should be noted that the Future with Enhanced Natural Heritage Cover land use scenario was developed using principles of the TRCA Terrestrial Natural Heritage Approach with consideration for practicality and feasibility of implementation in these watersheds. Therefore, this scenario represents a targeted terrestrial natural heritage system, from the standpoint of terrestrial habitat and species management objectives.

More details about this methodology, species scoring and ranking, data collection protocol, and landscape analysis can be found in the TRCA Terrestrial Natural Heritage Approach (report in progress, TRCA, 2003).

Results of the terrestrial natural heritage analysis are shown in section 3.3.5.

3.2.6 Public Use and Recreation

The primary indicators associated with recreation objectives relate to public use opportunities and experiences (e.g. area of publically accessible greenspace, recreational facilities, trail networks, etc.). A combination of quantitative and qualitative data were collected for these indicators, based on existing land use conditions. A qualitative assessment of changes in these areas was applied to the future land use scenarios. Particular consideration was given to the change in public use experience and opportunity for implementation provided by change in land ownership, land use, and population growth that may arise in the future.

3.2.7 Human Heritage

Key indicators associated with the human heritage objectives include the number of identified heritage sites, awareness and appreciation, and policy mechanisms for identifying and protecting sites. TRCA's existing database of known heritage (archaeological and built heritage) sites was reviewed.

TRCA's predictive model for identifying potential archaeological site locations was applied using Geographic Information Systems (GIS). The Archaeological Site Predictive Model (ASPM) was developed by TRCA (formerly MTRCA; MTRCA, 1990), based on correlations established within the TRCA jurisdiction, between an extensive database of known archaeological site locations and physical geographic features. The ASPM does not predict precise site locations rather it presents a generalized view of the current understanding of prehistoric settlement patterns in the watershed. In this application of the model, areas of potential archaeological sites were identified as those lands within 250 m of a waterbody and in areas of well-drained soils.

A qualitative assessment of the impacts or opportunities associated with future land use scenarios was carried out. Consideration was based on the opportunity to identify sites during the process of land use change and the relative opportunity for preservation of sites under different land ownership settings.

3.3 Integrated Findings by Technical Component

This section presents results of the analysis of three land use scenarios. A brief summary of the results and evaluation according to the watershed management objectives is included in **Appendix A.**

3.3.1 Surface Water Quantity

3.3.1.1 Water Balance

The details and findings of the water budget modelling can be found in *Water Budget in Urbanizing Watersheds: Duffins Creek Watershed (Clarifica, 2002)*. The following is a brief summary of these findings.

Understanding and quantifying water balance components is of particular interest when planning watershed management strategies. Land use changes during urbanization are known to shift the water balance in a watershed: increasing surface runoff and decreasing the amount of water retained on-site. After urbanization, water will be distributed differently, both temporally and spatially. Therefore, more water will be available in some places at certain times and less in others. There are also changes in the amount of water entering the ground with impacts to the water table levels. This can be significant in shallow, unconfined groundwater aquifer systems where groundwater supplies water to vegetation root zones and is a source of base flow in streams through seepage along stream valleys when there is a hydraulic gradient from water-bearing soil layers.

The objective of the Duffins Creek Water Balance Study was to characterize the surface water balance of the Duffins Creek watershed for existing and future land use conditions. Results from the study will be used to assist watershed managers deal with potential changes associated with future urbanization.

Three land use scenarios were considered in the Water Balance Study.

1. Existing Conditions;
2. Future (Land Use); and
3. Future (Land Use) with enhanced natural heritage cover.

The water balance analysis of the Duffins Creek watershed was completed using the Water Balance Analysis System (WABAS). The WABAS approach achieves multiple objectives such as consistency with existing hydrologic models, availability of data, flexibility for adaptation, simplicity, etc. The surface runoff response was calibrated at six historical stream flow gauging locations. The calibration showed good agreement between the model and the measured flows.

The long-term water balance analysis was completed using 15 years of climate data and future land-use scenarios for each of the 30 basins in the Duffins Creek Watershed. **Table 3-6** summarizes the watershed-weighted water budget components for each scenario. The "IN-OUT" term refers to the overall continuity of the analysis (Water in - Water out = Storage Change).

Table 3-6: Duffins Creek Watershed Water Budget for the Three Land Use Scenarios

Scenario	Precipitation (mm/yr)	Runoff (mm/yr)	GWI (mm/yr)	E (mm/yr)	IN-OUT (mm/yr)
Existing	844	145	206	489	4
Future (OP)	844	170	197	472	5
Future with Natural Heritage	844	162	195	481	6

GWI = Groundwater Infiltration, E = Evapotranspiration

As expected, runoff volume increases with uncontrolled development. This increase is a direct result of higher imperviousness. Imperviousness within the watershed increases from less than 1% to about 22% **(Figures 3-3 a and b)**. Overall, the reductions in groundwater infiltration under future conditions appear small due to the relatively small change in land use over each basin (i.e. small change in overall imperviousness). More significant changes are expected within each development site. The Enhanced Natural Heritage Scenario results in a small reduction in runoff due to the expected decrease in rainfall 'abstractions' associated with reforestation **(Figures 3-4 a and b).**

3.3.1.2 Watershed Hydrology

Design flows for the 2 year to 100 year return period and the Regional Storm were estimated using the VISUAL OTTHYMO model for the three land use scenarios: existing land use, future land use, and future with enhanced natural heritage. In terms of land uses, approximately 7% of the Duffins Creek Watershed is developed with urban land uses under the existing scenario. The future land use scenarios will increase the level of urban development to approximately 15%.

Based on the future scenario, peak flows are expected to be approximately 15% to 120% greater than existing flows for the 100-year event (**Figure 3-5a**). These increases only occur in areas that will be impacted from future development. Therefore, stormwater management measures are essential in these areas to ensure that pre-development peak flows are maintained. The future scenario also results in a number of subcatchments having no change in peak flows and a few having peak flows that are marginally less than existing peak flow rates for the 100-year event.
Based on the future with enhanced Natural Heritage scenario, peak flows are expected to be approximately 10% to 110% greater than existing flows for the 100-year event, which are slightly less than the increases expected with the future scenario (**Figure 3-5b**). As with the future scenario these peak flow increases only occur in future development areas. The future Natural Heritage scenario also results in a number of subcatchments having peak flow decreases that are expected to be approximately 0% to 25% less than existing flows for the 100-year event.

In order to mitigate against the potential for increased flood risk associated with increased peak flows under future scenarios, the implementation of flood plain management and stormwater management programs is essential. Additional analyses of alternative levels of control were carried out to provide guidance as to the most effective stormwater management strategies.

Stormwater Management

"Unit flow rates", expressed as litres per second per hectare (l/s/ha), were defined for catchments within the Duffins Creek watershed, as a means of standardizing the definition of pre-development flow conditions. Unit flow relationships were derived for three individual catchments with varying characteristics, located throughout the watershed. Unit flow equations were developed based on drainage area and location within the watershed, and the results of this analysis were then extrapolated to remaining catchments where future development may be planned. Unit flows are used as management criteria for designing flow control measures as part of new developments.

Based on a comparison of model results for existing and future landuse scenarios, "post-to-pre" flood control (i.e. 2-year to 100-year events) facilities are recommended for developments draining to the following tributaries:

- Reesor Creek;
- Whitevale Creek;
- Urfe Creek;
- Ganatsekiagon Creek;
- Millers Creek (north of Taunton Road);
- Mitchell Creek ;
- Brougham Creek (including Spring Creek);
- West Duffins Creek (north of Hwy. 7); and
- East Duffins Creek (north of Hwy. 7).

In addition, any proposed commercial infill development draining to Millers Creek (south of Taunton Road) will also require 2-year to 100-year "post-to-pre" control.

Based on a comparison of model results for existing and future landuse scenarios, Regional Storm control may be required for the following tributaries:

- Whitevale Creek;
- Urfe Creek; and
- Ganatsekiagon Creek.

A Regional Storm assessment will be required for proposed developments which drain to the above-mentioned tributaries to determine whether Regional control is required.

Should future development be proposed beyond those assumed in the Official Plan scenario, "post-to-pre" runoff controls may be required, regardless of the location within the watershed, and an assessment will also be required to determine whether Regional Storm controls will be necessary for such developments.

In addition, the hydrologic model should be further verified when rainfall and streamflow data becomes available for future storm events which are larger than those used for the calibration. The model should also be updated by development proponents as future development proceeds and future stormwater management facilities are constructed.

Floodplain Management

Existing regulatory floodlines are based on the future scenario peak flows for the regional storm from the 1991 Duffins Creek Hydrology by Aquafor Beech Ltd. These floodlines will be updated in forthcoming hydraulic updates in 2003/2004, using the future scenario peak flows for the regional storm from the 2002 Duffins Creek hydrology update by Aquafor Beech. The future scenario peak flows from the 2002 hydrology update are approximately 9% to 50% lower than the flows from the 1991 hydrology model, for a majority of the subcatchments. Peak flows from a few subcatchments resulted in higher regional flows when compared to the 1991 model, however, these increases are due to drainage boundary changes to the subcatchments that arose from better topographic information. As a result of the changes in future scenario peak flows for the regional storm, it is anticipated that the regulatory floodlines will possibly decrease for a majority of the subcatchments, which would result in a corresponding possible decrease in flood vulnerable areas (FVA) and flood vulnerable roads (FVR).

Under the future Natural Heritage scenario, peak flows for the regional storm are lower than the peak flows for the future scenario, therefore, even further possible reductions in regulatory floodlines would be expected if these flows were used in the floodplain mapping updates. However, using a precautionary approach, floodlines will be set using peak flows under the future scenario. Any further reductions that may arise from the establishment of enhanced natural heritage may not be realized for some years as the vegetation matures.

3.3.1.3 Baseflow Distribution

To illustrate the spatial distribution of baseflow within Duffins Creek, the watershed was broken down into 6 major drainage basins **(Figure 3-6)**. Present conditions show more than half (57%) of the total output of Duffins Creek is contributed by the East Duffins creek, a large portion of this is concentrated within the Oak Ridges Moraine. The West Duffins contributes approximately 38% of the total output, with the largest contributions emerging from the Uxbridge area headwaters and the Oak Ridges Moraine. The more southern basins contribute significantly less baseflow, with 2% contributions from Ganatsekiagon and Millers Creeks, and 1% of total output is contributed from Urfe Creek.

Carruthers Creek was not broken into sub-basins, but linear analysis was done through a percentage breakdown by segments, based on the total output equalling 100% **(Figure 3-7)**. It was found that in the Carruthers the baseflow contributions are more evenly distributed. Increases of approximately 15-25% were shown at most flow points. Baseflow losses were shown throughout the Carruthers watershed in the 4th Concession area. This is attributed to the Lake Iroquois Shoreline, where a hydraulic down gradient is known to exist. A marked increase is noted at Rossland Road at the edge of the Iroquois Shoreline, where sand and gravel deposits are exposed.

An interpretation of impacts on baseflows due to potential land use changes can be defined in the Duffins Creek watershed, based on results from the Water Budget Model and the Groundwater Flow Model. The Groundwater Model was used to predict changes in the amount of water being shown as discharge, in response to changes in groundwater infiltration volumes (GWI) generated from the Water Budget Model.

Under the Future Official Plan scenario, the modelled reductions in baseflows would range from 0 to approximately 26 percent when viewed on an individual drainage basin basis. Baseflow reductions by sub-watershed are modelled as; the Lower Duffins (26%), Ganatsekiagon (17%), Urfe (14%) and Millers Creeks (4%). Little change would be anticipated within the East (1%) or West branches (3%) which generate the bulk of the overall system baseflow. With the majority of the overall watershed's baseflow being from the East and West branches and the most significant baseflow reduction taking place within subwatersheds which contribute only a small percentage of overall baseflow, no significant impacts to overall baseflows would be expected within the lower reaches of the watershed.

Due to limitations within the current state of the art in water budget tools, the inclusion of the Enhanced Natural Heritage scenario also shows a minor effect on groundwater infiltration, that may impact baseflows. This is deemed to be more a reflection of the tool's limitations as opposed to a true reflection of the impacts of additional vegetation. In a report for the Ganaraska watershed, which exhibits similar geology to that of the Duffins, Richardson (1946) noted that springs were more numerous and streams commenced farther up slope when the watershed was more heavily timbered.

3.3.1.4 Surface Water Use Assessment

The impacts of surface water withdrawals, either permitted or un-permitted under the Provincial PTTW are difficult to assess solely through field observations, due to the nature of how the data were collected. If for instance, baseflow measurements were taken upstream and downstream of a permitted taking when the taking was not underway, a second reading downstream when the taking was underway would be required to clearly define the impact. The collection of data originally done by the Geologic Survey of Canada (GSC) in 1995 and 1996 on the Duffins Creek watershed was done as a single collection of data at each point. On the Carruthers Creek, data were collected by TRCA in 2000 in a similar fashion. A second collection of base flows within the Reesor creek sub-watershed in 2001 and the subsequent comparison to the 1995 GSC data did flag an occurrence of a surface water taking. The 2001 set of observations reflect a reduction in upstream to downstream baseflows of close to 80% due to a surface taking, which is a significant reduction in base flows within the Reesor Creek sub-basin.

As an alternative to field observations, a review of the PTTW database was undertaken and the significance of maximum annual permitted water withdrawals was considered in relation to total annual baseflow volume **(Table 3-7)**. It was found that within the Duffins Creek Watershed, known water takings represented a maximum withdrawal amounting to approximately 5% of measured annual baseflow for the overall watershed. When further analysis was completed at the subwatershed scale, it showed that Reesor Creek was one of the most affected with a maximum withdrawal of 16% of the annual measured baseflow, and the West Duffins was subject to removal of approximately 17% of annual measured baseflow. East Duffins Creek, the most significant contributor of baseflow to the overall watershed, with 10 identified surface water takers has a potential reduction of 12 % of annual measured baseflow.

Table 3-7: Estimated Surface Water Withdrawals as a Proportion of Total Annual Baseflow

Watershed/ Subwatershed	#PTTW	Maximum permitted annual water takings (Millions/L/yr)	Total annual Baseflow volume (Millions/L/yr)	Percent of total annual baseflow permitted to be withdrawn (%)
Duffins Creek watershed	29	4721	47400	10
West Duffins Creek	17	3348	19871	16.8
Reesor Creek	9	924	5765	16
East Duffins Creek	10	1258	10784	11.7
Ganatsekiagon Creek	0	n/a	n/a	n/a
Urfe Creek	0	n/a	n/a	n/a
Millers Creek	2	23	729	3.2
Carruthers Creek Watershed	2*	1458	1057	138

*current PTTW applications

While there are no active permits in the Carruthers Creek watershed, a PTTW application, currently under review by the Ministry of the Environment, would represent a potential withdrawal of approximately 138% of total annual baseflow. This withdrawal may represent a large potential for detrimental effects to the watercourse.

Initiatives currently underway in the PTTW program by the Ministry of the Environment will require all permitted surface takers to change the methods of taking in order to protect a significant portion of the baseflow. This change in requirements, if applied to all renewals and for new permits, will significantly reduce impacts to base flows. The availability and maintenance of the baseflow and PTTW databases should provide a basis for assessing both local and cumulative impacts to the baseflows within the watersheds. This knowledge will provide for improved decisions regarding future PTTW applications and renewals.

3.3.2 Groundwater Quantity and Quality

3.3.2.1 Groundwater Flow

The detailed findings of the groundwater flow modelling are found in *Duffins Creek Watershed Hydrogeology and Assessment of Land Use Change on the Groundwater Flow System* (Gerber Geosciences, 2003). The following is a summary of these findings. The initial sections discuss the background geology, flow, and aquifer characteristics. Latter sections present the impacts of the future land use scenario on the groundwater flow system.

Geologic Setting

The Duffins watershed is situated on the south flank of the Oak Ridges Moraine and drains southward towards Lake Ontario. Two landforms greatly influence the groundwater flow system. These are the Oak Ridges Moraine which forms the height of land in the northern part of the basin, and the Lake Iroquois shoreline which forms a topographic break in slope within the southern part of the basin. The regional ground surface gradient is approximately 0.009 toward the south. Both ground and surface water flows from north to south, or from the Oak Ridges Moraine highlands to Lake Ontario.

Hydrostratigraphic Units and Setting

Sibul et al. (1977) mapped fourteen overburden aquifer systems within the Duffins Creek and Rouge River surficial drainage basins and classified them as either upper or lower aquifer systems. These aquifer systems were originally interpreted to exist as discrete lenses of permeable sands and gravels within low permeability tills, silts and clays (Haefeli, 1970; Sibul et al., 1977). However, hydrochemical studies by Howard and Beck (1986) suggest that many of these aquifer systems (shallow and deep) are interconnected regionally and receive a significant component of recharge via the overlying till. This latter conclusion is supported by more recent investigations (Gerber and Howard, 1996; 2000; 2002).

Based on updated stratigraphic information for the basin (Boyce, 1997), the overburden aquifers are classified in this report as Upper, Middle and Lower systems, with Middle and Lower aquifers occurring below the Northern/Newmarket till within deposits of the Thorncliffe and Scarborough Formations, respectively. The Upper aquifer system occurs above the Northern/Newmarket till within Oak Ridges Moraine deposits and sand bodies associated with the Halton Till and Mackinaw Interstadial deposits. The shale bedrock is not considered to be a good aquifer from either a quantity or a quality perspective (Sibul et al., 1977). A schematic of these stratigraphic units is provided in **Figure 3-8.** A conceptual model of the groundwater flow system is shown in **Figure 3-9.**

The three-dimensional arrangement and classification of these geologic deposits into hydrostratigraphic units are illustrated on **Figure 3-10.**

It is important to note that not all hydrostratigraphic units are present throughout the study area. For example, some of the deposits older than the Northern/Newmarket till thin and pinch-out in the southern parts of the basin where the overburden sequence is thin. The Northern/Newmarket till has also been eroded in places south of the Lake Iroquois shoreline. These areas would be classified as Newmarket till breaching channels according to Sharpe et al. (2002).

Groundwater Recharge

Groundwater recharge occurs over most of the study area. Groundwater discharge occurs along stream reaches, and where upward vertical hydraulic gradients are associated with topographic breaks in slope along the flank of the Oak Ridges Moraine (e.g. Stouffville) and the Lake Iroquois shoreline. The Oak Ridges Moraine forms the major recharge area within the northern part of the study area with recharge estimated between 280 and 400 mm/a. Estimates of recharge through the Halton Till plain range from 125 to 200 mm/a.

The glaciolacustrine deposits associated with the Halton Till dramatically reduce recharge with estimates ranging from 35 to 50 mm/year. Beach sand and gravel deposits associated with the Lake Iroquois shoreline have estimated recharge rates of approximately 200 mm/year.

The sand and gravel deposits of the Oak Ridges Moraine are estimated to have higher recharge rates compared to similar deposits associated with the Lake Iroquois shoreline because of the presence of hummocky topography along the moraine. For large portions of the moraine, defined stream channels do not exist and much of the water surplus eventually forms groundwater recharge. The Lake Iroquois silt, clay and till deposits are estimated to have recharge rates less than 100 mm/year due to a combination of relatively low permeability and a high degree of urbanization.

Travel times from recharge to discharge zones can range from weeks/months to thousands of years. Present maximum estimates are up to 3000 years for water particles to travel from the recharge zone at the watershed divide along the crest of the moraine, to eventual groundwater discharge from the Lower aquifer to Duffins Creek south of Taunton Road (Gerber and Howard, 2002).

Groundwater Discharge

There are two main areas of groundwater discharge to streams as measured by Marc Hinton of the Geologic Survey of Canada (Hinton, 1996) and Don Haley of the TRCA (TRCA, 2003). These areas are depicted in the baseflow distribution mapping discussed in section 3.3.1.3. One area is the south flank of the Oak Ridges Moraine where groundwater discharge forms the headwaters for major streams within the Duffins basin and comprises 60% of the entire basin groundwater discharge to streams. Headwater discharge for West Duffins Creek and Duffins Creek headwaters alone account for 16% and 28% respectively of the entire basin groundwater discharge to streams. The second area of significant groundwater discharge occurs to Duffins Creek, Carruthers Creek, and the mouths of the Ganatsekiagon, Urfe and Brougham Creeks along and south of the Lake Iroquois shoreline. This discharge is received from all three aquifers but more significantly from the Middle and Lower aquifers which outcrop in this area. It is estimated that 77% of the entire basin groundwater discharge is received from the Upper aquifer, 21% from the Middle aquifer and 2% from the Lower aquifer (Gerber and Howard, 2002).

There are four general hydrogeologic settings which occur within the Duffins Creek basin. Setting one includes the deposits of the Oak Ridges Moraine and associated areas of hummocky Halton Till along part of the south flank. This area is characterized as a net groundwater recharge area. Setting two includes the areas of the south flank of the ORM, south of the hummocky terrain, which are a net discharge zone where groundwater discharge exceeds groundwater recharge. The third setting is the South Slope or Halton Till Plain situated between the headwaters and the Lake Iroquois shoreline, and is a net recharge zone. The fourth setting occurs south of the Lake Iroquois shoreline and is a net groundwater discharge zone. While recharge does occur over part of this area, the deeper aquifer discharge associated with the Lake Iroquois shoreline is greater than the relatively low recharge estimates for this area. Estimates of the relative groundwater recharge and discharge quantities for the various hydrogeologic settings are summarized in **Table 3-8.**

Table 3-8:Groundwater Recharge and Discharge Quantities by Hydrogeologic Setting

Hydrogeologic Setting Surficial Geology	**IN** Recharge	**OUT** Springs	River Discharge	**IN-OUT**
1. Headwaters > 275 m amsl				
ORM deposits	36200	0	16600	19900
Hummocky Halton Till	27900	0	7200	20700
Halton Till	4200	0	6200	-2000
Glacial Lake Peel	200	0	0	200
subtotal	**68500**	0	30000	38,500 net recharge
2. Headwaters < 275 m amsl				
ORM deposits	2600	0	9700	-7100
Hummocky Halton Till	3900	0	8900	-5000
Halton Till	6100	100	16100	-10100
Glacial Lake Peel	2100	0	8000	-5900
subtotal	**14700**	100	42700	-28,100 net discharge

Hydrogeologic Setting Surficial Geology	**IN** Recharge	**OUT** Springs	River Discharge	**IN-OUT**
3. South Slope				
Halton Till	24600	5400	15500	3700
Glacial Lake Peel	4500	1000	6200	-2700
subtotal	**29100**	6400	21700	1,000 net recharge
4. Glacial Lake Iroquois				
Lake Iroquois	14700	2500	20100	-7,900 net discharge
	127000	**9000**	**114500**	**3500**

Note: Quantities from Calibrated flow scenario described in Gerber and Howard, 2002. Hydrogeologic settings shown in Figure 12.

Ref.: Gerber Geosciences Inc., 2003

Upper Aquifer

Surface drainage divides coincide with groundwater flow divides for the Upper aquifer system and groundwater flow within this aquifer system is predominantly south to southeast toward Lake Ontario at regional horizontal hydraulic gradients of about 0.01. Local deflections in groundwater flow occur toward creeks and rivers where horizontal hydraulic gradients increase near discharge areas. Groundwater flow within the Upper aquifer system is generally horizontal and unconfined, however, confined conditions exist where Halton Till overlies Oak Ridges Moraine deposits along the southern slope of the moraine (e.g., Stouffville area) and within Mackinaw Interstadial deposits where the overlying Halton Till and glacial Lake Peel deposits are of sufficiently low hydraulic conductivity.

Middle Aquifer

The groundwater divide for the Middle aquifer system corresponds generally with the surface water drainage divides. The Middle aquifer system is recharged mainly by downward vertical leakage through the overlying Northern/Newmarket till from the Upper aquifer system with minor inter-aquifer flows entering the basin. Vertical hydraulic gradients downward through the Northern till range from 0.4 in the northern part of the study area and increase to approximately 0.8 in the southern part of the study area. The increase in downward vertical hydraulic gradient southward is caused by discharge from the Middle aquifer system to creeks where valleys have been eroded through the Northern/Newmarket till. Within the southern part of the study area near the Lake Iroquois shoreline, the Middle aquifer system also receives recharge by vertical leakage upwards through the Sunnybrook diamict from the Lower aquifer system.

The Middle aquifer system is confined by the Newmarket Till, except where the units outcrop adjacent to steep creek valleys within the southern part of the study area. Groundwater flow within this aquifer system is predominantly south to southeast toward Lake Ontario at regional horizontal hydraulic gradients of 0.001 to 0.01 in the southern part of the basin. Local deflections in groundwater flow occur toward creeks and rivers where horizontal hydraulic gradients increase near discharge areas.

Lower Aquifer

Groundwater divides for the Lower Aquifer system correspond generally with surface water drainage divides. Groundwater flow within this aquifer system is predominantly south to southeast toward Lake Ontario at regional horizontal hydraulic gradients of 0.001 to 0.01. Local deflections in groundwater flow occur toward creeks and rivers where horizontal hydraulic gradients increase near discharge areas. The Lower aquifer system is recharged by inter-aquifer regional groundwater flow entering the surficial drainage basin and vertical leakage from the Middle aquifer system in the northern part of the Study Area.

A preliminary discussion of groundwater flow across surficial drainage divides is included in Gerber and Howard (2000). Regional investigations are presently being conducted, as part of the Ontario Ministry of the Environment (MOE) Municipal Groundwater Study program, that aim to quantify the groundwater balance and the presence of groundwater flow across watershed divides in more detail. These investigations are scheduled for completion during June of 2003.

Hydrogeologic Effects of Changing Land Use

This section summarizes the hydrogeologic impacts of changing land use within the Duffins basin for recharge reductions as estimated by Clarifica Inc. (2002) using a water balance model described in section 3.2.1.1 and by Gerber Geosciences (2003) using a MODFLOW groundwater flow model described in section 3.2.2.1. The groundwater infiltration values (GWI) from the water balance analysis were incorporated into the numerical groundwater flow model (MODFLOW) which exists for the Duffins basin, as a means of estimating the effects of future land use scenarios on recharge and the groundwater system.

Under the Future land use (as per municipal Official Plans) scenario, significant GWI reductions occur within subcatchments 2, 12, 21, 23, 24, 25 and 28, which are the areas expected to undergo urbanization. The estimated change to the water table is shown in **Figure 3-11.** Due to the significance of potential changes in the Urfe and Ganatsekiagon Creek subwatersheds (subcatchments 22, 23, 24 and 25), associated with the planned community of Seaton, more detailed hydrogeological assessments were undertaken for the Future land use scenario to understand the local ground-surface water interactions. The details of this assessment are found in Gerber Geosciences (2003).

Under the Future land use with Enhanced Natural Heritage Cover scenario, the estimated changes to groundwater recharge from increasing the tree cover is negligible, therefore this scenario has not been modelled in the numerical groundwater flow model. The impacts of reforestation are difficult to quantify as discussed by Clarifica Inc. (May, 2002), and examples from the literature predict both increases and decreases in recharge following reforestation. In a report for the Ganaraska watershed, Richardson (1946) suggested that replanting should be beneficial to increasing groundwater recharge. Richardson based this opinion on inverse reasoning after observing the differences in streamflow on the Oak Ridges Moraine following extensive deforestation. Richardson argued that when the upper part of the watershed was heavily timbered, springs were more numerous, and the streams commenced farther up the slope compared to stream headwater areas following deforestation. It was felt that with replanting, the summer flow in streams would be increased and there would be more deep seepage through the moraine gravels for water supply to the wells on the area. Other quotes on the topic provided by Richardson, are as follows:

p. 58 “The influence of tree growth on the stream flow is emphasized also by the fact that on old maps of the area, notably Tremaine’s Map of Durham County, 1861, and the Historical Atlas of the Counties published in 1878, the headwater streams extend much farther up the morainic slope, which at that time was well wooded. Many of these dried-up water courses can still be followed, and these probably help to increase the rate of run-off on this part of the watershed at certain seasons of the year.”

p. 65 “But the function of the roots does not end with giving support and nourishment to the tree, since in the act of extending themselves for food they open up the soil and make thousands of small channels into the ground, which greatly increases its porosity.”

p. 66 “This assistance which the forest floor gives to the absorption of moisture by the soil is partly responsible for the feeding of springs and underground storage....... No one, who has lived in wooded areas of Ontario and has watched the forest being cut down over large areas, will gainsay the fact that the water supply in springs has been changed.”

A study conducted by Buttle (1996) compared stream flows in the Duffuns and Ganaraska basins for the period of record (since 1945). The headquarters of the Ganaraska basin have been reforested during the period of record whereas the headquarters of the Duffins basin have not. For the Ganaraska basin, Buttle interpreted a decrease in annual maximum daily runoff and an increase in annual minimum daily runoff following reforestation. These changes result in little change in annual streamflow. Buttle suggests that an increase in forest and ultimately soil cover limits rain-on-snow events which contribute to flood events, and increases interception and snowpack shading which enhances infiltration. The increase in recharge more than compensated for the higher evapotranspiration associated with increasing the forested area. The periods of greater recharge within southern Ontario (spring and fall) occur during lower periods of evapotranspiration. Buttle also cautioned that water management programs “need to be prepared for equivocal results to limited basin restoration”. Any reforestation program also needs to consider long-term climatic trends (figure 16) when analysing stream Hydraulic changes.

The anticipated impacts and benefits to the groundwater flow system from replanting large areas of the Duffins basin, as outlined in the Future land use with Enhanced Natural Cover scenario, remain unresolved with respect to numerical groundwater flow modelling.

3.3.2.2 Groundwater Use

The majority of the water wells within the Duffins and Carruthers Creek watersheds are for private potable supplies, which typically involve less than 175 L/person/day and discharge to the groundwater system via tile beds. These domestic wells are not required to have permits to take water (PTTW). However, larger scale users (>50,000 L/day), including golf courses (irrigation), municipal water supplies, and commercial enterprises are required to have a PTTW. The largest active PTTW on file with the MOE in these two watersheds is the municipal water supply for the Town of Whitchurch-Stouffville. (4,000 m^3/day), which draws water from the upper and middle aquifers (Gerber Geosciences, 2003). The treated wastewater generated by the Town of Whitchurch-Stouffville is currently discharged to Stouffville Creek. In the future, however, the wastewater will be sent via the York-Durham sewer system to a treatment plant on the shore of Lake Ontario.

The groundwater withdrawals by the Town of Whitchurch-Stouffville represent approximately 29% of the total streamflow in Stouffville Creek and 2% of the total streamflow in Duffins Creek (Gerber Geosciences, 2003).

3.3.2.3 Groundwater Quality

Upper Aquifer

The background groundwater quality in the upper aquifer is generally good, with moderate hardness (Gerber, 2003). Chloride, nitrate, and bacteria are elevated in some of the shallow wells in this aquifer, which is attributed to local contamination from road salt application and domestic sewage treatment systems (Gerber, 2003).

Middle Aquifer

The background groundwater quality in the middle aquifer is generally good, with slightly lower hardness and sulphate than in the Upper Aquifer. Some water well records report generation of hydrogen sulphide gas (Gerber, 2002). The TRCA is not aware of any significant impacts from chloride, nitrate, or bacteria in this aquifer.

Lower Aquifer

The background groundwater quality in the lower aquifer is generally good, with slightly higher hardness and suphate than in the Middle Aquifer. Some water well records report generation of hydrogen sulphide gas, likely associated with the underlying pertroliferous shale. TRCA is not aware of any significant anthropogenic impacts from chloride, nitrate, or bacteria in this aquifer.

Bedrock

The background bedrock groundwater is generally hard with high sodium, chloride, and sulphate (Gerber, 2003). TRCA is not aware of any significant anthropogenic impacts from chloride, nitrate, or bacteria in this unit.

3.3.3 Surface Water Quality

3.3.3.1 Agricultural Non Point Source (AGNPS) Modelling

The findings of AGNPS modelling for various storm events under different land cover scenarios are presented in a TRCA report entitled *Agricultural Non-point Source Modelling of the Duffins and Carruthers Creek Watersheds* (2003). The following is a brief summary of these findings.

Tables 3-9 and 3-10 summarize sediment yield and phosphorus results for model runs under existing conditions, the (Future Land Use), the (Future Land Use) and Enhanced Natural Heritage cover, and the “Priority Management Areas Revegetation (PMAS)” scenario, which simulated increased forest cover in priority grid cells. **Figures 3-12 and 3-13** summarize predominant source areas of phosphorus and sediments for the whole Duffins and Carruthers Creek watersheds, respectively.

Sediment yield

Storm events simulated under the official plan scenario (scenario 2) generally result in more sediment load than under existing conditions, particularly in study areas experiencing significant urban expansion, such as Urfe and Ganatsekiagon. Although these latter areas are small relative to other subwatersheds, the large increase in sediment yield represents an increase of 10% and 7% for the whole Duffins watershed yield under the official plan scenario.

For most watershed areas, scenario 3 (official plan plus enhanced natural heritage cover) produces sediment yield levels equal to or lower than existing conditions. Similarly, the BMP exercise of simulating increased forest cover in "priority management areas" (determined from the Trace Source Contribution analysis in scenario 1 for existing conditions) produced sediment yield levels that were approximately equal to or better than existing conditions in all but one study area (Urfe), and in several cases, were as good as the result obtained in scenario 3.

The Reesor and East subwatershed showed the most significant improvement in suspended sediment yield between scenario 3 and existing conditions because, relative to other subwatersheds, application enhanced natural heritage under scenario 3 would result in large conversions of agricultural land to forest cover in these areas. Since the Reesor/Stoufville subwatershed contributes 71% of the total sediment yield to the West Duffins, and the West Duffins contributes 76% of the sediment yield to the total Duffins yield, a large decrease in sediment yield under scenario 3 in the Reesor/Stouffville subwatershed would contribute substantially to sediment yield reductions in the watershed as a whole.

Phosphorus

Four of the eight subwatershed study areas show no change or only a slight change in phosphorus levels across the four scenarios, including the study areas: (1) Reesor, (2) West, (3) East, and (4) Whole Duffins. These four study areas exhibited the least amount of land use change relative to their total areas, and therefore changes in phosphorus sources would be expected to be minimal. Although phosphorus concentrations among scenarios show little change, phosphorus loads in the watershed would likely show greater increases under the OP scenario due to the increased volumes of overland runoff associated with urban expansion.

Of the remaining four study areas that exhibited phosphorus level changes between scenarios 1 and 2, three decreased (Ganatsekiagon, Miller, Whole Carruthers), and one increased (Urfe). The decreases are attributed to the significant conversion from agricultural land to urban land uses, which thereby removes a major source of phosphorus. The increase in Urfe may be partly explained by the predominantly sandy soils in this subwatershed, which are less capable of binding phosphorus compared to clay/loam soils.

Relative to the overall dry weather/wet weather phosphorus Provincial Water Quality Objective (PWQO) of 0.03 mg/l, all modeled storm events that generate runoff fail to meet the objective. However, water quality levels tend to be at their worst under storm conditions, and since phosphorus levels only marginally exceed the objective, it is possible that phosphorus concentrations averaged over dry and wet weather conditions may meet the PWQO.

Summary of AGNPS Model Findings

Overall, sediment loads can generally be expected to increase in the Duffins and Carruthers watersheds as a result of urban growth under the OP scenario. The enhanced natural heritage scenario can compensate for some of the negative impacts of urban growth by at least maintaining existing water quality conditions. A reasonable level of watershed protection could be achieved by incorporating rural and urban stormwater management practices in all new developments. Natural heritage enhancement programs focused on priority management areas have roughly the same benefit as the enhanced natural heritage scenario. Some differences in these overall trends occur in subwatersheds that have one predominant land use.

Table 3-9. Suspended sediment yield at the outlet cell of each study area under the various land use scenarios and rain events.

Watershed or Subwatershed	Storm Event	Sediment Yield (metric tons) *(Percent change compared to sediment yield under scenario 1 shown in parenthesis)*			
		Scenario1 - Existing	Scenario 2 - Official Plan (OP)	Scenario 3 - OP + Natural Heritage	BMP*
Reesor	15mm 9 hr	22.4	21.6 (↓4%)	5.2 (↓77%)	-
	25mm 12 hr	45.8	52.4 (↑14%)	20.8 (↓55%)	28.3 (↓38%)
West	15mm 9hr	28.7	31.3 (↑9%)	28.4 (↓1%)	-
	25mm 12hr	64.4	72.1 (↑12%)	63.4 (↓2%)	61.8 (↓4%)
East	15mm 9hr	2.3	2.6 (↑13%)	1.1 (↓52%)	-
	25mm 12 hr	4.8	4.0 (↓17%)	1.0 (↓79%)	-
	30mm 12 hr	38.8	44.5 (↑15%)	4.1 (↓89%)	29.7 (↓23%)
	35mm 12 hr	43.0	45.3 (↑5%)	5.7 (↓87%)	37.5 (↓13%)
	38mm 12 hr	-	-	23.5	-
Ganatsekiagon	15mm 9hr	no runoff	0.86	1.3	
	25mm 12hr	no runoff	11.4	10.3	
	35mm 12hr	1.2	32.6 (↑2617%)	27.3 (↑2217%)	-
	40mm 12hr	16.0	36.9 (↑131%)	34.5 (↑116%)	12.2 (↓24%)
Urfe	15mm 9hr	no runoff	1.01	0.85	-
	25mm 12hr	no runoff	7.55	5.70	-
	30mm 12hr	no runoff	-	-	-
	35mm 12hr	no runoff	-	-	-
	38mm 12hr	7.23	26.4 (↑265%)	18.1 (↑150%)	9.8 (↑36%)
	40mm 12hr	7.26	29.5 (↑306%)	22.1 (↑204%)	-
Miller	15mm 9hr	2.68	6.16 (↑130%)	3.91 (↑46%)	-
	25mm 12hr	15.1	18.7 (↑24%)	10.5 (↓30%)	10.9 (↓28%)
Whole Duffins	15mm 9hr	31.6	40.5 (↑28%)	28.9 (↓9%)	-
	25mm 12hr	84.2	110.4 (↑31%)	71.9 (↓15%)	73.4 (↓13%)
Whole Carruthers	15mm 9hr	2.69	1.80 (↓33%)	no runoff	-
	25mm 12hr	12.5	8.39 (↓33%)	7.8 (↓38%)	11.1 (↓11%)

* “BMP” - also referred to as “PMA Revegetation” Scenario simulated increased forest cover in“priority” grid cells determined from the trace source contribution analysis

Table 3-10: **Phosphate concentration results modeled with AGNPS from the outlet cell of each study and the conversion to total phosphorus based on an established relationship between PO_4 and Total P.**

Watershed or Subwatershed	Storm Event	Phosphate (PO_4) Concentration (mg/l)				Converted to Total Phosphorus (mg/l) Using Relationship Between PO_4 and Total P			
		Existing	Offical Plan (OP)	OP + Natural Heritage	BMP	Existing	Offical Plan (OP)	OP +Natural Heritage	BMP
Reesor	15mm 9 hr 25mm 12 hr	0.02 0.02	0.03 0.02	0.03 0.02	-0.02	0.06 0.06	0.08 0.06	0.08 0.06	-0.06
West	15mm 9hr 25mm 12hr	0.00 0.00	0.00 0.00	0.00 0.01	0	0.07 0.07	0.07 0.07	0.07 0.08	-0.07
East	15mm 9hr 25mm 12 hr 30mm 12 hr 35mm 12 hr 38mm 12 hr	0.15 0.11 0.09 0.08 -	0.15 0.12 0.11 0.09 -	0.15 0.15 0.10 0.09 0.09	- - 0.10 0.08 -	0.22 0.18 0.16 0.15 -	0.22 0.19 0.18 0.16 -	0.22 0.22 0.17 0.16 0.16	- - 0.17 0.15 -
Ganatsekiagon	15mm 9hr 25mm 12hr 35mm 12hr 40mm 12hr	no runoff no runoff 0.11 0.09	0.05 0.04 0.04 0.03	0.05 0.04 0.03 0.03	-0.09	no runoff no runoff 0.46 0.38	0.22 0.17 0.17 0.13	0.22 0.17 0.13 0.13	-0.38
Urfe	15mm 9hr 25mm 12hr 30mm 12hr 35mm 12hr 38mm 12hr 40mm 12hr	no runoff no runoff no runoff no runoff 0.01 0.01	0.05 0.04 - - 0.03 0.03	0.05 0.04 - - 0.03 0.03	0.01 -	no runoff no runoff no runoff no runoff 0.05 0.05	0.22 0.17 - - 0.13 0.13	0.22 0.17 - - 0.13 0.13	0.05 -
Miller	15mm 9hr 25mm 12hr	0.12 0.10	0.02 0.02	0.03 0.02	-0.08	0.19 0.17	0.09 0.09	0.10 0.09	-0.15
Whole Duffins	15mm 9hr 25mm 12hr	0.09 0.07	0.07 0.06	0.07 0.05	-0.07	0.16 0.14	0.14 0.13	0.14 0.12	-0.14
Whole Carruthers	15mm 9hr 25mm 12hr	0.10 0.08	0.03 0.03	no runoff 0.06	-0.08	0.17 0.15	0.10 0.10	no runoff 0.13	-0.15

* BMP tested simulated increased forest cover in "priority" grid cells determined from the trace source contribution analysis

3.3.3.2 Spreadsheet Modelling

The detailed findings of the spreadsheet modelling are found in “Dry and Wet Weather Modelling of Water Quality under Alternative Land Use Scenarios in the Dussins and Carruthers Creek Watersheds - A Simple Spreadsheet Approach”. (Stantec and Aquafor Beech, 2003).

Wet weather

Model results for loads and concentrations under different land use scenarios during wet weather are presented in **Table 3-11.** In general, the change in pollutant concentrations and loads under future land use scenarios was strongly influenced by urbanization. The largest planned increase in urbanization is in Ganetsekiagan, Urfe, Millers and the Lower Main Duffins subwatersheds. Consequently, these areas also had the largest increase in runoff and pollutant concentrations under future scenarios. However, since these areas comprise less than 20% of the Duffins watershed, their overall water quality impact on the Duffins watershed as a whole is relatively small.

Conversion of rural to forested land use under the Future Land Use with Enhanced Natural Cover Scenario results in a small decrease in pollutant concentrations and runoff volumes, and hence, a relatively minor impact on loads. The smallest change occurs in Ganetsekiagan, Urfe, Miillers, Lower Main Duffins and Carruthers Creek areas, where the Enhanced Natural Heritage strategy results in no change or only a very small increase in total wooded area over the Official Plan scenario **(Table 3-11)**.

Table 3-11: **Estimated wet weather loads and concentrations for a) existing land use; b) projected land use under the Official Plan; and c) projected land use under the OP with Enhanced Natural Heritage Cover.**

		Loads (kg/day)			Concentrations (mg/L)			Land use (%)			Runoff (m^3/yr)
		TP	TSS	Cl	TP	TSS	Cl	Rural	Wooded	Urban	
West Duffins (13,539 ha)	a	8.5	4477.2	1174	0.18	92.8	24.3	64.5	32.1	3.5	17609789
	b	9.9	5228	1235.1	0.18	96.4	27.9	59.3	31.9	8.6	19778548
	c	8.8	4716.3	666	0.17	91.9	24	44.2	47.2	8.6	18737994
East Duffins (9,202 ha)	a	5.3	2802.4	666	0.17	89	21.1	51.1	45.3	3.6	11499156
	b	5.4	2920.8	715.6	0.17	89.8	22	49.2	45.7	5.1	11869204
	c	4.6	2495.4	513.9	0.15	84.2	17.4	30.5	64.4	5	10812808
Ganetsekiagan (1,305 ha)	a	0.8	417.9	101.2	0.17	89.8	21.7	57.7	39.8	2.5	1698791
	b	2	1113.3	472.3	0.22	120	51	23.4	33.4	43.1	3380821
	c	2	1107.6	468.9	0.22	119.9	50.8	22.5	34.3	43.1	3371259
Urfe (1,437 ha)	a	1	526.2	118.6	0.17	87.5	19.7	53.8	44.9	1.4	2195203
	b	2.1	1158	440.4	0.2	110.9	42.2	30.6	37.6	31.7	3809847
	c	2.1	1151.2	436.7	0.2	110.7	42	29.9	38.4	31.7	3795484

Millers (1,698 ha)	a	2.6	1145.4	593.2	0.22	119.1	49.5	37.5	24.6	37.8	4369051
	b	3.2	1814.8	879.3	0.24	136	65.9	16	22.8	61.1	4872120
	c	3.2	1811.2	877	0.24	135.8	65.8	15.5	23.2	61.1	4867174
Lower Main Duffins (1,124 ha)	a	2	1140.9	467.6	0.2	115.6	47.3	0	54.5	45.6	3603906
	b	2.7	1571.9	738.6	0.23	130.6	61.4	0	39.4	60.6	4392176
	c	2.7	1571.6	738.5	0.23	130.6	61.4	0	39.4	60.6	4391273
Whole Duffins (28,305 ha)	a	19.9	10509.7	2847.6	0.18	93.6	25.4	55.1	37.8	7.1	40975895
	b	24.5	13159.6	4135	0.19	99.9	31.3	48.1	36.4	15.4	48102717
	c	22.1	12066.9	3526.5	0.18	95.8	28	34.6	50	15.4	45975992
Carruthers (3,810 ha)	a	5.1	2751.3	910.1	0.19	102.6	33.9	47.6	34.1	18.3	9786674
	b	6.2	3388.1	1325.1	0.21	113.3	44.3	27.4	39.6	33	10913549
	c	6	3322.7	1271.7	0.2	111.2	42.5	33.3	33.4	33.3	10902470

Dry weather

Modelled loads and concentrations under different land use scenarios during dry weather are presented in **Table 3-12.** There was little or no change in dry weather concentrations of phosphorus and TSS under the three scenarios modelled because median concentrations were similar among all three land use categories. Chloride median concentrations varied more with land use and hence concentrations increased slightly in areas where urban growth was part of the Official Plan (esp. Ganatsekiagon and Urfe).

Dry weather loads of TSS and phosphorus were similar under the three land use scenarios in all subwatersheds except Ganatsekiagon, Urfe and, to a lesser extent, Millers subwatershed. Future scenarios in these areas increased the impervious cover, resulting in less groundwater recharge and lower baseflows. Increased forest cover under the Official Plan with Enhanced Natural Heritage cover had a relatively minor impact on baseflow generation.

Table 3-12: **Estimated dry weather loads and concentrations for a) existing land use; b) projected land use under the Official Plan; and c) projected land use under the Official Plan overlain with enhanced natural heritage cover.**

		Loads (kg/day)			Concentrations (mg/L)			Land use (%)			Base Flow (m^3/yr)
		TP	TSS	Cl	TP	TSS	Cl	Rural	Wooded	Urban	
West Duffins (13539 ha)	a	1.01	326.7	744.3	0	6	13.7	64.5	32.1	3.5	19870965
	b	0.97	317.6	766.2	0	6	14.5	59.5	31.9	8.6	19324560
	c	0.94	317.6	668.6	0	6	12.6	44.2	47.2	8.6	19324560
East Duffins (9202 ha)	a	1.08	359.5	725.3	0	6	12.1	51.1	45.3	3.6	21867515
	b	1.06	356	728.2	0	6	12.3	49.2	45.7	5.1	21656545
	c	1.02	356	595.3	0	6	10	30.5	64.4	5	21656545

Ganetsekiagan (1305 ha)	a	0.12	39.1	82.1	0	6	12.6	57.7	39.8	2.5	2380530
	b	0.1	32.4	105.4	0	6	19.5	23.4	33.4	43.1	1975380
	c	0.1	32.4	104.8	0	6	19.4	22.5	34.3	43.1	1975380
Urfe (1437 ha)	a	0.1	29.5	58.3	0	6	11.8	53.8	44.9	1.3	1798355
	b	0.1	25.5	73.3	0	6	17.3	30.6	37.6	31.7	1552345
	c	0.1	25.5	73	0	6	17.1	29.9	38.4	31.7	1418390
Millers (1698 ha)	a	0.1	24.3	79.8	0	6	19.7	37.5	24.6	37.8	1478615
	b	0.1	23.3	91.1	0	6	23.4	15.9	22.8	61.1	1418390
	c	0.1	23.3	90.8	0	6	23.3	15.5	23.2	61.1	1418390
Lower Main Duffins (1124 ha)	a	0	13	37.6	0	6	17.3	0	54.5	45.6	793510
	b	0	10.9	38.9	0	6	21.4	0	39.4	60.6	665395
	c	0	10.9	38.9	0	6	21.4	0	39.4	60.6	665395
Whole Duffins (28305 ha)	a	2.39	792.1	1785.6	0	6	13.5	55.1	37.8	7.1	48189490
	b	2.27	765.8	1906.6	0	6	14.9	48.1	36.4	15.4	46592615
	c	2.2	765.8	1699.5	0	6	13.3	34.6	50	15.4	46592615
Carruthers (3810 ha)	a	0.1	54.5	142.1	0	6	15.6	47.6	34.1	18.3	3312098
	b	0.2	52.2	156.6	0	6	18	33.3	33.4	33.4	3177194
	c	0.2	52.2	149.7	0	6	17.2	27.4	39.6	33	3177194

3.3.3.3 Wastewater Discharge Assessment

The dilution ratios and phosphorus concentrations attributed to the Stouffville WPCP under existing conditions for a range of flows at stream gauging stations downstream of the plant are presented in **Table 3-13.** The WPCP was not found to impact water quality during high flow conditions associated with precipitation events. During dry weather, the impact of the plant on phosphorus concentrations immediately downstream of the plant in Stouffville Creek failed to meet the Provincial Water Quality Objective (PWQO) for phosphorus (0.03 mg/L) for at least half of the monthly average flows. At 8th concession on Reesor Creek, the phosphorus concentration was above the PWQO for approximately one quarter of the monthly average flows. During extreme low flow conditions, represented as the minimum observed 7 day flow (7Q20), phosphorus concentrations exceeded the phosphorus PWQO as far downstream as the Green River station on West Duffins Creek.

Table 3-13: **Dilution ratios and phosphorus concentrations attributed to the Stouffville WPCP at four locations downstream of the plant.**

Location	Average streamflow percentiles	Dilution ratio	P concentration attributed to WPCP (mg/L)
Stouffville Creek	median 25th percentile 10th percentile 7Q20	3.2 2.3 2 n/a	0.05 0.07 0.09 n/a
Reesor Creek @ 8th concession	median 25th percentile 10th percentile 7Q20	7 5 4 n/a	0.02 0.03 0.04 n/a
West Duffins Creek @ Green River	median 25th percentile 10th percentile 7Q20	n/a n/a n/a 2	n/a n/a n/a 0.09
Duffins Creek Mouth @ Kingston Road	median 25th percentile 10th percentile 7Q20	4633259	0.004 0.01 0.01 0.02

Notes: Provincial Water Quality Objective for phosphorus is 0.03 mg/L; 7Q20 represents the minimum 7 day flow over a 20 year recurrence interval.

Table 3-14 shows observed phosphorus concentrations above and below the plant for the 1988 to 1994 period. At least 75% of samples were collected during dry weather. Median concentrations met the PWQO for phosphorus of 0.03 mg/L at the monitoring station above the plant but exceeded it at all stations downstream of the plant. These results are consistent with Table 1 estimates of phosphorus contributions to the stream associated with plant discharges.

Table 3-14: Average phosphorus concentrations (mg/L) and PWQO exceedence frequencies for phosphorus at stations upstream and downstream of the Stouffville WPCP (1988-1994).

	# Obs.	Min	Max	Mean	Median	Frequency of PWQO Exceedance
Stouffville Ck above WPCP	70	0.008	2.09	0.081	0.03	49%
Stouffville Ck below WPCP	70	0.008	0.268	0.1	0.091	89%
Reesor Ck @ 8th Concession	69	0.006	0.348	0.072	0.051	78%
Duffins Ck @ Bayly Street	72	0.002	0.54	0.053	0.024	38%

Under the Official Plan and Natural Heritage/Official Plan scenarios, a reduction in phosphorus concentration associated with decommissioning of the WPCP would be expected. The magnitude of this reduction downstream of the plant would depend on the contribution of other sources of phosphorus to the stream, and the decrease in stream flow that would result from plant decommissioning. Increased natural cover under the Natural Heritage/Official Plan scenario would normally be expected to reduce phosphorus loading to the Creek. Further modelling work is required to quantify the magnitude of expected improvement under future scenarios.

3.3.4 Aquatic Habitat and Species

Fish and Invertebrate Community Makeup

Based on the fisheries potential and resource use/fisheries management issues, fisheries management zones were developed for both watersheds **(Figure 3-14)**. They are shown as follows:

Table 3-15: Fisheries Management Zones

DUFFINS CREEK		CARRUTHERS CREEK	
MANAGEMENT ZONE	TARGET SPECIES PRESENT	MANAGEMENT ZONE	TARGET SPECIES PRESENT
Brook trout, Atlantic salmon	1 of 2	Brook trout	No
Redside dace, darter species	1 of 2	Redside dace, darter species	No
Redside dace, rainbow trout	1 of 2	Redside dace, rainbow trout	1 of 2
Smallmouth bass	No	Smallmouth bass	No

Based on the above status, the ratings of good and fair for Duffins and Carruthers Creeks, respectively, was assigned.

Index of Biotic Integrity

The modified IBI scores ranges from a low of nine (scoring one for each index) to a high of 45 (scoring five for each index). Four ranges of IBI scores have been designated to reflect stream quality and are listed in **Table 3-16.**

Table 3-16: 2000 IBI Ratings and Scores.

IBI RATING	IBI SCORE	NUMBER OF STATIONS	
		DUFFINS CREEK	CARRUTHERS CREEK
Poor	9 - 20	6	0
Fair	21 - 27	13	5
Good	28 - 37	13	1
Very good	38 - 45	0	0

Instream Habitat

Baseflow As A Percent of Total Annual Flow

The empirical relationship between aquatic community type and the ratio of baseflow to total annual flow was used as the basis for predicting the potential impacts of future land uses on the aquatic community (i.e. the higher the ratio, the more stable the baseflow and more likely the habitat is suitable for sensitive coldwater species). Using the annual groundwater discharge estimates from Gerber (2003), as an indicator of baseflow, and annual run-off estimates from the water budget (Clarifica, 2002), a rough approximation of groundwater discharge and total flow was estimated for each of the 30 sub-basins for each scenario. It was felt that an evaluation of the percent difference in the ratio of annual discharge to total annual flow among the three scenarios provided a better gauge of change than using the actual ratio values.

The most significant changes in the ratio of baseflow to total annual flow from the existing to future scenarios were seen in the watersheds where urban landuse is expected to increase. These changes are summarized in **Table 3-17** and shown in **Figures 3-15 a and b**. These findings suggest that, as urban development proceeds, extra care should be taken to ensure the protection of local water balance, including groundwater infiltration, discharge and overland runoff. Otherwise, the future land use change may result in a shift away from the existing coldwater community.

Table 3-17: Change in the ratio of basefow to average annual flow in sub-basins with increased urbanization

Subwatershed	Sub-basin	Change in % urban area	Change in the Ratio of Baseflow to Total Annual Flow From Existing Scenario (%)	
			Future Scenario	Future + Natural Heritage Scenario
West Duffins Creek	2	21.71	-8.79	-7.68
West Duffins Creek	12	32.8	-15.1	-15.11
Ganatsekiagon Creek	24	29.85	-14.94	-14.81
Ganatsekiagon Creek	25	53.74	-27.34	-27.34
Urfe Creek	23	48.65	-24.55	-24.55
East Duffins Creek	21	24.44	-7.82	-7.82
Main Duffins Creek	28	29.11	-9.6	-9.59

It should be noted that in all the sub-basins except for sub-basin 2, natural heritage goals were not aggressively pursued, and therefore the benefits from implementing the natural heritage approach are not seen. It is also important to note that for the purposes of this modelling, stormwater management controls were not incorporated.

However, in sub-basins where the natural heritage approach was aggressively pursued, a positive change in the ratio of baseflow to annual average flow is seen, as shown in **Table 3-18**.

Table 3-18: Change in the ratio of basefow to average annual flow in sub-basins with the Enhanced Natural Heritage Cover

Subwatershed	Sub-basin	Change in % natural area	Change in the Ratio of Baseflow to Total Annual Flow From Existing Scenario (%)	
			Future Scenario	Future + Natural Heritage Scenario
West Duffins Creek	1	20.08	-0.6	1.87
West Duffins Creek	37925	8.43	-0.12	0.6
West Duffins Creek	15	45.01	-0.01	7.55
West Duffins Creek	5	27.76	-0.03	2.59
West Duffins Creek	7	22.41	0	1.97
West Duffins Creek	6	31.87	-0.08	1.99
West Duffins Creek	8	1.94	-0.02	0.1
West Duffins Creek	4	1.46	-0.11	0.05
East Duffins Creek	13	26.72	-0.01	4.36
East Duffins Creek	14	15.9	-0.04	1.73
East Duffins Creek	16	24.02	0	2.37
East Duffins Creek	17	25.73	0	2.14
East Duffins Creek	18	45.15	-0.01	4.62
East Duffins Creek	19	11.15	-0.05	0.92

Water Chemistry

Total Suspended Solids

Both watersheds have data indicating that TSS concentrations do not exceed 30mg/L more than 80% of the time. Based on this information, TSS levels are considered to be good for aquatic communities in both watersheds. The greatest increases in TSS concentrations in the future land use scenarios will be in the sub-basins experiencing urban growth (ie. Urfe, Ganetsekiagon, and West Duffins Creeks) (Stantec and Aquafor Beech, 2003). Although the increase in TSS concentrations is not significant, the loads are expected to double due to increased runoff volume. Increased duration and frequency of elevated TSS concentrations could impact aquatic communities and should be addressed through preventive and mitigative measures.

Phosphorus

Both watersheds have data indicating that phosphorus concentrations exceed 0.03 mg/L more than 50% of the time. Similar to TSS, modelling has indicated that under future land use scenarios phosphorus concentrations will likely increase marginally and loads will increase more significantly, especially in sub-basins with urban growth. This trend will be offset somewhat in the West Duffins Creek by the decommissioning of the Stouffville Sewage Treatment Plant. Elevated phosphorus is a contributor to a change in species composition at lower trophic levels and overall oxygen demand that could effect a change in the aquatic community composition.

Chlorides

Water quality monitoring data indicates that no station exceeds 250 mg/l in either watershed.

This is within acceptable levels for the aquatic community. It should be noted, however, that chlorides are most noxious during spring run-off when eggs and alevins are very vulnerable, and water quality sampling programs may fail to detect event-related elevated chloride incidents. Chloride concentrations were predicted to be approximately 30% higher than current levels in Carruthers Creek and double current levels in the Ganetsekiagon and Urfe Creeks under future land use scenarios (Stantec and Aquafor Beech, 2003). However, according to the model, predicted levels will remain within the 250 mg/L threshold of toxicity to aquatic organisms. It should be noted that the model was unable to predict chloride concentrations during snowmelt events and these peak levels may be of most concern.

Fish Passage

In total, 102 instream barriers (not including road and rail crossings) were located within both watersheds.

Riparian Zone

In the Duffins Creek watershed, 76% of the riparian zone is naturally vegetated with either forest, successional, meadow, or wetland type habitat. This percentage does not include manicured grasses or agricultural crop lands. Fifty percent of the total stream bank length is considered to have a woody vegetation component.

In the Carruthers Creek watershed, 75% of the riparian zone is naturally vegetated with either forest, successional, meadow, or wetland type habitat. This percentage does not include manicured grasses or agricultural crop lands. Forty-two percent of the total stream bank length is considered to have a woody vegetation component.

3.3.5 Terrestrial Habitat and Species

Five measures were used to evaluate the health of the terrestrial natural heritage system under the different land use scenarios: quantity of natural cover; distribution of natural cover; matrix influence, size of natural cover patches; and shape of natural cover patches.

The results of the Duffins Creek Watershed analysis are presented in **Table 3-19.** The scenario involving Future land use with Enhanced Natural Cover represents a net increase in area under natural land cover, in such a way that also improves the average size and shape scores for natural land cover patches as compared to Existing land use conditions. In the “Future with Enhanced Natural Cover” scenario, increases to natural land cover are concentrated in the northern portions of the watershed, which result in a greater distance-to-centroid value, and represents a less desirable condition for the distribution of natural land cover over the watershed. The average matrix influence score improves under this scenario, due to the increased proportion of natural cover relative to urban or rural land uses. The benefits to other scores (i.e., average patch size and shape), and to the connectivity of the natural system as a whole that are associated with this change makes this condition a preferable option.

Overall, the scores for the Existing land use scenario in the Duffins Creek watershed reflect the fact that the existing amount of natural land cover provides a good basis on which to build a healthy and functioning terrestrial system. However, improvements to the size, shape and distribution of natural land cover patches are needed to provide the conditions necessary to achieve biodiversity targets (i.e., support species-of-concern).

Table 3-19: Duffins Creek Watershed Terrestrial Natural Heritage System Analysis

Measure	Scores for Each Land Use Scenario*		
	Existing	Future**	Future with Enhanced Natural Heritage Cover
Percent of watershed under natural cover	37%	36%	≥48%
Distribution of natural cover in relation to total watershed area as measured by distance to centroid (metres)	992 m	Not modelled	≤2351 m
Matrix influence score	2.68		4.16
Average patch size score	2.23		≥3.87
Average patch shape score	1.621		≥2.79

* The technical analyses conducted to develop these scores utilized the Duffins Creek watershed boundary that was derived from 1:50 000 scale topographic mapping data. Subsequent technical studies utilized a new watershed boundary that was derived using higher resolution data (1:10 000 scale digital elevation model). This discrepancy accounts for the difference between the percent natural cover scores indicated here (e.g. 48% for the "Future Enhanced" scenario) and the target indicated in the watershed plan (49% using the higher resolution watershed boundary, in association with the land use scenario descriptions). In this reporting period, the technical analyses required to calculate the terrestrial scores were not repeated using the new watershed boundary.
**Future scenario was not modelled as part of the terrestrial studies, because the difference in natural cover between this scenario and the Existing land use scenario was limited to localized areas, and differences in scores would probably not be detected by the landscape level analysis. Percent natural cover has been provided from subsequent watershed planning studies, noted above.

The results of the terrestrial analysis for the Carruthers Creek Watershed are presented in **Table 3-20.** The Future land use with Enhanced Natural Cover scenario in this watershed results in a net loss in natural land cover associated with the expansion of urban settlement areas, while improving the average size of natural land cover patches. Improvements to the size of existing natural cover patches contribute to a shifting of the centroid of all natural land cover patches further away from the centroid of the watershed, thus improving the distribution of natural cover. Despite increases in the average patch size, the average patch shape scores are somewhat reduced.

It is important to acknowledge that the target for natural land cover (i.e. the Future land use with Enhanced Natural Cover scenario) in the Carruthers Creek watershed was established with consideration of the constraints associated with existing developed areas and lands that are designated for development in the future. Fewer opportunities exist for restoring natural land cover in the Carruthers Creek watershed, than in the Duffins Creek watershed because the proportion of the watershed in public ownership is much less.

It is acknowledged that the target for natural land cover in the Carruthers Creek watershed does not reflect conditions required to achieve biodiversity targets (i.e., support species-of-concern) or to significantly enhance recreational use opportunities to the same extent that the targets for the Duffins Creek watershed do. However, the target does represent a significant improvement from Existing conditions and is believed to be the best condition that could be achieved within the constraints to regeneration that currently exist.

Table 3-20: Carruthers Creek Watershed Terrestrial Natural Heritage System Analysis

Measure	Scores for Each Land Use Scenario*		
	Existing	Future**	Future with Enhanced Natural Heritage Cover
Percent of watershed under natural cover	28%	25%	≥27%
Distribution of natural cover in relation to total watershed area as measured by distance to centroid (metres)	784 m	Not modelled	≤1750 m
Matrix influence score	2.67		3.11
Average patch size score	2.1		≥2.89
Average patch shape score	2.02		≥1.89

* The technical analyses conducted to develop these scores utilized the Duffins Creek watershed boundary that was derived from 1:50 000 scale topographic mapping data. Subsequent technical studies utilized a new watershed boundary that was derived using higher resolution data (1:10 000 scale digital elevation model). This discrepancy accounts for the difference between the percent natural cover scores indicated here (e.g. 48% for the "Future Enhanced" scenario) and the target indicated in the watershed plan (49% using the higher resolution watershed boundary, in association with the land use scenario descriptions). In this reporting period, the technical analyses required to calculate the terrestrial scores were not repeated using the new watershed boundary.
**Future scenario was not modelled as part of the terrestrial studies, because the difference in natural cover between this scenario and the Existing land use scenario was limited to localized areas, and differences in scores would probably not be detected by the landscape level analysis. Percent natural cover has been provided from subsequent watershed planning studies, noted above.

Figures 3-16 a and b illustrate the differences in individual habitat patch size scores, between the Existing land use and Future land use with Enhanced Natural Cover scenarios. The figures show improvements in individual patch size scores under the "future enhanced" scenario, particularly in the northern parts of the watersheds where the majority of the enhancements to the terrestrial system have been targeted. The figures also show how, overall, the average patch size scores are improved under the "future enhanced" scenario.

3.3.6 Public Use and Recreation

A qualitative assessment of challenges and opportunities for public use and recreation under the alternative land use scenarios was completed. Under existing land use conditions, the large amount of publicly owned land in the watersheds is very positive and, coupled with private landowner cooperation, provides very good opportunities for achieving an accessible and integrated greenspace system. If urban development proceeds under the Future Official Plan scenario, without integrated planning for greenspace and recreation, the available public use opportunities will fail to meet the demands of the increased population base. Furthermore, over use of existing greenspace areas will negatively impact the environment, through over use of existing trails, creation of informal trails, and other impacts, and the quality of the user's experience will deteriorate due to crowding and user conflicts. Under the Future Official Plan with Enhanced Natural Heritage scenario, there will be greater opportunity for the creation of integrated, accessible and extensive greenspace system, however, again, without planning for recreational use opportunities, the potential may fail to be realized and negative impacts from informal, unplanned use may result.

3.3.7 Human Heritage

Known archaeological and built heritage sites are shown on maps published in the Duffins and Carruthers Creek State of the Watershed Reports. Application of TRCA's Archaeological Site Predictive Model suggests that many more archaeological sites may exist than those that have been identified to date (Results of a partial application of this model are shown in **Figure 4-1g and 4-2a**). Many more built heritage sites are generally known in the watersheds, that are not yet designated or listed. As urban development proceeds under the Future Official Plan scenario, there will be opportunities through the normal development process to identify archaeological sites and arrange for their protection. Under this scenario there will likely be a reduction in the number of built heritage sites, unless the municipal policies and tools for their protection are strengthened. Under the Future Official Plan with Enhanced Natural Heritage scenario, there will be an increase in the number of archaeological sites identified and protected *in situ* (within natural heritage restoration areas). There may be a reduction in the number of built heritage sites identified, as in the Future Official Plan scenario, but an increase in the level of protection afforded to existing listed sites, where they are located in areas identified for the targeted natural heritage system.

3.4 Summary Evaluation of Findings

The technical study findings were reviewed and evaluated according to the Task Forces' management objectives, indicators and targets, and the results of this analysis has generally been presented in the preceding sections of Chapter 3. **Appendix A** contains a brief summary of the results from the evaluation of each land use scenario for each objective.

Within the Watershed Plan, key management considerations and issues have also been summarized by subwatershed, in order to provide further direction on priorities for local stakeholders.

Results of the assessment of watershed health under existing land use conditions, as compared to the management objectives and targets, were further reviewed and a rating of health was applied to each. A detailed description of the rating methodologies for each objective and set of indicators is documented in *Ratings Report for the 2003 Duffins and Carruthers Creek Watersheds Report Card* (TRCA, 2003). A summary of the final ratings was published in the Watershed Plan, and is intended to serve as the baseline "report card" of conditions, from which progress can be measured in future years.

Figure 3-1: Duffins Creek Watershed Alternative Land Use Scenarios

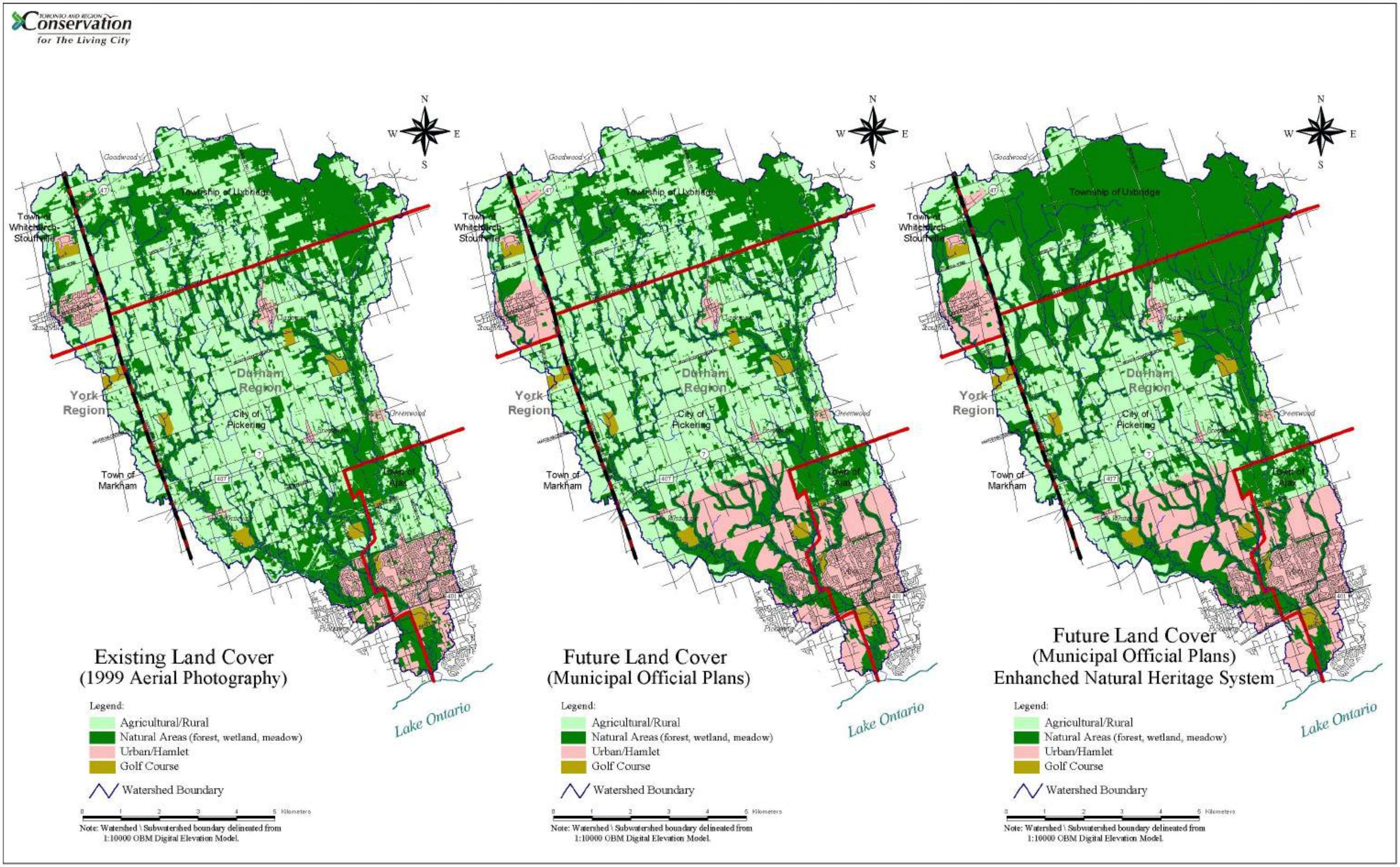


Figure 3-2: Carruthers Creek Watershed Alternative Land Use Scenarios

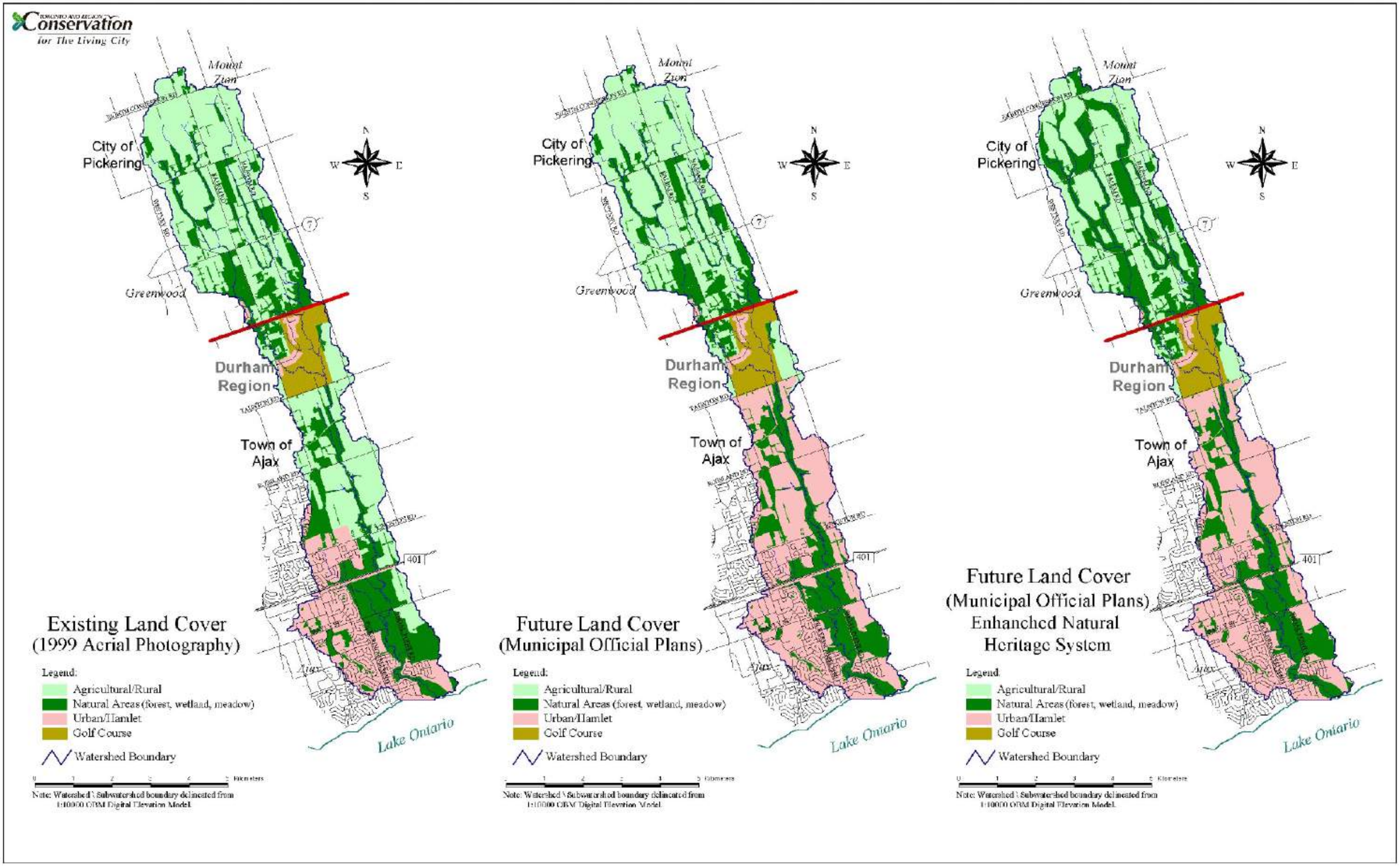


Figure 3-3: Duffins Creek Watershed - Percent Impervious - Existing and Future Land Use Scenarios

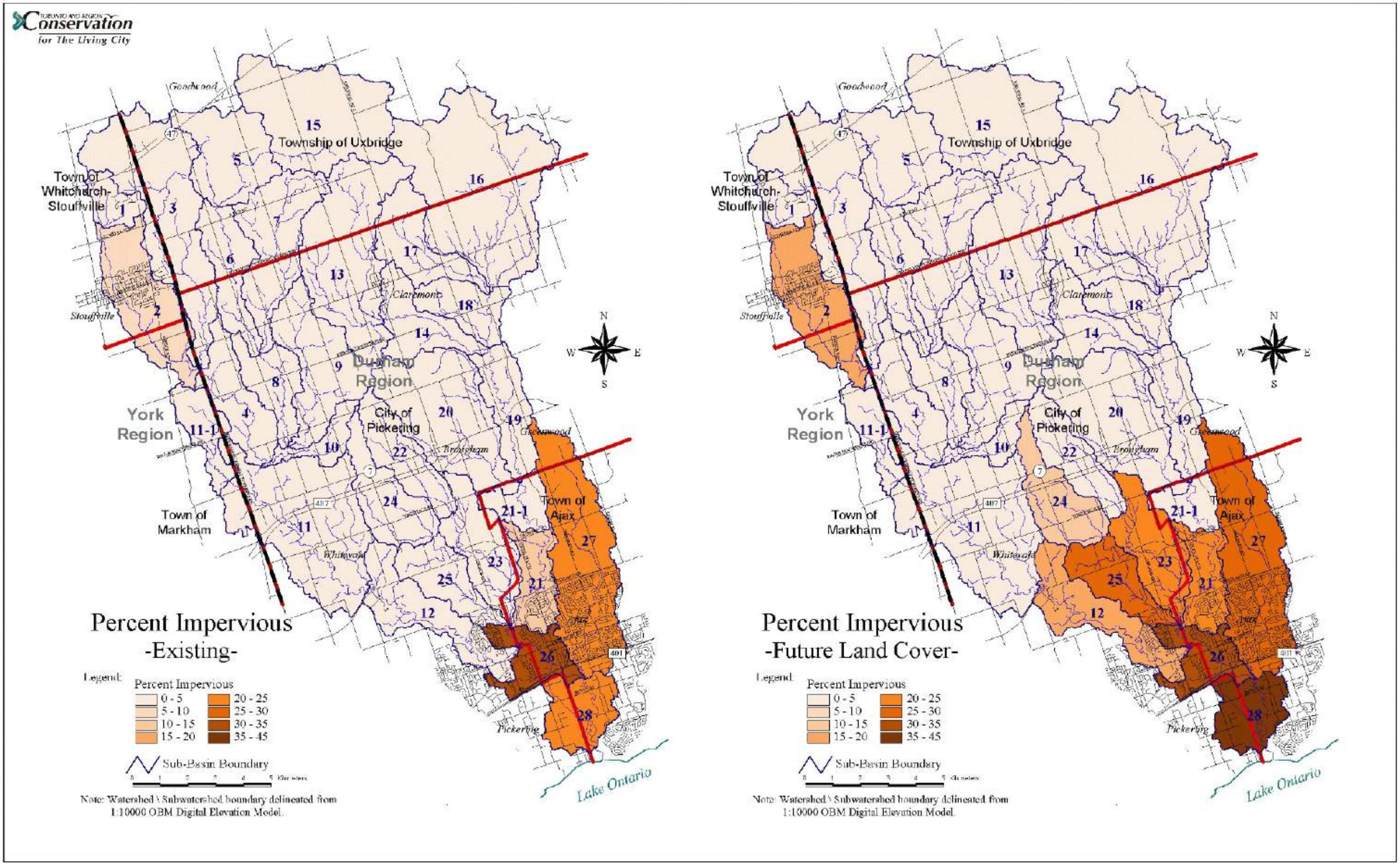


Figure 3-4: Duffins Creek Watershed - Groundwater Infiltration Rates under Existing Land Use Scenario and Groundwater Infiltration Recharge Deficit under Future Land Use Scenarios

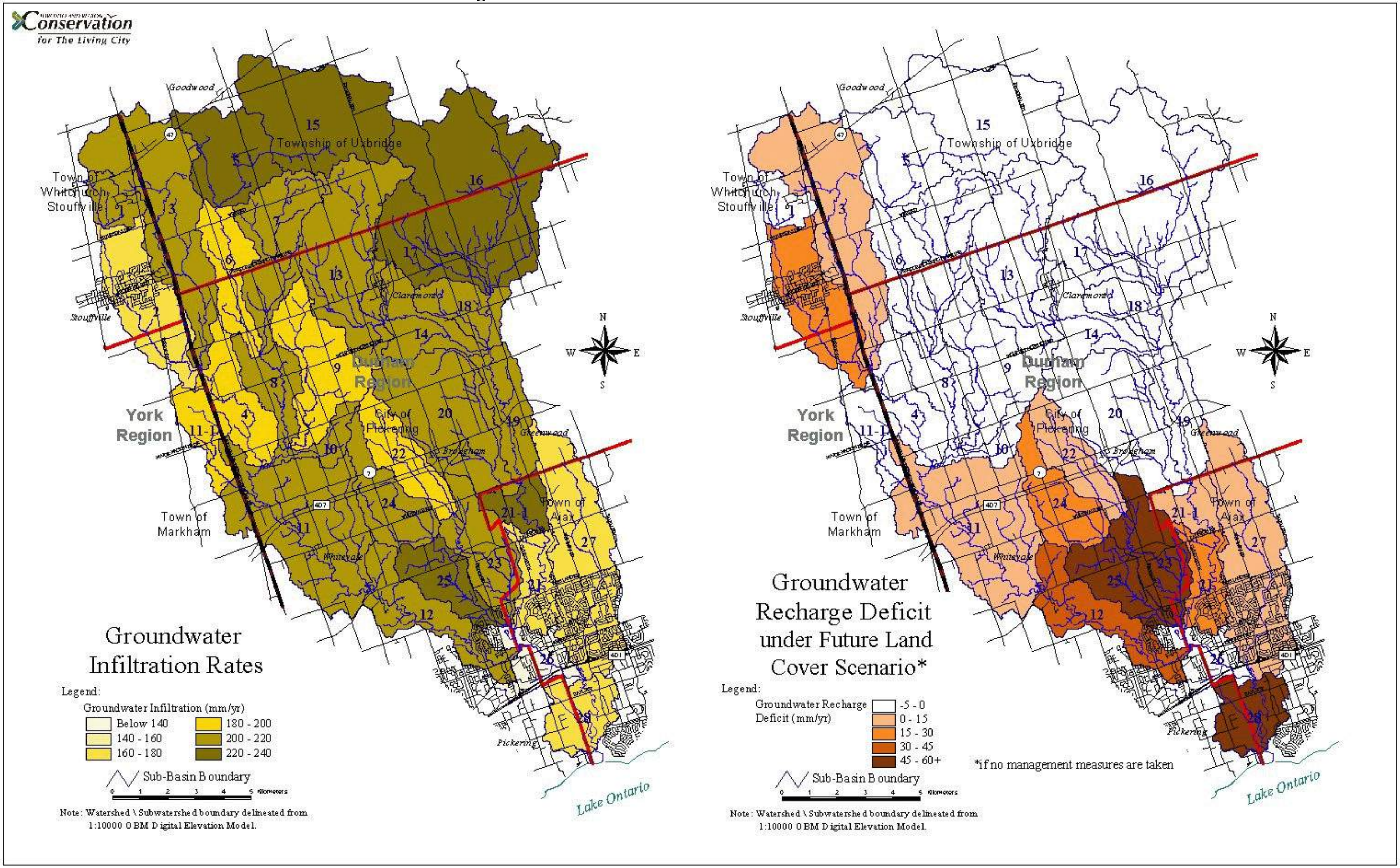


Figure 3-5: Duffins Creek Watershed - Peak Flow Reduction - Future Land Use
Enhanced Natural Heritage Cover

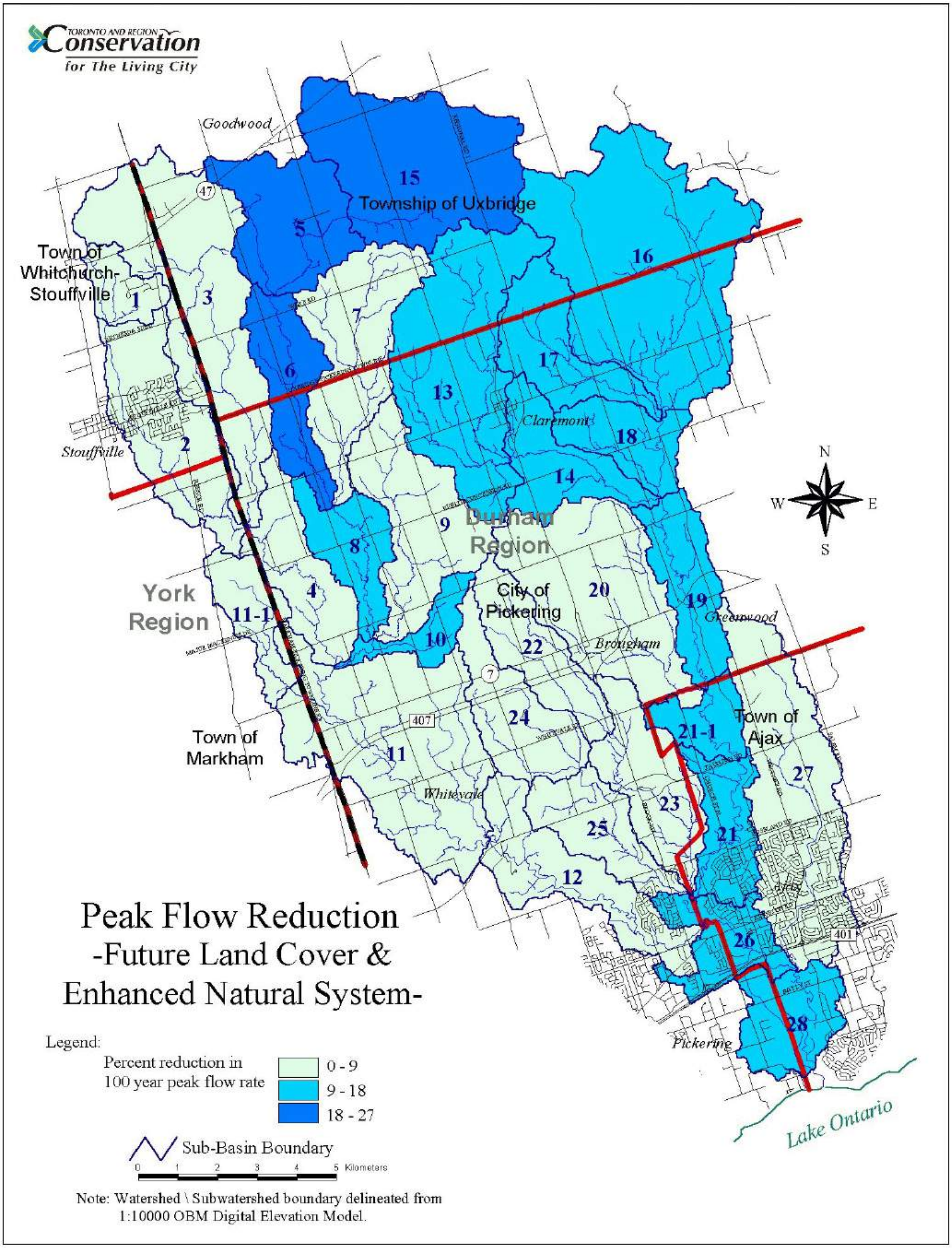


Figure 3-6: Duffins Creek Subwatershed Baseflow Contributions

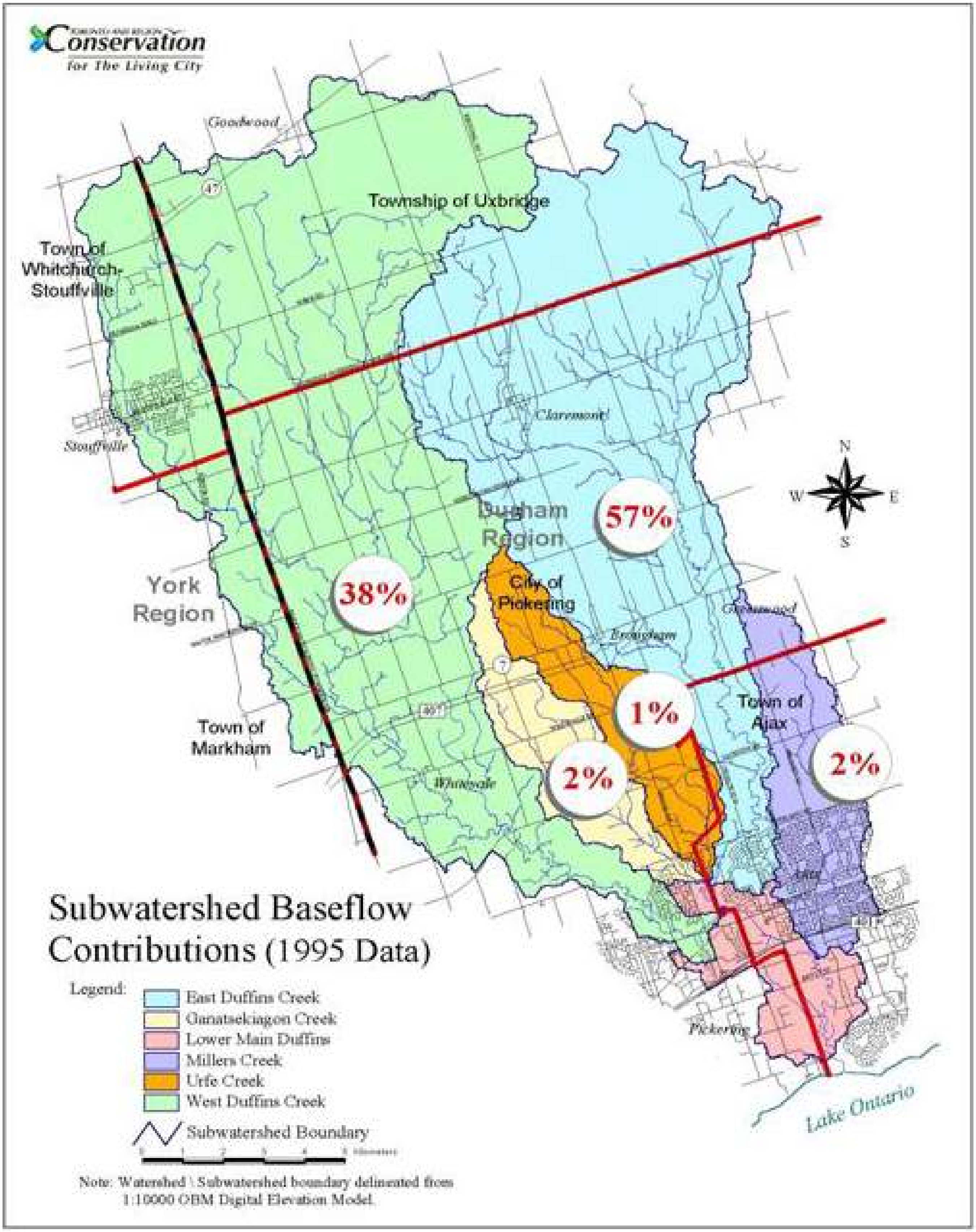


Figure 3-7: Carruthers Creek Baseflow Discharge

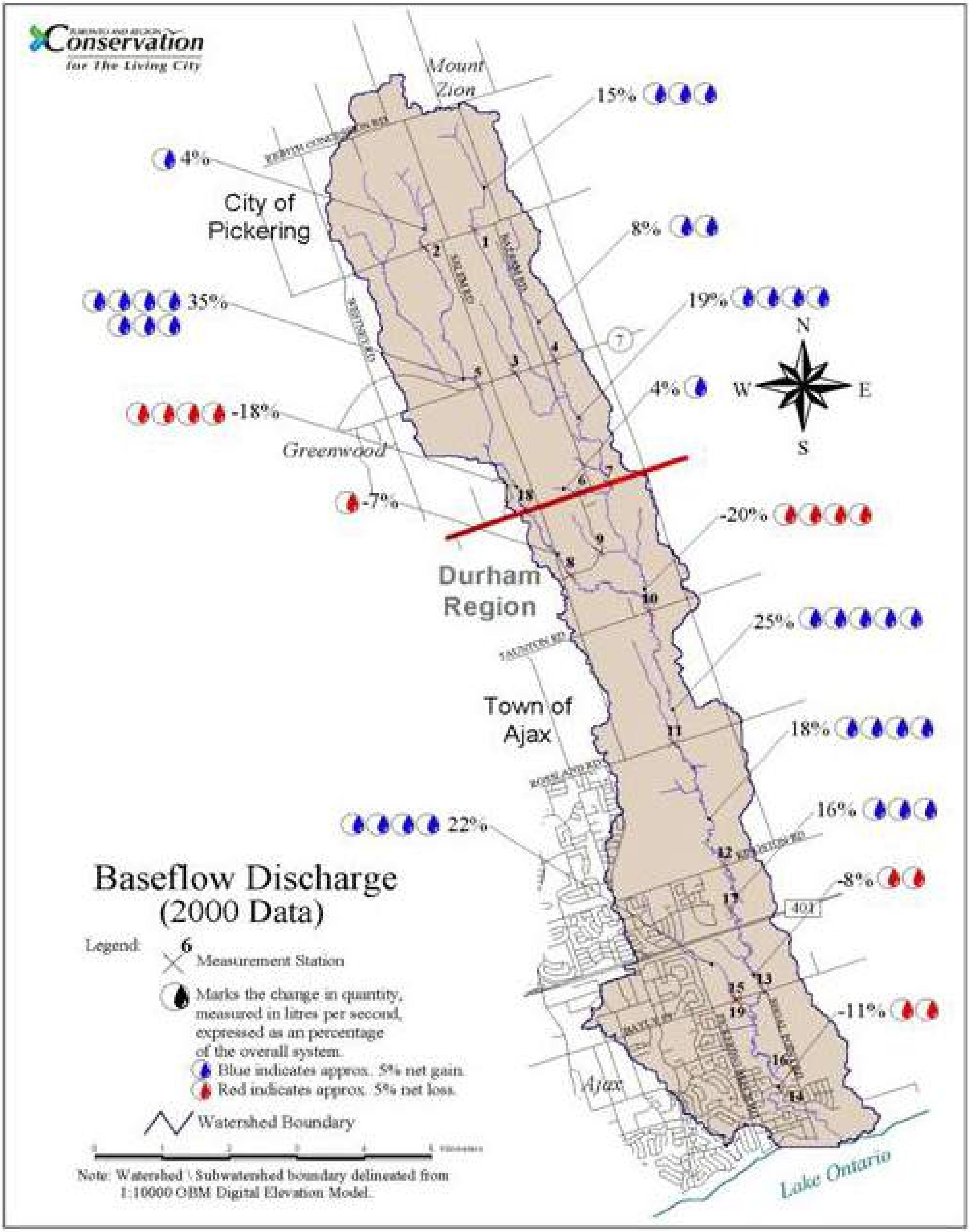


Figure 3-8 Sedimentary Deposits Exposed in the Toronto Area

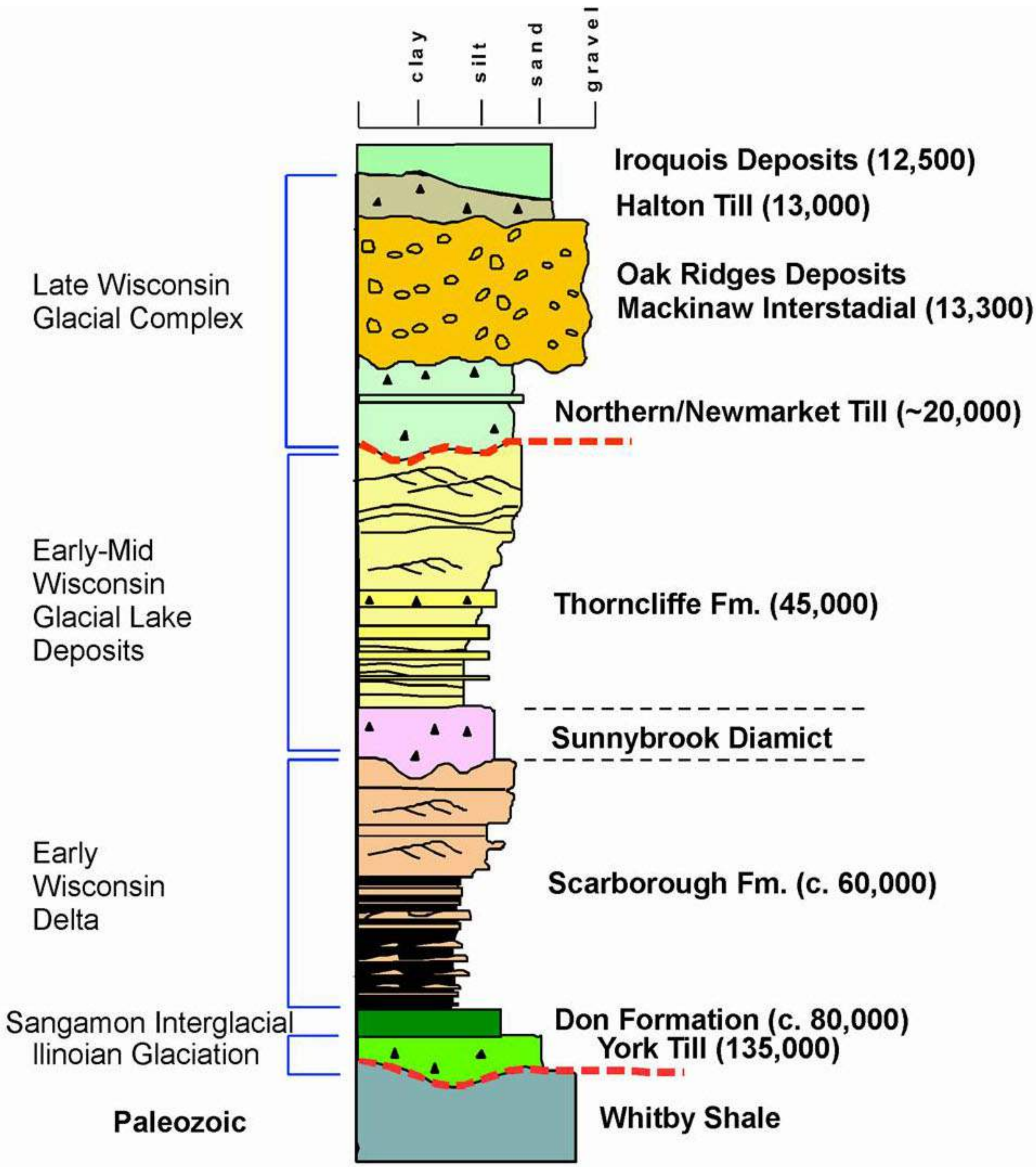


Figure 5: Quaternary deposits found in the Toronto area. Figure from Eyles (2002).

Figure 3-9: North-South Stratigraphic Cross-Section Showing Surface Geologic Deposits of the Duffins Creek Watershed

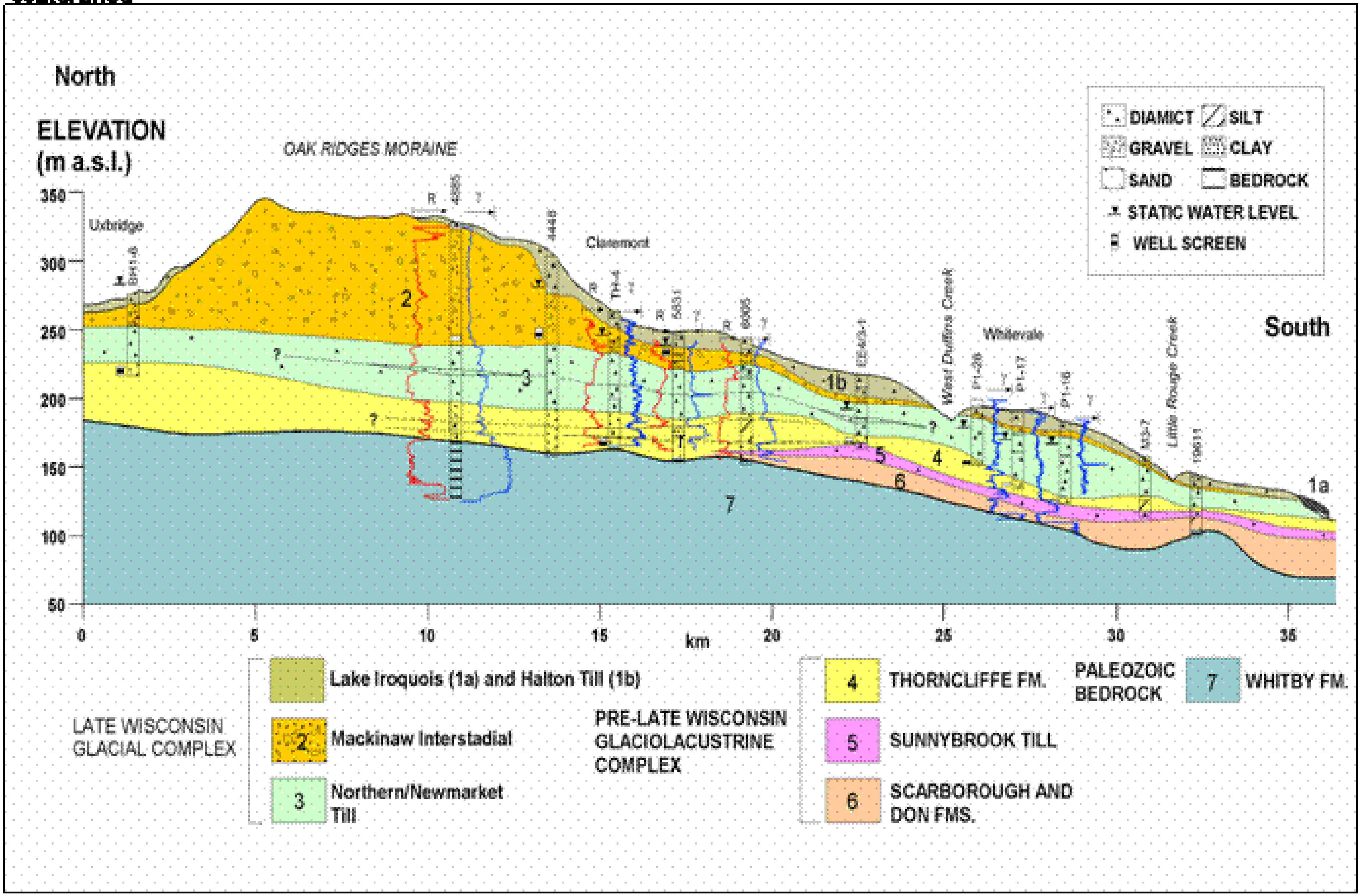
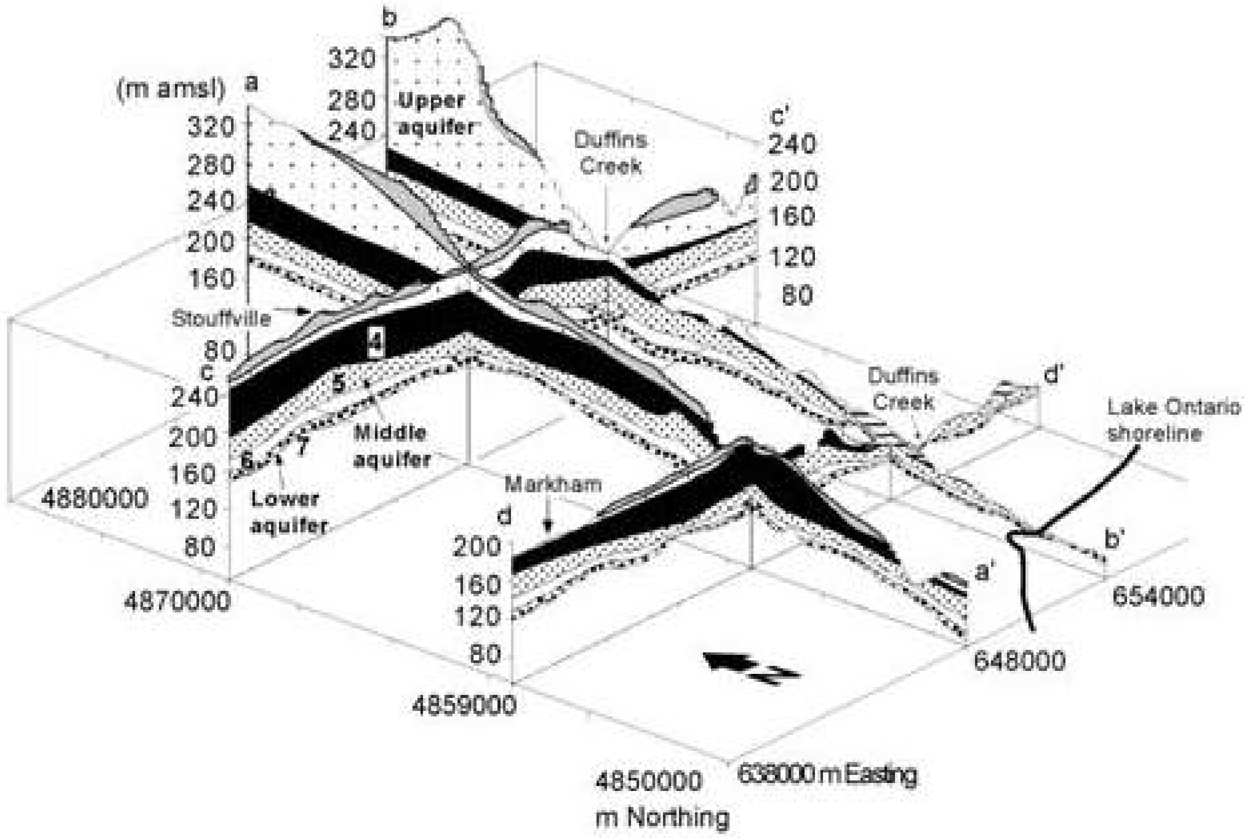


Figure 3-10: Duffins Watershed Fence Diagram



Late Wisconsinan	Model Layer #
Lake Iroquois	1,2
Halton Till	1,2
Mackinaw Interstadial/Oak Ridges Complex (**Upper aquifer**) Glaciofluvial and glaciolacustrine with sand and gravel outwash.	3
Northern/Newmarket till (23-18,000 y BP)	4
Middle Wisconsinan	
Thorncliffe Fm. (**Middle aquifer**) Deltaic sand and lacustrine silt and clay interbedded with diamict (<50,000 y BP)	5
Early Wisconsinan	
Sunnybrook Diamict	6
Scarborough Fm. (**Lower Aquifer**) Deltaic sands and glaciolacustrine silt and clay (~70,000 y BP)	7

Figure 3-11: Duffins Creek Watershed – Decline in Water Table Elevation Under Future Land Cover Scenario

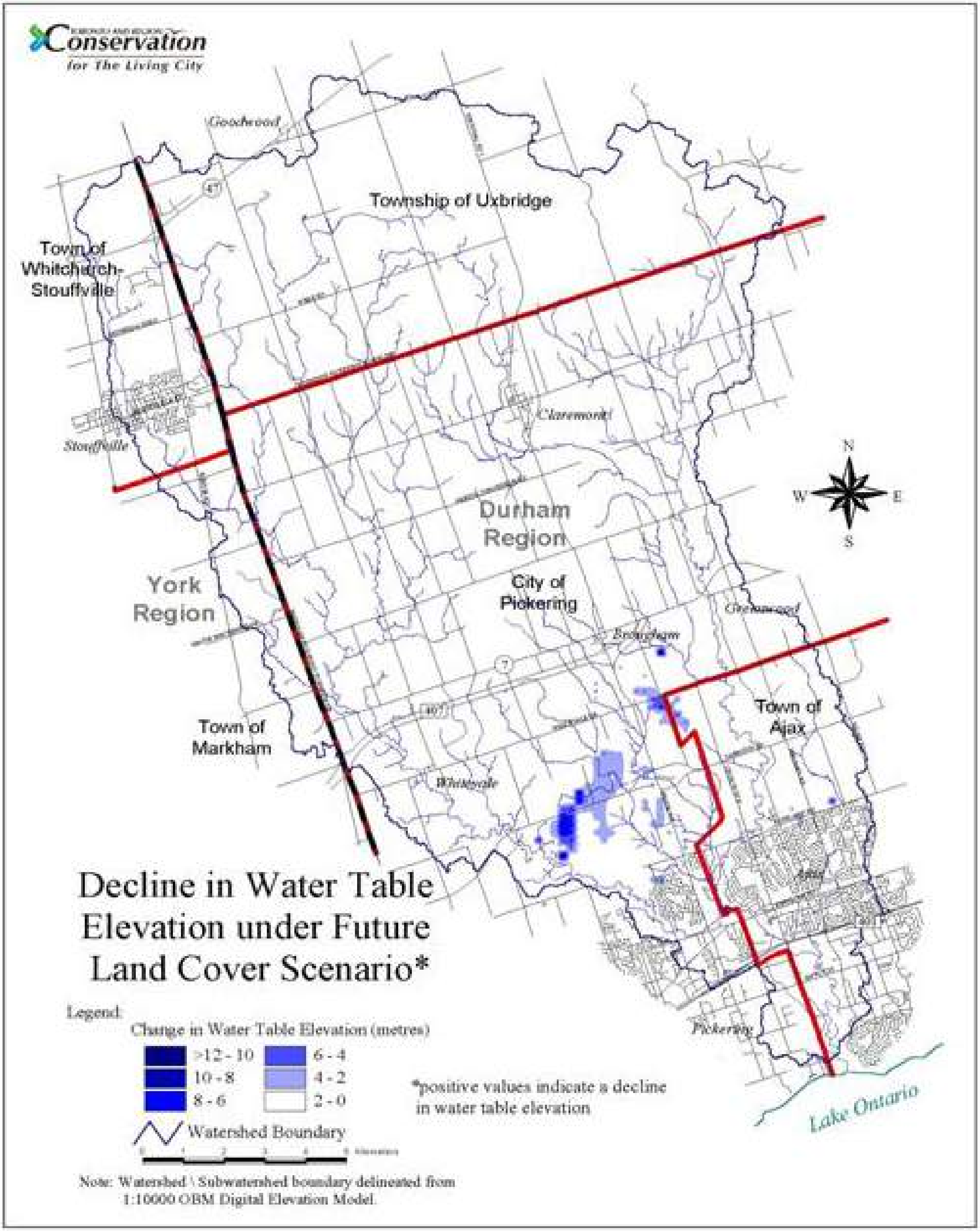


Figure 3-12: Duffins Creek Watershed - Predominant Sources of Sediment Load

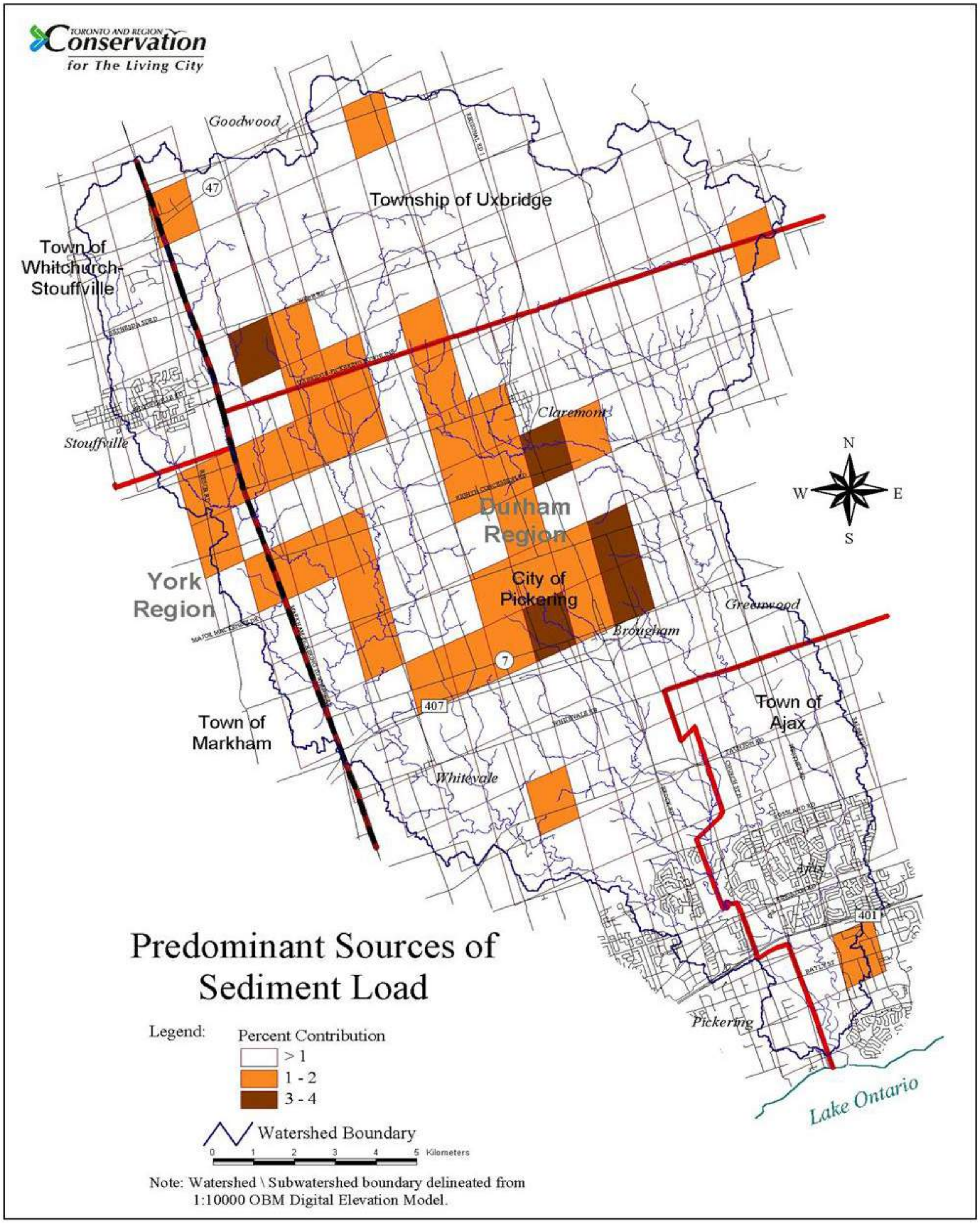


Figure 3-13: Carruthers Creek Watershed - Predominent Areas of Sediment

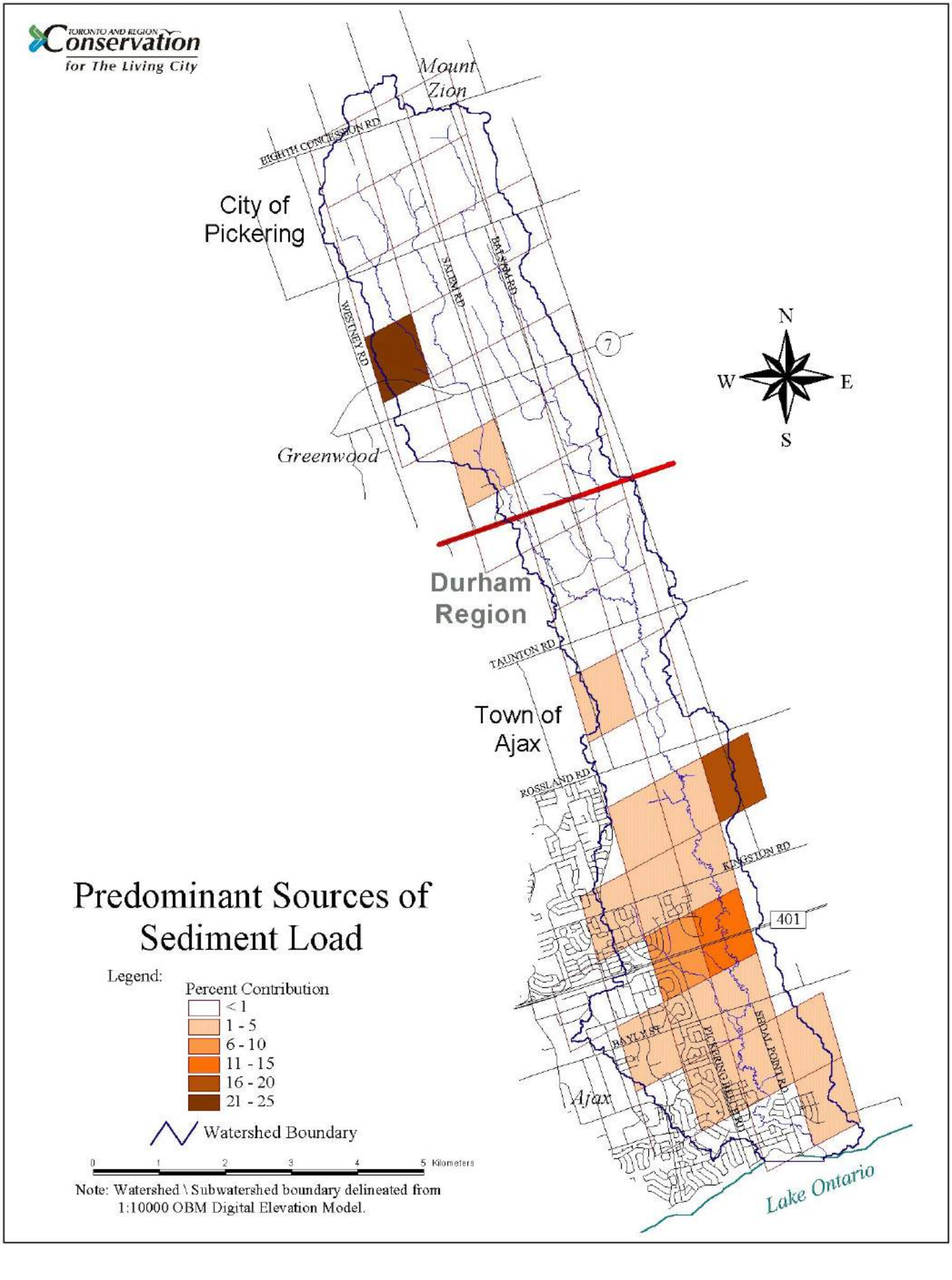


Figure 3-14: Duffins and Carruthers Creek Watersheds Fisheries Management Zones

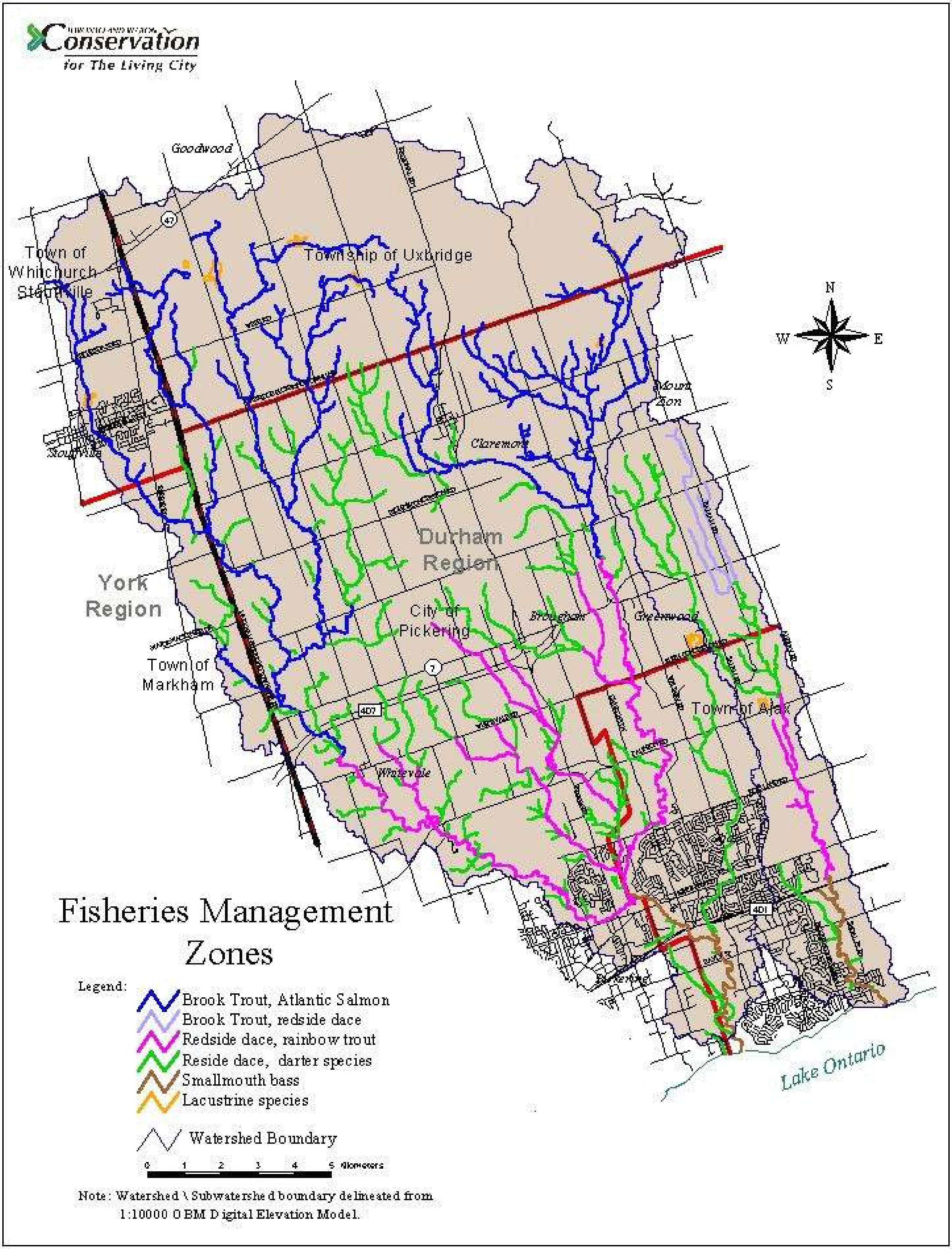


Figure 3-15: Duffins and Carruthers Watersheds - Change in Proportion of Total Annual Flow from Groundawater Sources under Future Land Cover and Future Land Cover with Enhanced Natural Heritage System

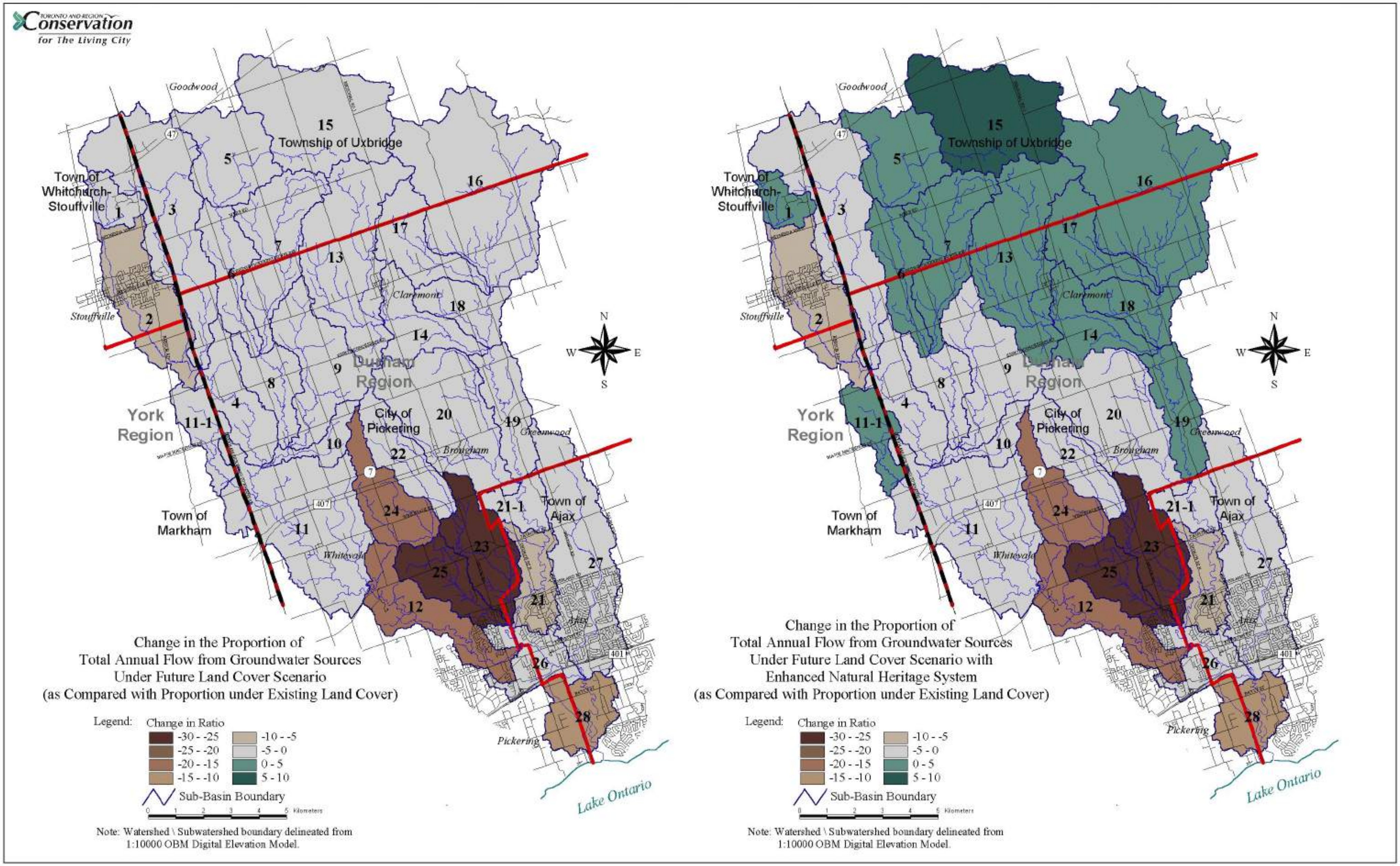
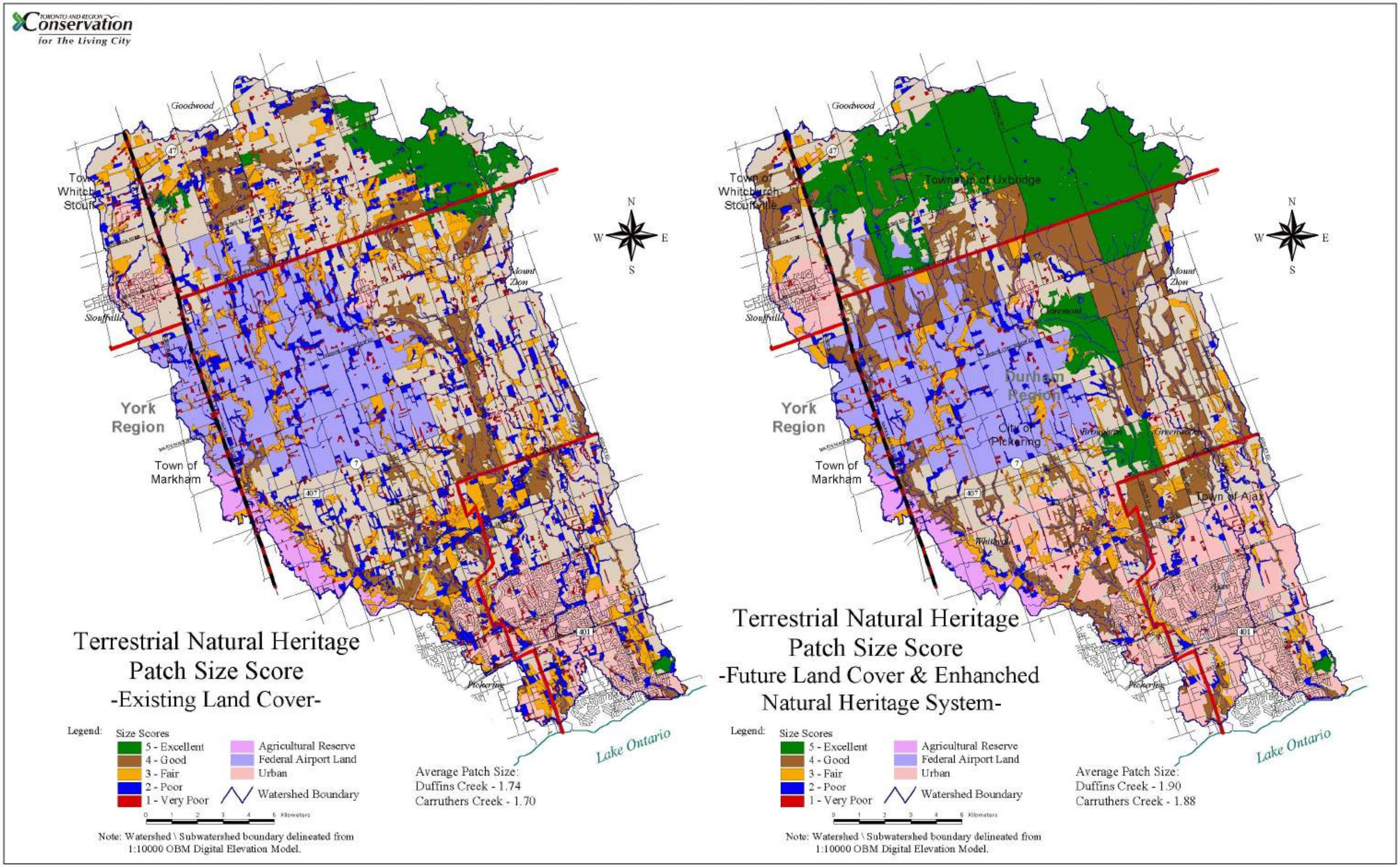


Figure 3-16: Duffins and Carruthers Watersheds - Terrestrial Natural Heritage Patch Size Scores
Existing Land Cover and Future Land Cover with Enhanced Natural Heritage System



4.0 DEVELOPMENT OF RECOMMENDED MANAGEMENT APPROACH

4.1 Evaluation Criteria and Selection of the Preferred Approach

Based on the results of the technical studies, the Watershed Task Forces have recommended that the most effective approach for managing the Duffins and Carruthers Creek watersheds would involve achievement of the targeted natural heritage system, together with the application of state of the art management practices that would be employed in all aspects of land use activities. The concept of a targeted natural heritage system, at the watershed scale, is depicted in the "Future Land Use (as per Official Plans) with Enhanced Natural Heritage Cover" scenario. The scenario was not intended to limit revegetation to these specific geographic areas. Implementation of the watershed plan would involve a review of opportunities for enhancing natural heritage systems at subwatershed and site scales. The technical studies have recommended guidelines and criteria for the design and application of best management practices that would contribute to maintaining the function of the natural heritage system.

The selection of this preferred management approach was based on a number of considerations:

Consistency with Task Force Management Philosophy

The Task Forces articulated a management philosophy that was to be used to guide in the achievement of their vision for the watersheds. The management philosophy consists of five key elements:

- Net Gain
- Environment First
- Balance Land Use
- Human Health and Safety
- Everyone Counts - Ownership, Commitment & Follow Through

The establishment of a natural heritage system, together with sustainable agricultural and urban land uses, is consistent with this Task Force's management philosophy.

Effectiveness

Technical analysis of the watersheds' response to alternative land use and management scenarios enabled the Task Forces to establish benchmarks of watershed condition, which were used as a guide in formulating and justifying this management plan. Results from the analysis of the "Future Land Use (as per the Official Plans) with an Enhanced Natural Heritage System" scenario repeatedly demonstrated the multiple watershed management benefits that can be realized by achieving a targeted natural heritage system. In addition to benefits associated with terrestrial habitat and species objectives, a natural heritage system was shown to contribute to the management of hydrological, hydrogeological, water quality, aquatic resource, recreation, and human heritage concerns.

Long Term Sustainability

At a watershed scale, the protection of a viable natural heritage system, will provide the foundation for a sustainable watershed. By protecting the ability of natural systems to carry out watershed management functions, there will be:

- less need for costly maintenance of infrastructure;
- less risk involved with unproven technological solutions to watershed management; and
- cost savings in taking a preventitive approach rather than a reliance on remedial or "end-of-pipe" solutions.

Wise choices regarding "backyard practices", urban form, and transportation design, made at site and community scales within the watershed will complement the level of protection provided by natural systems and contribute to overall watershed sustainability.

Feasibility

Due to unique opportunities in the Duffins and Carruthers Creek watersheds, the Task Forces deemed the achievement of an enhanced natural heritage system to be feasible in these watersheds. Unique opportunities in these watersheds include:

- Provincial legislation - Since the Task Force began its work, the Ontario Government passed the Oak Ridges Moraine Act and Conservation Plan, which effectively protects a significant area of land for a natural heritage system in the headwaters of the Duffins Creek

- Public land holdings - Federal, provincial, and municipal governments and the TRCA own significant lands in these watersheds and expect to be able to realize watershed plan objectives with public support. For example, in March 2001, Transport Canada identified lands surplus to its needs for an airport and announced that these lands would be protected as greenspace in perpetuity. There may be further lands deemed surplus as airport planning proceeds.

- Private landowner willingness to participate in environmental programs in these watersheds, as has been demonstrated by the significant number of conservation easements that have been established since the watershed planning process began.

Consistency with Great Lakes Basin Management Objectives

The Canada-Ontario Agreement on Great Lakes Water Quality (2002) commits Canada and Ontario to increase natural areas and practice sound watershed management as a means of protecting coastal wetlands and the overall health of the Great Lakes.

4.2 Integral Management Actions

A detailed list of management actions was identified for the achievement of each of the watershed plan's objectives. These actions are presented within the watershed plan document. Following a review of these management actions, it was recognized that a number of them are common, in that they contribute toward the fulfillment of numerous objectives. Certain actions are considered especially important because they have benefits that are realized upstream, downstream, or well beyond their site specific application. These particular management actions are considered to be so important that they are integral to the overall health of the watersheds and should be afforded Top Priority for implementation.

The Integral Management Actions are presented in **Table 4-1.**

Table 4-1: Integral Management Actions

✔ Protect existing meadows, wetlands, and forests identified in the targeted terrestrial natural heritage system and secure lands to be restored.
✔ Actively restore areas within the targeted natural heritage system, which contribute multiple watershed benefits, and allow passive restoration to occur in the remaining areas.
✔ Provide stormwater quantity controls for new and existing development, including transportation corridors.
✔ Manage land uses and water withdrawals to maintain or enhance infiltration patterns, groundwater pathways, and resultant baseflows.
✔ Eliminate the remaining point source of pollution (i.e. Stouffville Water Pollution Control Plant) and manage non-point sources of pollution, in particular stormwater runoff and infiltration from urban land uses, transportation corridors, and rural contributions.
✔ Enforce stringent erosion and sediment controls for construction and infrastructure maintenance activities.
✔ Protect and restore natural streams and stream processes by managing runoff and sediment loss at source, and protecting valley and stream corridors, and naturalizing altered streams.
✔ Remove and/or mitigate human-built barriers to fish passage and sediment transport, including on-line ponds, where recommended by the Fisheries Management Plan.
✔ Maintain self-sustaining, resident/migratory fish and wildlife populations as barometers of a healthy natural heritage system
✔ Identify and raise awareness of past and present human influences on the watersheds and the strong link between human heritage, watershed recreation and human and environmental health.

4.3 GIS Based Mapping of the Multiple Benefits of Natural Heritage

Objective of this exercise

As part of the integrated watershed planning process, key management related mapping products from each of the technical study components were correlated with one another in order to identify lands where the protection or restoration of natural heritage cover contributes to the achievement of multiple watershed management goals. The resulting maps were intended to serve two purposes:

1. Provide further rationale and spatial justification for the targeted terrestrial natural heritage system; and

2. Direct initial management activities associated with land securement, outreach/education, and active regeneration and stewardship to areas where the greatest net benefits could be achieved.

The resulting maps illustrate locations in the watersheds where protection and/or active restoration of natural heritage cover would result in additional benefits, above and beyond the goal of protecting and enhancing terrestrial habitats and species.

The maps are strictly intended to be used as a guide, which will be supported by the more detailed technical studies, policies, and criteria.

Method

The various mapping products, or layers of information were correlated by utilizing the data processing capabilities of a Geographic Information System (GIS). For each technical component, a map, or layer of information was generated that delineated all of the portions of the watershed where the protection or restoration of natural land cover would contribute to achieving the primary management goal associated with that component. **Table 4-2** identifies the information layers used for each component. Individual layers are illustrated in **Figures 4-1 (a-g) and 4-2 (a-d)**. Each of these maps or data layers were converted into a common mapping data format, the raster, or “grid” data format, where each grid cell that makes up a layer of information has a value associated with it (i.e., all vector-format maps were converted into raster-format maps using a common grid-cell size). The “grid” data format enables the planner to easily quantify the extent to which overlap occurs between the multiple data layers.

For each map or information layer, a value of 1 was assigned to all grid cells representing portions of the watershed where the presence of natural vegetation cover was identified as having a high potential to contribute to achieving the respective management goal, and a value of zero (0) was assigned to the grid cells representing the remaining portions of the watershed.

Using the overlay and data processing capabilities of the GIS, a new map was generated by overlaying all of the layers and adding the overlapping grid cell values together to generate a common grid. This resulting map can be thought of as a representation of the number of management goals that are addressed by preserving or restoring natural land cover in the areas indicated. Areas where the highest grid cell values occur can be thought of as being where the greatest “net benefits” can be achieved by protecting or enhancing natural land cover.

This map also suggests that areas with high grid cell values that fall outside of areas of existing natural land cover are locations were active restoration of natural land cover would provide the greatest net benefits.

Table 4-2: Layers of Information included in the Management Integration Map: "Multiple Benefits of Natural Heritage Cover"

Management Component	Information layer	Condition	Rationale
Groundwater Quantity and Quality*	grid surface of the change in groundwater infiltration (GWI) (by sub-catchments) between the "Official Plan with Enhanced Natural Heritage" scenario and the "Existing Conditions" scenario	all grid cells where "Existing" GWI values are maintained or enhanced in the "Official Plan with Enhanced Natural Heritage" scenario get a value of 1	represents all sub-catchment areas where the targeted terrestrial natural cover contributes to maintaining the existing water balance (through maintaining or enhancing infiltration and evapo-transpiration contributions) and protecting and enhancing groundwater quantity and quality
Surface Water Quantity*	grid surface of values for % reduction in 100 year peak flow rate (by sub-catchments) for the "Official Plan with Enhanced Natural Heritage" scenario	all grid cells where % peak flow reduction is ≥ 10%	represents all sub-catchment areas where the targeted terrestrial system contributes significantly to minimizing risks to human life and property due to flooding, and maintaining natural stream channel stability as a result of the reduced run-off and increased evapo-transpiration rates associated with the enhanced natural cover
Surface Water Quality	output of AGNPS modelling identifying Predominant Pollutant Source Areas in terms of suspended sediment loading	all areas identified as contributing the greatest portion of the total suspended sediment load during storm events (areas where ≥ 1% of the soil is made up of clay-sided particles) get a value of 1	represents areas which contribute the greatest proportion of the total sediment load and where natural land cover would reduce erosion rates.

Aquatic Habitat and Species (Also addresses Water Quantity and Quality Goals)	**the valley and stream corridor = combination of the fill regulation line and the fill extension line**	**all lands within the stream and valley corridor, as defined by TRCA's Valley and Stream Corridor Management Program, get a value of 1**	**captures the riparian zone, floodplain hydrologic function, streambank and valley slope erosion - all of which benefit from natural cover**
Terrestrial Habitat and Species	**the targeted natural heritage system, as per the "Official Plan with Enhanced Natural Heritage" scenario**	**all lands within the targeted natural heritage system get a value of 1**	**protection or restoration of natural cover in areas identified for the targeted system maintain or improve habitat quality**
Recreational Use*	**existing and proposed trail right of way (5 m buffer on either side of the line)**	**all lands within the right-of-way of existing trails get a value of 1**	**natural land cover along trails adds value to the outdoor recreation experience.**
Human Heritage	**combination of a 250 metre buffer around known archaeological sites and all lands within 250 metres of a waterbody which are located on well-drained soils (represents areas with a high potential for archaeological significance)**	**All lands within the areas of existing or potential archaeological significance get a value of 1**	**Maintaining natural cover on known and potential archaeological site areas protects them in situ.**

*Mapping outputs from the watershed plan components indicated with an asterik were used in the analysis for Duffins Creek watershed only, as these layers of mapping information are not yet available for Carruthers Creek.

It should be noted that, since the design of the enhanced natural heritage scenario did not aggressively pursue gains in natural cover in sub-catchments where urbanization was planned to occur as per the Official Plans, any modelling results drawn upon to form information layers for this "integration map" may not reflect all the potential benefits of natural cover in those subcatchments.

The information layer chosen to highlight lands where there are groundwater management benefits of natural heritage cover is not ideal. By using water budget modelling results of the enhanced natural heritage scenario, this method introduces two limitations: 1) design of the enhanced natural heritage scenario did not aggressively pursue gains in natural cover in sub-catchments where urbanization was planned to occur as per the Official Plans, so the map may not provide a true indication of the potential groundwater benefits of natural cover in these areas; and 2) it is suspected that the water budget model has limitations in its ability to estimate the effects of natural cover on infiltration rates. Furthermore, at this time, the information layer does not address groundwater quality. When improved groundwater management mapping becomes available, the layer of information used to integrate groundwater quantity and quality management will be updated. Improved mapping will involve a combination of the following: aquifer vulnerability areas, well-head protection zones, groundwater discharge areas, and critical groundwater recharge areas. The latter may be delineated with reference to flow path mapping that links sensitive discharge areas and aquifers with recharge areas.

Additionally, this analysis assumes a flat weighting scale where each management component (i.e. input layer of information) is considered to be of equivalent importance or value in the analysis. The assumption of equivalent ratings is not necessarily valid in all cases, as the presence of natural cover in a given area does not always produce equal benefits to water management objectives as to habitat objectives. However, in the absence of a stronger basis upon which to assign a relative rating of value within each management component, an equal rating system was used. This method for identifying areas for active regeneration/stewardship/acquisition and/or enumerating the benefits of integrated management could be refined through the use of weighting factors assigned to each information layer that are based on a mutually agreed upon value system. These weighting factors could be based on watershed issues, concerns, or opportunities identified through characterization studies, issues scoping work, public input (i.e. social values), or economic values in terms of monetary costs/benefits associated with the anticipated outcomes of land use change.

Findings

Duffins Creek

The integrated GIS mapping analysis for Duffins Creek strongly supports the axiom that maintaining or restoring natural land cover in the headwaters of a watershed, and along the valley and stream corridor provides the greatest net benefits to overall watershed health (**Figure 4-3**).

Table 4-3 summarizes the values calculated for the total area of land (in hectares), and the proportion of the total watershed area (% of total) where protecting or restoring natural land cover would address multiple management goals and thereby provide multiple benefits, beyond those related to improving the quality of terrestrial habitat. Based on the degree to which all of the layers of mapping information overlap with one another, it was found that maintaining or restoring natural land cover on a total area of land equivalent to approximately half (49%) of the total watershed area would significantly contribute to three or more management goals. These results help to further illustrate the multiple watershed management benefits that could be achieved by the targeted terrestrial natural heritage system and highlights the importance of planning and implementing management measures using an integrated approach that considers interconnections between all of the components of the natural system.

Carruthers Creek

In the absence of GIS mapping information pertaining to peak flow rates, groundwater infiltration rates, and recreation trails, a similar GIS mapping analysis was conducted for the Carruthers Creek watershed. In this analysis, four layers of mapping information pertaining to findings from the Surface Water Quality, Aquatic Habitat and Species, Terrestrial Natural Heritage, and Human Heritage components of the watershed plan were correlated with one another. As in the Duffins, the output of this analysis generally supports maintaining or restoring natural land cover along the valley and stream corridor (see **Figure 4-4**). It was found that maintaining or restoring natural land cover on a total area of land equivalent to approximately 37% of the total watershed area would significantly contribute to two or more of the four management goals considered in this analysis (**Table 4.3**). This analysis should be repeated in the future when layers of mapping information pertaining to all of the components of the watershed plan are available in order to provide a more detailed analysis and quantification of the benefits derived from the targeted natural heritage system.

Table 4-3: Percent of Watershed Area Where Natural Heritage addresses Multiple Goals

Duffins Creek				Carruthers Creek			
# of goals addressed	Area (ha.)	% of total watershed area	Cumulative % of total watershed	# of goals addressed	Area (ha.)	% of total watershed area	Cumulative % of total watershed
6	246.5	0.9	0.9	4	58.5	1.5	1.5
5	1930.8	6.8	7.7	3	530.7	13.8	15.3
4	4231	14.9	22.6	2	848.5	22.1	37.4
3	7460.1	26.4	49	1	1499.2	39	76.4
2	6049.7	21.4	70.4	0	903	23.5	99.9
1	5070.9	17.9	88.3				
0	3312.4	11.7	100				

Targeted Areas for Active Stewardship, Regeneration and/or Securement

The output of the GIS mapping analysis also provides a means of targeting areas on the Duffins and Carruthers Creek watersheds where management actions to protect and restore natural land cover would result in the greatest net benefits to the natural system, and therefore, where such management actions should be focussed in the immediate future. To demonstrate this, a map was prepared for the Duffins Creek watershed showing only areas where three or more management goals are addressed by the targeted terrestrial natural heritage system (**Figure 4-5**). Areas where the protection or restoration of natural land cover would significantly contribute to achieving multiple management goals were found to be concentrated in and around the valley and stream corridor and in the headwaters areas, with particular emphasis on the sub-catchments of West Duffins Creek, Mitchell Creek, and East Duffins Creek.

For the Carruthers Creek watershed, a map was prepared showing where two or more management goals are addressed (**Figure 4-6**). The areas indicated in these figures can be thought of as generally representing locations on the watersheds where management actions such as promoting stewardship activities in existing natural areas, initiating active restoration on lands where permitted by current landownership/land use, or pursuing protection through securement should be focussed in order to maximize net benefits to the natural system.

Considerations for Future Studies

In future watershed planning processes, this type of exercise should be considered at an interim point in the study process. The results could then be used to design a targeted natural heritage system, where the distribution of natural cover is such that the number of other management goals addressed are maximized while also meeting the terrestrial goals. Then, the technical studies and modelling exercises could undertake a more detailed analysis and quantification of the benefits derived from the targeted natural heritage system.

4.4 Implementation Strategy

The specific management directions were presented in the watershed plan in several user-friendly formats, in an effort to facilitate implementation by multiple partners. The implementation strategy consisted of a set of implementation mechanisms, a model policy framework, and a map illustrating the multiple benefits of natural heritage. The latter mapping product was intended to facilitate or direct initial implementation efforts.

4.4.1 Implementation Mechanisms

Common to many watershed plans in Ontario, key implementation mechanisms include:

- Policy and planning tools
- Regulations and permits
- Stewardship and Regeneration
- Land Securement and Acquisition
- Education and Awareness
- Monitoring and Reporting

The watershed plan identifies specific actions and responsibilities in these areas, and provides supportive mapping, guidelines and criteria, as generated by the technical studies.

4.4.2 Model Policy Framework

A framework of model policies was prepared as part of the watershed planning process to illustrate effective policy approaches which could be used to achieve the watershed plan's objectives. The framework was developed by the Policy Working Group, a sub-committee of the Task Forces, together with TRCA and municipal staff. The framework is based on a review of numerous existing policy documents of the local and regional municipalities within the watershed and leading municipalities from other jurisdictions. The framework borrows heavily on a state-of-the-art provincial environmental policy document, the Oak Ridges Moraine Conservation Plan. The framework was intended to facilitate amendments to Regional and Local Official Plans and operating policies of the municipalities, TRCA, and other watershed implementors that could assist in implementing the watershed plan.

Figure 4-1: Duffins Creek Watershed Integration Map

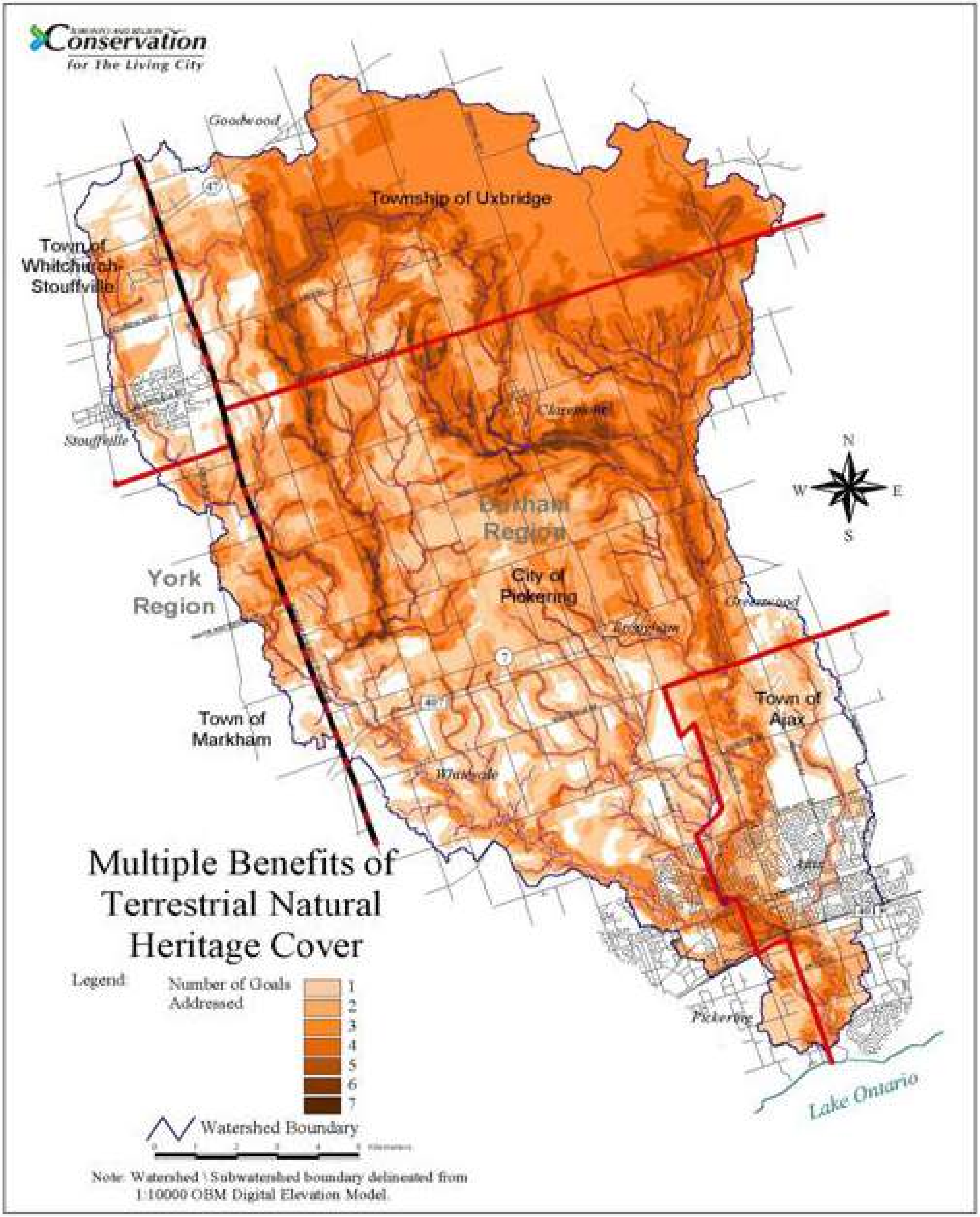


Figure 4-2: Carruthers Creek Watershed Integration Map

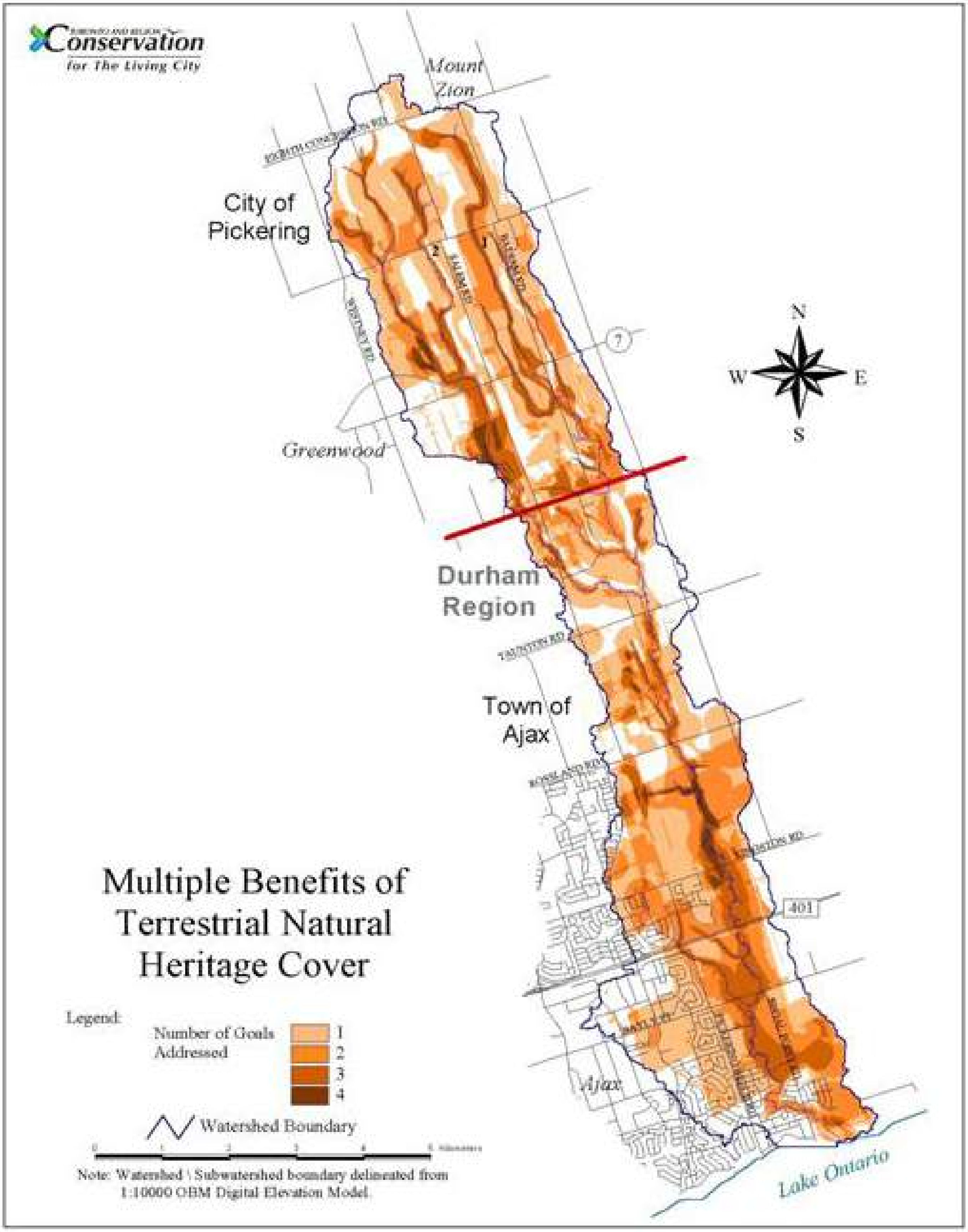


Figure 4-3: Duffins Creek Watershed – Targeted Areas for Active Stewardship, Regeneration and/or Securement

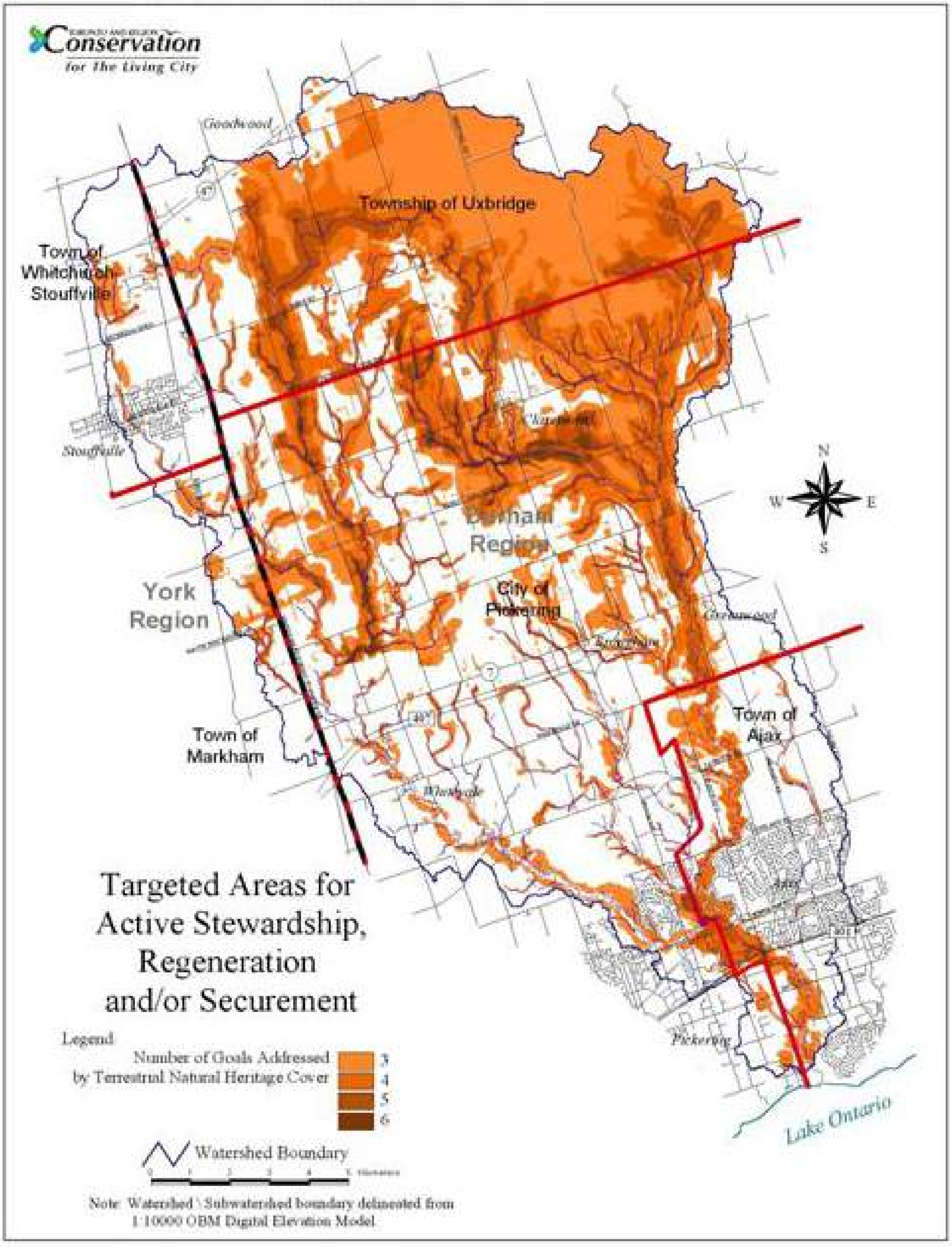
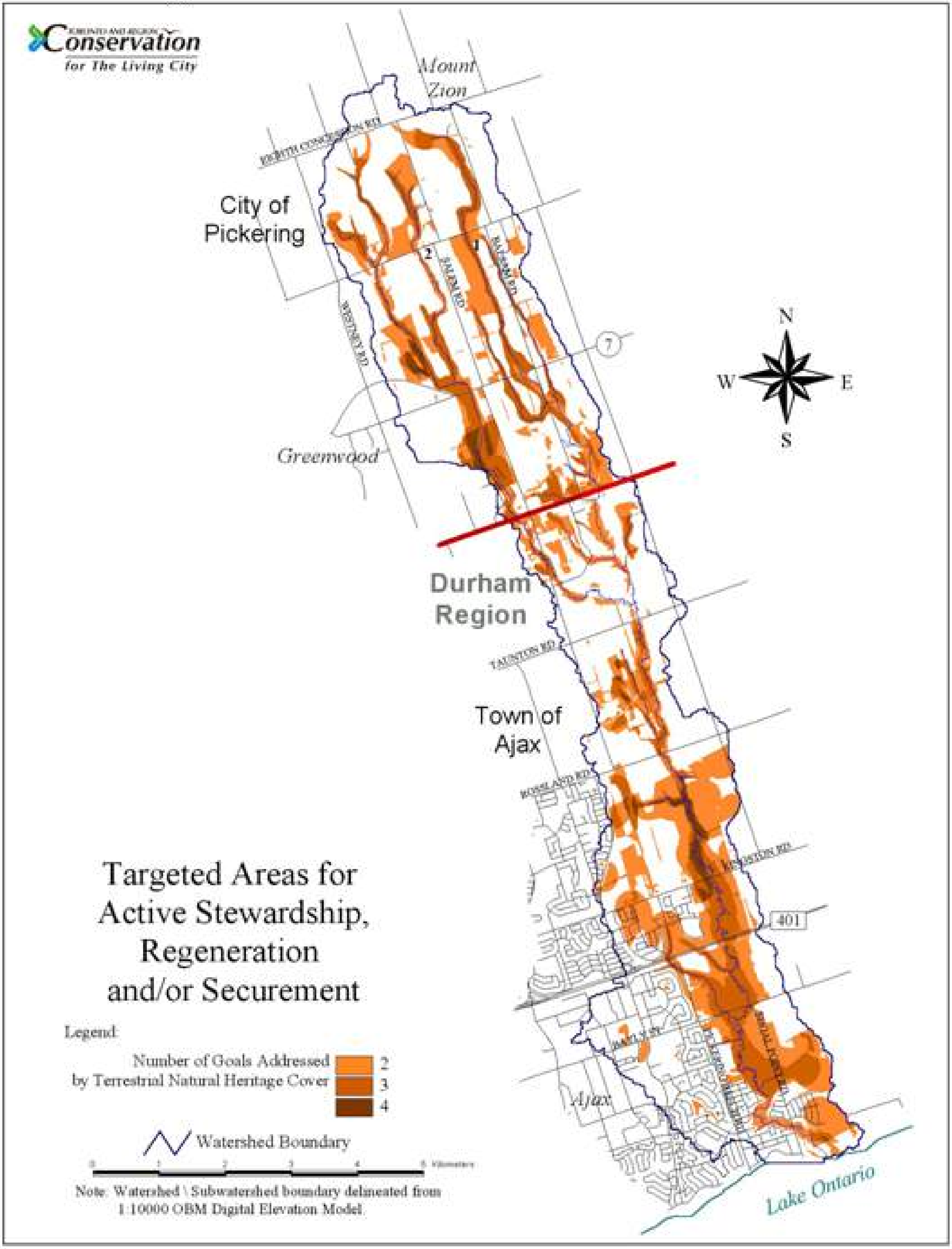


Figure 4-4: Carruthers Creek Watershed- Targeted Areas for Active Stewardship, Regeneration and/or Securement



5.0 PUBLIC CONSULTATION AND PEER REVIEW

5.1 Watershed Task Forces

Continuing its very successful model for empowering watershed stakeholders, TRCA formed two Watershed Task Forces in June 2000 and charged them with the responsibility of developing a Watershed Management Strategy for the Duffins and Carruthers Creek Watersheds over a 24 month term. The Task Forces or their designated Working Groups were presented with proposed technical approaches and findings on a regular basis throughout the process so that they could provide input and guidance. Task Force members helped to ensure that all key issues were being addressed, and that the strategy document that was being developed would be understood and supported by municipal and agency politicians and staff, community groups, business and industry, watershed residents and the general public.

Membership of the two Task Forces consisted of elected municipal representatives, watershed residents, and representatives from key stakeholder groups **(see Table 5-1)**. In each Task Force a citizen member was elected as Chair of the Task Force and a municipal councillor was elected as Vice-Chair. Staff from the planning and engineering departments of local and regional municipalities regularly attended meetings to support their elected representatives. The provincial ministries of Natural Resources and Environment were invited, but declined to participate. Staff from the Ministry of Natural Resources participated in an advisory role on matters pertaining to the preparation of the Fisheries Management Plans. The Task Forces are accountable to the TRCA's Watershed Management Advisory Board (WMAB), and as such minutes and reports from the monthly Task Force meetings were provided to the WMAB.

Table 5-1: Watershed Task Force Membership

Duffins Creek Task Force	Carruthers Creek Task Force
One elected representative from each of: Region of Durham Region of York City of Pickering Town of Ajax Town of Whitchurch-Stouffville Town of Uxbridge Town of Markham Five residents One representative from each: Aggregate Producers Assoc. of Ontario Urban Development Institute Watershed golf courses Transport Canada	One elected representative from each of: Region of Durham City of Pickering Town of Ajax Four residents One representative from each: Aggregate Producers Assoc. of Ontario Urban Development Institute Watershed golf courses Citizens for Carruthers Ministry of Transportation

The two Task Forces and their Working Groups often convened joint meetings and workshops, where they considered technical advice from staff. During 2000-2001, a Land and Water Working Group provided input to the draft State of the Watershed Reports. A Policy Working Group assembled and reviewed existing policy documents at the local and regional municipal level and the new provincial Oak Ridges Moraine Conservation Plan. The Policy Group identified key issue areas and associated "best policy practice" for which watershed policy concepts were to be refined.

During 2001-2002, the Task Forces refocused their Working Groups. The new Strategy Working Group developed the Vision for the two watersheds and reviewed the proposed management strategy framework consisting of goals, objectives, indicators, measures, targets and management actions. TRCA staff consulted with the Strategy Group and the Task Force as a whole on: the choice of alternative land use scenarios to be analysed; the choice of subwatershed units; the overall management philosophies; and development of the final management strategies and policy concepts. The Public Outreach and Education Working Group assisted in promoting the opportunities for public consultation.

5.2 Public and Stakeholder Consultation

Throughout the process, numerous opportunities were provided for key stakeholders and members of the public to share their views on the emerging strategy. Members of the public were invited to comment on watershed issues, vision and proposed management goals, objectives, and approaches at a series of open houses that were held throughout the watersheds during November and December 2001. Open houses were held in the Township of Uxbridge, Town of Ajax, City of Pickering (urban and rural), and the Town of Whitchurch-Stouffville. At those meetings, a commitment was made to return to the public with a refined document in the spring of 2002. In keeping with that commitment, a second round of public open houses was held in Claremont and Ajax and completed in June 2002.

During the 24 month mandate of the Task Forces, TRCA staff and Task Force members also convened an average of 2-3 individual meetings with representatives from each of the key stakeholder groups. These meetings allowed an opportunity to discuss issues and implications of the strategy that pertained to the specific interests of each group. Four meetings were held with the agricultural and golf course communities. Two meetings were held with the Durham Chapter of the Urban Development Institute. Separate meetings were also held with municipal staff, Environmental Advisory Committees, Green Door Alliance, Uxbridge Conservation, Durham Conservation, Uxbridge Naturally, and Citizens for Carruthers.

5.3 External Technical Peer Review

Prior to the formation of the Task Forces, TRCA established a Technical Advisory Committee (TAC) in 1999 to oversee the initial scientific studies that contributed to the development of the State of the Watershed Reports and set the stage for the ensuing technical analysis and integration process. The TAC consisted of scientists and experts from federal, provincial, and municipal governments, academia, and the consulting field. TAC members examined groundwater, surface water, terrestrial and aquatic resources information, climate change, and land use planning for the Duffins and Carruthers Creek Watersheds. Although this Technical Advisory Committee discontinued formal meetings as a group, once the Task Forces were established, individual expertise from the committee was called upon on an ad hoc basis throughout the study.

Although the Task Force members and watershed stakeholders possessed a significant and somewhat unique level of technical expertise, which they shared throughout the process, TRCA and Task Force members convened a final peer review workshop near the end of the process (April, 2003) to obtain expert feedback on the strengths and weaknesses of the technical analysis and integration process and the resulting watershed plan. Prior to the workshop, participants were invited to review the final draft reports. A professional facilitator was hired to facilitate the discussion. The workshop was attended by 22 participants with expertise in watershed planning and associated disciplines from a variety of sectors, including conservation authorities, universities, government agencies, consultants, and power generation. A number of TRCA staff members who had been involved in the plan's development also took part in the workshop in a resource capacity.

Feedback from the peer review workshop can be summarized as follows:

- *The watershed response model used to guide the technical analysis and integration process was described as state-of-the-art.*

- *The integration process represents a major step forward, particularly in the links between surface and ground water models and between natural heritage cover and water management.*

- *The need to rely on professional judgement as a predictive tool for changes in aquatic habitat and species is a weakness, but it was acknowledged that there are no current models available for use in this area. Practitioners were cautioned against placing too much reliance on the baseflow to total flow ratio, as it may not be very sensitive to changes imposed by water withdrawals (i.e. they affect both the nominator and denominator).*

- *Water budget modelling is a key strength of this study. Future studies should address the significance of closed drainage storage systems on local water balance and the effects of lawn watering in areas to be supplied by Lake Ontario water sources. A significant difference was noted between recharge rates generated by the water budget model, which relies on soil/land use data, and the groundwater flow model, which relies on surficial geology, with the recommendation that the source of these differences be investigated.*

- *More attention should be given to recreational fishing usage and associated values within the watershed and on the impacts of sport fishing on game fish.*

- *The plan was found to be well communicated to the public and the "buy in" of watershed partners was noted.*

- *The framework of goals, objectives, indicators, measures, and targets is very good. It provides a clear description and benchmark against which to measure progress.*

- *Sustainability concepts need to continue to be developed, as part of watershed plans.*

- *Clarify the scale over which the targets are to be met, as part of the preparation of user-friendly implementation policies and guides.*

Overall, workshop participants agreed that the Duffins and Carruthers technical process and plan has advanced the state-of-the-art in integrated watershed planning, but that similar to other jurisdictions, further work is needed to refine predictive tools, particularly in the area of aquatic resources, and to translate science into policy.

The outcome of the workshop will be used to identify further work needed to supplement the existing knowledge base for the Duffins and Carruthers Creek Watersheds and to guide TRCA as it designs its next integrated watershed management approach.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Key management issues in the Duffins and Carruthers Creek Watersheds are associated with urban growth, the potential development of a regional airport, the ongoing stewardship needs associated with existing agricultural and urban land use activities, and the protection of existing natural lands. Alternative land use scenarios were defined for further analysis, including existing, future, and future land use with enhanced natural heritage cover.

Technical studies were conducted to develop benchmarks of watershed condition in response to these alternative land use and management scenarios. Results were evaluated according to defined watershed management objectives, indicators, measures and targets.

An innovative integrated approach was followed when undertaking the technical studies, in that common units and scales of study were defined, opportunities for communication and information exchange among study teams were provided, and the resulting primary management directions were correlated. Based on the results of the technical studies and other management considerations, the Task Forces recommended that the most effective approach for amanging these watersheds would involve achievement of the target terrestrial natural heritage system together with the application of state of the art management practices.

The technical studies repeatedly demonstrated the multiple watershed management goals addressed by the protection and enhancement of terrestrial natural heritage cover. A GIS-based mapping technique was used to illustrate this finding. The map product was further interpreted to show areas targeted for active stewardship, regeneration and/or acquisition activities. This tool will assist in directing initial implementation efforts.

The technical studies have generated a valuable set of data, modelling tools, information, and criteria that will greatly assist in the future management of these watersheds.

This study advanced the state-of-the-art in integrated watershed planning studies, but much work remains to be done to further refine predictive modelling tools and develop relationships, particularly in the areas of aquatic resources, recreation, and human heritage links to changes in terrestrial natural heritage cover and subsequent impacts on the watershed water systems.

6.2 Study Limitations and Recommendations for Further Work

Further studies and applications of the available modelling tools within the Duffins and Carruthers watersheds

- verify the database on actual surface and ground water use

- develop long term water use projections for all water users
- re-run the Water Balance Model and Groundwater Flow Model, and interpret the results according to water quality and aquatic resource management objectives, once improved databases on actual water use and long term water use projections are available
- develop climate change scenarios and re-run the models to evaluate potential watershed management concerns

Initiatives to Guide Implementation of the Watershed Plan

- develop a road salt management strategy for ORM municipal roads
- undertake more intensive monitoring of the impacts of urban development in the Seaton community and the Regional Airport (if built), to track watershed changes and the effectiveness of watershed plan recommendations. Groundwater infiltration and stream baseflow and temperature should be a monitoring focus.

Refinement of Predictive Tools and Science of Integrated Watershed Planning

- develop improved predictive tools for evaluating the response of the aquatic community to changes in watershed hydrology, etc. (i.e. refine the relationships between aquatic community composition and changes in baseflow, flow, temperature, and water quality)
- develop improved predictive tools for assessing impacts of recreation on the terrestrial natural heritage system (i.e. for defining recreational carrying capacity)
- develop methods for valuing the benefits of watershed management

This body of technical work and the integrated watershed plan it supports provide a blueprint for the management of a sustainable watershed and its community. There is a further need for innovation in the application of sustainable living practices and in the planning for sustainable communities that will be necessary to fully realize the objectives of the plan and apply the knowledge developed thus far.

REFERENCES

Aquafor Beech Ltd. , 2001. *Compilation of Stormwater Average Event Mean Concentration Data*, Working Paper developed for the City of Toronto's Wet Weather Flow Management Master Plan, June 11, 2001.

Aquafor Beech Ltd. 2002. Duffins Creek Hydrology Update.

Barnett, P.J., Sharpe, D.R., Russell, H.A.J., Brennand, T.A., Kenny, F.M., and Pugin, A.. 1998. On the origins of the Oak Ridges Moraine. *Canadian Journal of Earth Science*. Vol. 5, pp. 1152-1167.

Beak Consultants Limited (Beak). 1993. *Pilot Watershed Study Soil and Water Environmental Enhancement Program (SWEEP), Report # 6: Evaluation of Conservation Systems, Water Quality*. Agriculture Canada, Guelph, Ontario.

Bowlby, J. M. and J. C. Roff. 1986. Trout biomass and habitat relationships in southern Ontario streams. *Transactions of the American Fisheries Society*. Vol. 115, pp. 503-514.

Boyce, J.I., 1997. *Facies Architecture and Stratigraphic Heterogeneity in Glacial Deposits and their relation to Hydrogeologic Function*. Ph.D. thesis, University of Toronto, Toronto, Ontario.

Buttle, JM. 1996. Identifying Hydrological Responses To Basin Restoration. An Example From Southern Ontario*. In Watershed Restoration Management, Proceedings From the AWRA Annual Symposium, July 14-17, 1996*, Syracuse, New York: 5-13.

Campbell, M.E. and V.W. MacLaren. 1995. An Overview of Municipal State of the Environment Reporting in Canada. *Canadian Journal of Public Health.* Vol. 86(6), pp. 413.

City of Toronto. 2001. *City of Toronto Natural Heritage Study.*

Clarifica Inc. 2002. *Water Budget in Urbanizing Watersheds: Duffins Creek Watershed*. TRCA. Ontario.

Credit Valley Conservation. 2001. Caledon Creek and Credit River Subwatershed Study (Subwatersheds 16 and 18) Phase 2 Report - Impact Assessment.

Conservation Ontario. 2001. The Importance of Watershed Management in Protecting Ontario's Drinking Water Supplies. Research Paper submitted to Part 2 of the Walkerton Inquiry.

Credit Valley Conservation, Grand River Conservation Authority, and the Toronto and Region Conservation Authority. 2002. Watershed Management in Ontario: Lessons Learned and Best Practices in Watershed Planning, Implementation, and Monitoring in the CVC, GRCA, and TRCA. Report prepared for the Province of Ontario.

Environment Canada and Health Canada, 2001. *Road Salts: Priority Substances List Assessment Report*. Prepared for the Canadian Environmental Protection Act, 1999 Priority Substances List. Internet Publication.

Environment Canada and U.S. Environmental Protection Agency. 1999. *State of the Great Lakes 1998.* Canada and United States.

Executive Resource Group. 2001. *Managing the Environment: A Review of Best Practices*. Prepared for the Secretary of Cabinet (Ontario).
Fahring, L. 1997. Relative effects of habitat loss and fragmentation on population extinction. *Journal of Wildlife Management*. Vol. 61, pp. 603-610.

Formann, R.T.T. 1995. *Land mosaics: The ecology of landscapes and regions*. Cambridge University Press.

Freemark, K. 1988. Landscape ecology of forest birds in the Northeast. In: Degraff, R.M., and W.M. Healy, eds. United States Department of Agriculture, Northeast Forest Experimental Station. *General Technical Report NE-140.*

Freeze, R. A. and J. A. Cherry. 1979. *Groundwater*. Prentice-Hall, New Jersey. 604pp.

Government of Ontario. 2002. Oak Ridges Moraine Conservation Plan.

Gerber Geosciences Inc., 2003. Duffins Creek Watershed Hydrogeology and Assessment of Land Use Change on the Groundwater Flow System.

Gerber, R.E., 1994. *Recharge Analysis for the Central Portion of the Oak Ridges Moraine.* M.Sc. Thesis, University of Toronto.

Gerber, R.E., 1999. *Hydrogeological Behaviour of the Northern Till Aquitard near Toronto, Ontario.* Ph.D. Thesis, University of Toronto.

Gerber, R.E., and KWF Howard, 1996. "Evidence for Recent Groundwater Flow through Late Wisconsinan Till near Toronto, Ontario". *Canadian Geotechnical Journal*, 33:538-555.

Gerber, R.E., and KWF Howard, 1997. "Groundwater Recharge to the Oak Ridges Moraine". In *Environmental Geology of Urban Areas*, edited by Nick Eyles, Geological Association of Canada, *Geotext* 3, pp 173-192.

Gerber, R.E., and KWF Howard, 2002. "Hydrogeology of the Oak Ridges Moraine Aquifer System: Implications For Protection and Management from the Duffins Creek Watershed. *Canadian Journal of Earth Sciences*, 39: 1333-1348

Gerber, R.E. and K. Howard, 2000. Recharge through a regional till aquitard: three-dimensional flow model water balance approach. *Groundwater*. Vol. 38(3), pp. 410-422.

Haefeli, C.J., 1972. *Regional Groundwater Flow Between Lake Simcoe and Lake Ontario*; Dept. of Energy, Mines and Resources, Inland Waters Branch, Technical Bulletin No. 23.

Heathcote, Isobel W. 1998. *Integrated Watershed Management Principles and Practice*. John Wiley & Sons Inc..

Hinton, M.J. 1996. Measuring stream discharge to infer the spatial distribution of groundwater discharge. *In Proceedings of the Watershed Management Symposium, Canada Centre for Inland Waters*, Burlington, Ontario, Canada. December 6-8, 1995, pp. 27-32.

Howard, KWF and P. Beck. 1986. "Hydrochemical Interpretation of Groundwater Flow Systems in Quarternary Sediments of Southern Ontario". *Canadian Journal of Earth Sciences*, 23: 938-947.

Interim Waste Authority (IWA), 1994a. *EA Document IV, Geology/Hydrogeology, Technical Appendix 1: Site T1 (P1) for Durham Region Landfill Site Search*. Prepared by M.M. Dillon Limited, February, 1994.

Interim Waste Authority (IWA), 1994b. *EA Document IV, Geology/Hydrogeology, Technical Appendix 2: Site EE4 for Durham Region Landfill Site Search*. Prepared by M.M. Dillon Limited, February, 1994.

Interim Waste Authority (IWA), 1994c. *EA Document IV, Geology/Hydrogeology, Technical Appendix 3: Site EE10 for Durham Region Landfill Site Search.* Prepared by M.M. Dillon Limited, February, 1994.

Interim Waste Authority (IWA), 1994d. *IWA Landfill Site Search, Metro/York Region, Step 6, Hydrogeological Report Site M6.* Prepared by Fenco MacLaren Inc., February, 1994.

Interim Waste Authority (IWA), 1994e. *Detailed Assessment of the Proposed Site EE11 for Durham Region Landfill Site Search, Technical Appendices Parts 1 and 3 of 4*. Prepared by M.M. Dillon Limited, October, 1994.

JDE Ventures, 1998. *1998 Survey of Farming Practices and Fertilizer use in the Stouffville and Reesor Creeks Watershed for AGNPS Model Appliction,* A final report to the Ontario Ministry of the Environment, Standards Development Branch and the Toronto and Region Conservation Authority, 15pp.

Karr, J. R. 1981. Assessment of biotic integrity using fish communities. *Fisheries.* Vol. 6(6), pp. 21-27.

Lake Simcoe Region Conservation Authority. 2002. *Town of Newmarket Natural Heritage Study, Draft.*

Leon, L.F., W.G. Booty, G.S. Bowen, D.C.L. Lam, 2002 (in print).

Leon, L.F., 1997, *AGNPS Interface for RAISON/Windows.* University of Waterloo, Department of Civil Engineering.

M.M. Dillon Limited, 1990. *Regional Municipality of Durham Contingency Landfill Site Assessment Technical Support Volume B, Technical Report, Hydrogeology.* Prepared for the Regional Municipality of Durham, September, 1990.

Macdonald, MG and AW Harbaugh. 1998. A Modular Three-Dimensional Finite-Difference Ground-Water Flow Model, Book 6, Modeling Techniques. *Techniques of Water-Resources Investigations of the United States Geological Survey.*

MacRae, C.R. and A.C. Rowney. 1992. The Role of Moderate Flow Events and Bank Structure in the Determination of Channel Response to Urbanization. In: *Resolving Conflicts and Uncertainty in Water Management. Proc. 45th Annual Conference*, Canadian Water Resources Association. Kingston, Ontario.

Marshall, Macklin, Monaghan Ltd., 2002. Duffins Creek Watershed Hydraulic Modelling and Flood Plain Mapping Project.

Martin, PJ and EO Frind. 1998. Modeling a complex muti-aquifer system: The Waterloo Moraine. *Ground Water*, 36(4): 679-690.

Metropolitan Toronto and Region Conservation Authority. 1990. *Archaeological Resource Management for the Metropolitan Toronto and Region Conservation Authority.*

Ministry of the Environment. 1994. Stormwater Management Practices Planning and Design Manual. Queen's Printer for Ontario.

Ministry of the Environment. 1999. Stormwater Management Planning and Design Manual. Draft Final Report.

Ministry of Municipal Affairs and Housing. 2002. Richmond Hill Agreement Protects Vital Corridor. Web site posting April 22, 2002; Updated November 26, 2002 (http://www.mah.gov.on.ca/userfiles/HTML/nts_1_7606_1.html). Viewed 12/30/02.

Ostry, R.C., 1979. *The Hydrogeology of the IFYGL Duffins Creek Study Area*: Water Resources Report 5c, Ministry of the Environment, Water Resources Branch, Toronto, Ontario.

Raleigh, R. F. 1982. *Habitat Suitability Information: Brook Trout*. U.S. Department of the Interior, Fish and Wildlife Service. FWS/OBS-82/10.24. 42pp.

Raleigh, R. F., T. Hickman, R. C. Soloman and P. C. Nelson. 1984. *Habitat Suitability Information: Rainbow Trout.* U.S. Fish and Wildlife Service. FWS/OBS-82/10.60. 64pp.

Raleigh, R. F., L. D. Zuckerman and P.C. Nelson. 1986. *Habitat Suitability Index Models and Instream Flow Suitability Curves: Brown Trout, Revised*. U.S. Fish and Wildlife service. Biol. Rep. 82(10.124). 65pp. [First printed as: FWS/OBS-82/10.71, September 1984.

Richardson, A.H. 1974. *Conservation By the People. The History of the Conservation Movement in Ontario to 1970*. University of Toronto Press, Toronto.

Sharpe, D.R., Barnett, P.J., Brennand, T.A., Finley, D., Gorrell, G., Russell, H.A.J. and Stacey, P.. 1997. Surficial geology of the Greater Toronto and Oak Ridges Moraine area, southern Ontario. Geological Survey of Canada, Ottawa. Open File 3062, Scale 1:200 000.

Sharpe, DR., MJ Hinton, HAJ Russell and AJ Desbarats. 2002. The Need For Basin Analysis in Regional Hydrogeologic Studies: Oak Ridges Moraine, Southern Ontario. *Geoscience Canada*, 20(1): 3-20.

Sibul, U., K.T. Wang, and D. Vallery, 1977. *Groundwater Resources of the Duffins Creek-Rouge River Drainage Basins:* Ontario Ministry of the Environment Water Resources Report 8.

Smart, PJ. 1994. *A Water Balance Numerical Groundwater Flow Model Analysis of the Oak Ridges Aquifer Complex, South-central Ontario*. University of Toronto, unpublished M.Sc. Thesis.

Snodgrass, W.J., B.W. Kilgour, M. Jones, J. Parish, and K. Reid. 1996. Can Environmental Impacts of Watershed Development be Measured (pp. 351-385). In: *Effects of Watershed Development and Management on Aquatic Ecosystems*. Proceedings of an Engineering Foundation Conference held in Snowbird, Utah, August 4-9, 1996. Edited by Larry A. Roesner. Copyright 1997 by the American Society of Civil Engineers.

Stantec, Consulting Ltd. And Aquafor Beech Ltd. 2003. Dry and Wet Weather Modelling of Water Quality Under Alternative Land Use Scenarios. In: *The Duffins and Carruthers Creek Watersheds - A Simple Spreadsheet Approach.*

Steedman, R. J. 1987. Comparitive Analysis of Stream Degradation and Rehabilitation in the Toronto Area. Ph.D. Thesis. University of Toronto. vii + 172pp.

Toronto and Region Conservation Authority. 1997. Turning the Corner - A Report Card on the Health of the Don Watershed.

Toronto and Region Conservation Authority. 1997. Legacy: A Strategy for a Healthy Humber.

Toronto and Region Conservation Authority. 2000. Regional Watershed Monitoring Network.

Toronto and Region Conservation Authority. 2000. The Humber Watershed Report Card.

Toronto and Region Conservation Authority. 2001. Bold Steps - The Don Watershed Report Card.

Toronto And Region Conservation Authority. 2002. Carruthers Creek State of the Watershed Report.

Toronto and Region Conservation Authority. 2002. Duffins Creek State of the Watershed Report.

Toronto and Region Conservation Authority. 2002. Greening Our Watersheds - Watershed Strategy and Report Card for the Etobicoke and Mimico Creek Watersheds.

Toronto and Region Conservation Authority. 2003. Agricultural Non-Point Source (AGNPS) Modelling of the Duffins and Carruthers Creek Watersheds. Toronto, Ontario.

Toronto and Region Conservation Authority. 2003. Duffins and Carruthers Creek Watersheds Fisheries and Management Plan.

Toronto and Region Conservation Authority. 2003. Duffins and Carruthers Creek Low Flow Study and Management Plan.

Toronto and Region Conservation Authority. 2003. Ratings Report for the 2003 Duffins and Carruthers Creek Watersheds Report Card.

Toronto and Region Conservation Authority. 2003 (Draft). Terrestrial Natural Heritage Program Methodology Report.

Toronto and Region Remedial Action Plan. 1994. Clean Water Clear Choices.

Upper Thames River Conservation Authority and Rideau Valley Conservation Authority. 2002. Watershed Reporting Guide. Draft Report of the Watershed Pilot Project.

Waterloo Hydrogeologic Software Inc. 1996. Visual MODFLOW, User's Manual. Version 2.60. Waterloo, Ontario, Canada.

Watershed Planning Implementation Project Management Committee (WPIPMC). 1997. An Evaluation of Watershed Management in Ontario. Final Report. Government of Ontario.

APPENDIX A

Summary Evaluation of Study Findings According to Watershed Management Objectives, Indicators, Measures, and Targets

Surface Water Quantity

OBJECTIVE	INDICATOR	MEASURE	TARGET	LAND USE/ MGMT. SCENARIO	DUFFINS CREEK WATERSHED STATE/CONDITION	CARRUTHERS CREEK WATERSHED STATE/CONDITION
Goal: to maintain the existing hydrologic function of the watershed						
1. Maintain the existing water balance within the watershed.	• Watershed hydrology (as measured by sub-catchment)	• Total annual infiltration rate (mm/yr) • Run-off volume (m^3/yr) • Seasonal and annual baseflow (m^3/yr) at indicator sites	• Maintain or reduce baseline run-off volume • Maintain or reduce baseline run-off volume • Maintain or enhance baseline seasonal and annual baseflows	Existing	The hydrologic response of the Duffins and Carruthers Creek watersheds reflect non-urbanized conditions, or watersheds that are predominantly under a combination of rural/agricultural land use and natural land cover, with a minor amount of urban development (7% urban land use in Duffins Creek and 13% in Carruthers Creek). In the Duffins Creek watershed, the water balance model output is as follows: 58% evapo-transpiration, 24% Groundwater Infiltration (GWI), and 17% run-off. A water balance model for Carruthers Creek is scheduled to be developed in 2003/04.	
				Future (OP)	Total annual run-off volume would increase by an estimated 3% and evapo-transpiration would decrease by 2% with uncontrolled development as a direct result of higher imperviousness and reduced vegetation cover. A 1% reduction in GWI is predicted to occur. Impacts associated with this change would be significant at the subwatershed level. Modelled reductions in baseflows would range from 0 to 26% when examined on a subwatershed basis.	Analysis to be completed following water balance model completion and hydrology model update in 2003/04. Similar responses would be expected as predicted in the Duffins watershed.
				Future (OP) + Enhanced Natural Heritage	This scenario would result in a smaller increase in run-off (2%) and a smaller decrease in evapo-transpiration (1%) than the Future (OP) scenario due to the increased vegetation cover. Due to limitations within the current state-of-the-art water budget tool, this scenario is predicted to result in lower GWI than the Future (OP) scenario.	Analysis to be completed following water balance model completion and hydrology model update in 2003/04. Given the relatively small increases in natural cover on the watershed scale and limitations of the model, it is not expected that significant responses could be modelled.

OBJECTIVE	INDICATOR	MEASURE	TARGET	LAND USE/ MGMT. SCENARIO	DUFFINS CREEK WATERSHED STATE/CONDITION	CARRUTHERS CREEK WATERSHED STATE/CONDITION
2. Maintain or enhance baseflows	• Baseflow	• Seasonal and annual baseflow (m^3/yr) at indicator sites	• Maintain or enhance baseline seasonal and annual baseflows	Existing	In general, baseflow in Duffins Creek remains continuous for the majority of the reaches in the watershed throughout the year. The Duffins Creek watershed baseflow assessment shows that the majority of the overall system baseflow is split between the East Branch (57 %), and the West Branch (38 %) of the creek, with the combined contributions of Urfe, Ganatsekiagon and Millers Creek subwatersheds contributing the remaining flow (5 %). Known surface water takings represent a maximum withdrawal of about 5% of annual baseflow for the overall watershed. Reesor Creek and West Duffins are most impacted with withdrawals of up to 17%.	In the Carruthers baseflow contributions are evenly distributed along its length. Baseflow losses were observed along the Lake Iroquois shoreline where porous sands and gravels become exposed. Surface water takings are occurring in this watershed to a greater extent than in the Duffins. Continuous stream flow data and additional baseflow monitoring data from indicator sites is needed to better characterize typical low flow conditions. A permanent stream flow gauge was installed in Carruthers Creek in 2002 to address this information deficiency. There are no active permits to take water. Permit applications under review have the potential to cause detrimental effects.
				Future (OP)	Modelled reductions in baseflows would range from 0 to 26% when examined on a subwatershed basis. Baseflow reductions by sub-watershed are modelled as; the Lower Duffins (26%), Ganatsekiagon (17%), Urfe (14%) and Millers Creeks (4%). Little change would be anticipated within the East (1%) or West branches (3%) which contribute the majority of the overall baseflow.	Analysis to be completed following water balance model completion 2003/04 and upon availability of improved records of water users and projected needs.

OBJECTIVE	INDICATOR	MEASURE	TARGET	LAND USE/ MGMT. SCENARIO	DUFFINS CREEK WATERSHED STATE/CONDITION	CARRUTHERS CREEK WATERSHED STATE/CONDITION
				Future (OP) + Enhanced Natural Heritage	Due to limitations in the current state-of-the-art water budget tool, this scenario is predicted to result in slightly lower Groundwater Infiltration than the Future (OP) scenario and this effect may in turn reduce baseflow. This is deemed to be more a reflection of the tool's limitations as opposed to a true reflection of how additional vegetative cover would affect GWI and baseflows.	Analysis to be completed following water balance model completion 2003/04 and upon availability of improved records of water users and projected needs.
3. Minimize or reduce risks to human life and property due to flooding	• Number of flood vulnerable areas (FVAs) and flood vulnerable roads (FVRs)	• Peak flow rate (unit flows) • Water level (floodlines) • Number of Flood Vulnerable Areas (FVA) and Flood Vulnerable Roads (FVR) • Ice jams (frequency and location)	• Maintain baseline peak flows (2-100 year and Regional control if required) • Maintain baseline water levels (floodlines) • Reduce or as a minimum maintain the baseline number of FVAs and FVRs (and the design storm frequency at which they flood) • Develop and maintain documentation of the number of sites and frequency of ice jams	Existing	Existing peak flow rates are described by the newly updated Duffins Hydrology Model (Aquifor Beech Ltd.,2002). Existing floodlines are based on future scenario peak flows from the 1991 Duffins Creek Hydrology by Aquafor Beech. The current FVAs and FVRs are based on these floodlines. The number of FVAs and FVRs will be updated based on the forthcoming floodplain mapping updates based on the 2002 peak flows (Marshall Macklin Monaghan, 2003).	An updated hydrology model is scheduled for completion for the Carruthers Creek watershed in 2003/04, which will be the basis for establishing baseline peak flow rates, flood lines, and FVA/FVRs. Existing floodlines are based on future scenario peak flows from the 1999 Carruthers Creek Hydrology Update by Totten Sims Herbieki. The current FVAs and FVRs are based on these floodlines.

OBJECTIVE	INDICATOR	MEASURE	TARGET	LAND USE/ MGMT. SCENARIO	DUFFINS CREEK WATERSHED STATE/CONDITION	CARRUTHERS CREEK WATERSHED STATE/CONDITION
				Future (OP)	Peak flow rates would increase in this scenario between 15% and 120% for the 100 year event, for subcatchments that have future urban development area. Floodlines will be updated based on the future scenario peak flows for the regional storm from the newly updated Duffins Hydrology Model (Aquafor Beech Ltd, 2002) in the forthcoming floodplain mapping updates in 2003. As regional storm peak flows have decreased from the 1991 Hydrology model, floodlines are expected to possibly decrease as well as the number of FVAs and FVRs.	Analysis to be completed following the hydrology model update in 2003. Updated floodplain mapping is scheduled for 2004, which would be the basis for new floodlines, FVAs and FVRs.
				Future (OP) + Enhanced Natural Heritage	Peak flow rates would increase in this scenario between 10% and 110% for the 100 year event, for subcatchments that have future urban development area. This scenario also results in a number of subcatchments having peak flow decreases that are expected to be approximately 0% to 25% less than existing flows for the 100-year event. If peaks flows for the regional storm from this scenario were used in the floodplain mapping updates, further possible decrease in floodlines, FVAs and FVRs could be expected.	Analysis to be completed following the hydrology model update in 2003.

OBJECTIVE	INDICATOR	MEASURE	TARGET	LAND USE/ MGMT. SCENARIO	DUFFINS CREEK WATERSHED STATE/CONDITION	CARRUTHERS CREEK WATERSHED STATE/CONDITION
4. Maintain or restore natural stream channel stability	• In-stream erosion	• Erosion index • Percent of developed area that has adequate erosion controls in place (according to 2003 criteria) • Rate of erosion at indicator sites	• Maintain baseline erosion index • 100% of developed area with adequate erosion controls in place • Maintain or reduce the baseline rate of erosion	Existing	Studies to determine the baseline erosion index, establish erosion control criteria for SWM facilities, and to determine the baseline rate of erosion at indicator sites are scheduled for completion in 2003.	Baseline erosion index and erosion control criteria have been established for the A8 Secondary Plan area, which represents most of the future urban growth in the Town of Ajax.
				Future (OP)	Erosion rates will increase with future development if no stormwater controls are put in place.	Erosion rates will increase with future development if no stormwater controls are put in place.
				Future (OP) + Enhanced Natural Heritage	Erosion rates will increase without controls but not as drastically as in the OP scenario.	Erosion rates will increase without controls but not as drastically as in the OP scenario.

Groundwater Quality and Quantity

OBJECTIVE	INDICATOR	MEASURE	TARGET	LAND USE/ MGMT. SCENARIO	DUFFINS CREEK WATERSHED STATE/CONDITION	CARRUTHERS CREEK WATERSHED STATE/CONDITION
GOAL: to protect groundwater quality and quantity						
5. Maintain or enhance groundwater levels and baseflow for watershed functions	• Water table level • Aquifer water level elevations • Baseflow	• Water table levels at indicator sites • Piezometric surfaces at indicator sites • Seasonal and annual baseflow	• Establish and maintain baseline water table levels • Maintain baseline piezometric surfaces • Maintain or enhance baseline seasonal and annual baseflows	Existing	Groundwater levels are monitored regularly at six nested piezometer locations within the Duffins Creek watershed, providing a database of natural groundwater fluctuations over various temporal scales. Existing data shows no long term decline in water levels. Baseflow surveys have been conducted in 1995 (Geological Survey of Canada) and 2001 (TRCA). Groundwater discharge contributing to baseflow occurs mainly along the south flank of the Oak Ridges Moraine as well as along and south of the Lake Iroquois shoreline.	No groundwater monitoring stations are located within the Carruthers Creek watershed. Trends observed in data obtained from the six locations on the Duffins Creek watershed will be considered to be generally reflective of groundwater conditions within the Carruthers Creek watershed.
				Future (OP)	The estimated reductions in Groundwater Infiltration (GWI) associated with this land use scenario are predicted to reduce aquifer water levels and baseflow. It is predicted that water table elevations will be reduced by up to 8 metres in subwatersheds subject to urbanization. Areas most sensitive to reductions in GWI include the south slope till plain. The predicted decline in water table levels over this area is greater than for areas of sand and gravel because of the lower effective porosity and permeability of the till, silt and clay deposits.	A water balance model is not yet completed for Carruthers Creek watershed, which prevents predictions to be made with regard to Groundwater Infiltration (GWI) associated with future land use scenarios. Continuous stream flow data being collected in 2002/03 will be used to develop and calibrate the Carruthers Creek water balance model. In general, it is predicted that increased urban land use will result in reduced water table elevations and annual baseflow volumes.

OBJECTIVE	INDICATOR	MEASURE	TARGET	LAND USE/ MGMT. SCENARIO	DUFFINS CREEK WATERSHED STATE/CONDITION	CARRUTHERS CREEK WATERSHED STATE/CONDITION
				Future (OP) + Enhanced Natural Heritage	Using the water balance model outputs, the estimated changes to Groundwater Infiltration (GWI) from increasing vegetation cover is negligible, therefore this scenario was not modelled using the numerical groundwater flow model. Predicting the impacts of reforestation on groundwater recharge is uncertain at this time, as examples from scientific literature predict both increases and decreases in recharge under different site conditions.	Predicting the impacts of reforestation on groundwater recharge is uncertain at this time, as examples from scientific literature predict both increases and decreases in recharge under different site conditions.
6. Protect groundwater quality to ensure provision of safe water supplies and ecological functions	• Groundwater chemistry	• Chlorides • Nutrients • Total Organic Carbon (TOC) • Phenols • Conductivity • Metals • pH • Bacteria • Parameters in MOE Ontario Drinking Water Standards	• MOE Ontario Drinking Water Standards	Existing	Groundwater quality regionally within these basins appears to be good, with local quality concerns attributed to occurrences of nitrates and bacteria associated with septic system effluent entering private wells and high chloride concentrations above Ontario Drinking Water Standard criteria (250 mg/L) occurring in private wells situated near salted roadways (Gerber Geosciences Inc., 2003).	
				Future (OP)	No predictions were made with regard to changes to groundwater quality associated with this land use scenario.	
				Future (OP) + Enhanced Natural Heritage	No predictions were made with regard to changes to groundwater quality associated with this land use scenario.	
7. Ensure sustainable rates of groundwater use	• Water table levels • Aquifer water levels • Baseflow • Groundwater withdrawals	• Water table levels at indicator sites • Piezometric surfaces at indicator sites • Seasonal and annual baseflows • Maximum annual volume of groundwater withdrawal permitted by active MOE Permits To Take Water	• Establish and maintain baseline water table levels • Maintain baseline piezometric surfaces • Maintain or enhance baseline seasonal and annual baseflows • Sustainable rate of groundwater use to be determined pending further study	Existing	The majority of the water wells within the Duffins and Carruthers Creek watersheds are for private potable supplies, which typically involve less than 175 L/person/day and discharge to the groundwater system via tile beds. However, larger scale users, including golf courses (irrigation), municipal water supplies, and commercial enterprises do have PTTWs on file with the MOE (Gerber, 2002). The largest active PTTW in these two watersheds is the municipal water supply for the Town of Whitchurch-Stouffville (4,000 m^3/day), which draws water from the upper and middle aquifers. This volume of groundwater represents approximately 29% of the total streamflow in Stouffville Creek and 2% of the total streamflow in Duffins Creek (Gerber, 2002).	

OBJECTIVE	INDICATOR	MEASURE	TARGET	LAND USE/ MGMT. SCENARIO	DUFFINS CREEK WATERSHED STATE/CONDITION	CARRUTHERS CREEK WATERSHED STATE/CONDITION
				Future (OP)	Comprehensive assessments of water use in these watersheds are required to properly establish existing conditions and to predict the response of the natural system to future land and water use scenarios. The Region of Durham is currently conducting a water use assessment for the entire region, which is scheduled for completion in 2003.	
				Future (OP) + Enhanced Natural Heritage	Comprehensive assessments of water use in these watersheds are required to properly establish existing conditions and to predict the response of the natural system to future land and water use scenarios. The Region of Durham is currently conducting a water use assessment for the entire region, which is scheduled for completion in 2003. Furthermore, improvements in the state-of-the-art water balance modelling tool will enhance the ability to estimate changes in groundwater infiltration and subsequently groundwter levels.	

Surface Water Quality

OBJECTIVE	INDICATOR	MEASURE	TARGET	LAND USE/ MGMT SCENARIO	DUFFINS CREEK WATERSHED STATE/CONDITION	CARRUTHERS CREEK WATERSHED STATE/CONDITION
Goal: to protect and improve surface water quality						
8. Manage the quality and quantity of runoff from rural and urban areas to maintain in-stream uses.	• In-stream water chemistry	• Concentrations of nutrients (phosphorus and nitrogen), suspended solids, bacteria, chloride	• Concentration targets (PWQO or other guideline): • Total P <0.03 mg/L • NO_2 < 0.06 mg/L • TSS < 30 mg/L • Bacteria < 100 counts/100 mL • Chlorides < 250 mg/L • Unionized NH_4 < 0.02mg/L	Existing	Elevated P, TSS and bacteria levels, particularly during wet weather periods, attributed to various urban and rural non-point sources. Wet weather load is 13 times higher than the dry weather load. 62% of existing urban areas in the watershed have no stormwater treatment measures in place.	Elevated P, TSS and bacteria levels, particularly during wet weather periods, attributed to various urban and rural non-point sources. Wet weather load is 20 times higher than dry weather load. 29% of existing urban areas in the watershed have no stormwater treatment measures in place.
		• Annual loads of suspended sediment and phosphorus	• Maintain annual loadings at or below the targeted "background annual load"	Future (OP)	TSS wet weather loads increase by 25% TP wet weather loads increase by 23% Cl wet weather loads increase by 45% Although pollutant concentrations don't very much, loads increase due to increased volume of runoff.	TSS wet weather loads increase by 23% TP wet weather loads increase by 22% Cl wet weather loads increase by 46% Although pollutant concentrations don't very much, loads increase due to increased volume of runoff.
	• Stormwater management (SWM)	• Percent of developed area within watershed having adequate stormwater controls in place (both quantity and quality control)	• Stormwater management - 100% of area having Level 1 water quality control (80% TSS removal) for all new and retrofitted development	Future (OP) + Enhanced Natural Heritage	TSS wet weather loads increase by 15% TP wet weather loads increase by 11% Cl wet weather loads increase by 24% Increased area of natural cover helps moderate the adverse effects of urban development on water quality.	TSS wet weather loads increase by 21% TP wet weather loads increase by 18% Cl wet weather loads increase by 40% Increased area of natural cover helps moderate the adverse effects of urban development on water quality.
9. Minimize in-stream sediment associated with construction activity	• Compliance with Municipal Erosion and Sediment Control Bylaws	• Percent of construction permits found to be in compliance with Municipal Erosion and Sediment Control By-laws • Percent of sediment ponds checked annually • Percent of sediment ponds maintained when required	• 100 % compliance with approved permits under Municipal Erosion and Sediment Control By-laws • 100% of sediment ponds checked annually • 100% of sediment ponds maintained when required	Existing	Currently, Erosion & Sediment Control By-Laws have been implemented in the Municipality of Ajax and are lacking in the remaining municipalities within the watershed.	Currently, Erosion & Sediment Control By-Laws have been implemented in the Municipality of Ajax and are lacking in the remaining municipalities within the watershed.

OBJECTIVE	INDICATOR	MEASURE	TARGET	LAND USE/ MGMT SCENARIO	DUFFINS CREEK WATERSHED STATE/CONDITION	CARRUTHERS CREEK WATERSHED STATE/CONDITION
				Future (OP)	Estimates cannot be made until Bylaws are in place and data in compliance rates are available.	Estimates cannot be made until Bylaws are in place and data in compliance rates are available.
				Future (OP) + Enhanced Natural Heritage	Estimates cannot be made until Bylaws are in place and data in compliance rates are available.	Estimates cannot be made until Bylaws are in place and data in compliance rates are available.
I0. Reduce water quality contamination associated with wastewater discharges	• In-stream water chemistry • Effluent quality • Sewage treatment plant bypasses	• Phosphorus levels in stream due to sewage treatment plant • Sewage treatment plant effluent quality • Number of sewage treatment plant bypasses	• In-stream phosphorus concentration due to sewage treatment plant should meet PWQO (0.03 mg/L) for all flow levels upon leaving sub-catchment (i.e. at 8th Concession and Reesor Creek) • Sewage treatment plant effluent quality meets Certificate of Approval • Zero sewage treatment plant bypasses	Existing	Phosphorus levels attributed to plant effluent exceed the Provincial Water Quality Objectives in the Reesor Creek tributary and 8th Concession about 25% of the monthly average flows and in the West Duffins Creek at Green River during extreme low flow conditions. .	Not applicable*
				Future (OP)	The Stouffville STP is scheduled to be decommissioned in 2003. A decrease in Phosphorus concentration is expected.	Not Applicable*
				Future (OP) + Enhanced Natural Heritage	The Stouffville STP is scheduled to be decommissioned in 2003. A decrease in Phosphorus concentration is expected.	Not Applicable*

* There are no point source discharges of Sewage Treatment Plant effluent in Carruthers Creek.

Aquatic Habitat & Species

OBJECTIVE	INDICATOR	MEASURE	TARGET	LAND USE/ MGMT SCENARIO	DUFFINS CREEK WATERSHED STATE/CONDITION	CARRUTHERS CREEK WATERSHED STATE/CONDITION
Goal: to protect aquatic habitat and species						
11. Protect and restore native aquatic species and communities.	• Fish and invertebrate communities • Instream habitat • Water chemistry • Fish passage to critical habitat (breeding, rearing, foraging grounds)	• Invertebrate indices • Index of Biotic Integrity (IBI) • Indicator species and abundance • Percent instream woody cover • Per cent riffle substrate • Ratio of baseflow to total annual flow • Water temperature • Total Suspended Solids (TSS) • Phosphorus • Chlorides • Presence of instream barriers	• To be determined pending further study • Minimum IBI of "Good" • Maintain/achieve historical distribution of targetted indicator species (as specified for reach in Fish Mgmt. Plan) • To be determined pending further study • To be determined pending further study • As specified for reaches in FMP • As specified for reaches in FMP(*) • Only strategic barriers for fisheries management to remain	Existing	Median IBI score of "Fair" stream quality indicates that there are some issues relating to the health of aquatic habitat, however, there were few stations with "good" stream quality. In terms of the presence of indicator species, there is a good diversity of cold water species of fish that have been observed. Three indicator species not found in 2000 were redside dace, Atlantic salmon and smallmouth bass. Reintroduction of Atlantic salmon is a long term goal. Water chemistry conditions are generally good throughout the watershed. Poorer water chemistry conditions are found in more developed areas of the watershed. Three existing barriers (west of Church St., north of Whitevale Rd. On the West Duffins Creek, north of Highway 7 on East Duffins Creek) are to remain as fisheries management barriers. Numerous barriers in headwater areas have thermal and fish passage impacts. Ratio of baseflow to total annual flow considered to be "good" on average for the lower Duffins creek, and generally high in many reaches.	Median IBI score of "fair" stream water quality indicates that there are some issues relating to the health of aquatic habitat. Indicator species not found in 2000 were brook trout and smallmouth bass. Additional surveys should be done to assess the presence of smallmouth bass. Reintroduction of brook trout is a long term goal. Water chemistry conditions are generally good throughout the watershed. Poorer water chemistry conditions are found in more developed areas of the watershed. Barriers concentrated north of Taunton Road likely have thermal and fish passage impacts. .

OBJECTIVE	INDICATOR	MEASURE	TARGET	LAND USE/ MGMT SCENARIO	DUFFINS CREEK WATERSHED STATE/CONDITION	CARRUTHERS CREEK WATERSHED STATE/CONDITION
				Future (OP)	Ratio of baseflow to total annual flow is predicted to decrease with the most significant changes occuring in sub basins where urbanization will occur. The resultant increase in water temperature and loss of habitat may cause a shift to warm water tolerant fish communities in certain basins. Duration and frequency of elevated TSS and Chloride concentrations could be of concern, especially downstream of urbanizing areas. Typically as areas are developed aquatic health decreases ut these changes were not modelled for the other measures.	Duration and frequency of elevated TSS and Chloride concentrations could be of concern, especially downstream of urbanizing areas. Typically as areas are developed aquatic health decreases but these changes were not modelled for the other measures.
				Future (OP) + Enhanced Natural Heritage	Ratio of baseflow to total annual flow is predicted to increase sub basins with enhanced natural cover. As only limited to no enhanced cover was assumed in the sub basins identified for urban development and due to the localized groundwater system in these areas, the scenario is not expected to moderate the decreases in the ratio under the future scenario. Typically as areas are developed aquatic health decreases but these changes were not modelled for the other measures. Achievement of Natural Heritage goals will help ameliorate impacts from development.	Typically as areas are developed aquatic health decreases, but these changes were not modelled for the other measures. Achievement of Natural Heritage goals will help ameliorate impacts from development.

OBJECTIVE	INDICATOR	MEASURE	TARGET	LAND USE/ MGMT SCENARIO	DUFFINS CREEK WATERSHED STATE/CONDITION	CARRUTHERS CREEK WATERSHED STATE/CONDITION
12. Protect and restore the riparian zone and associated functions.	• Riparian zone vegetation	• Percent of total stream bank length with riparian vegetation cover • Percent of total stream bank length with woody riparian vegetation cover	• 100% coverage with riparian vegetation • Minimum 75% coverage with woody vegetation	Existing	76% of total stream bank length with riparian vegetation (all categories except Bare). 51% of total stream length with woody riparian vegetation cover (Forest and Successional categories only). Achievement rating of "Fair".	75% of total stream bank length with riparian vegetation (all categories except Bare). 42% of total stream length with woody riparian vegetation cover (Forest and Successional categories only). Achievement rating of "Poor".
				Future (OP)	Additional development will likely mean loss of riparian vegetation.	Additional development will likely mean loss of riparian vegetation.
				Future (OP) + Enhanced Natural Heritage	Loss of riparian vegetation still occurs in urbanized areas. Gains in riparian cover in upstream areas where Natural Heritage System is increased.	Loss of riparian vegetation still occurs in urbanized areas. Gains in riparian cover in upstream areas where Natural Heritage System is increased.
13. Maintain or restore the natural variability of annual and seasonal stream flow	• Stream hydrograph (annual and seasonal variation in hydrological regimes).	• Flow events (timing, duration, frequency, and rate of change)	• To be determined with consideration for maintaining or restoring historical variability of the hydrograph, and consideration of the timing of flows with respect to sensitive life cycle requirements of aquatic communities	Existing	Further study required to predict the timing, duration, frequency and rate of change of flow events.	Further study required to predict the timing, duration, frequency and rate of change of flow events.
		• Ratio of baseflow to total annual flow		Future (OP)	Modeling suggests impacts to the ratio of baseflow to total annual flow in developing sub-basins.	N/A
		• Ratio of seasonal baseflow to total seasonal flow		Future (OP) + Enhanced Natural Heritage	Modeling suggests impacts to the ratio of baseflow to total annual flow in developing sub-basins and some improvements in areas with increased natural cover.	Further study required

(*) Reach-specific targets will be specified in the Fish Management Plans, based on literature-supported physical and chemical requirements associated with each indicator species/community.

Terrestrial Habitat and Species

OBJECTIVE	INDICATOR	MEASURE	TARGET	LAND USE/ MGMT. SCENARIO	DUFFINS CREEK WATERSHED STATE/CONDITION	CARRUTHERS CREEK WATERSHED STATE/CONDITION
Goal: to protect and enhance terrestrial habitat and species						
14. Increase the percent natural cover to a quantity which provides targeted biodiversity and supports recreational uses	• Quantity • Distribution	• Percent natural cover • Distribution of the natural cover in relation to total watershed area (distance- to-centroid)	• ≥ 49% in Duffins Creek and, ≥30% in Carruthers Creek • ≤2351 m for Duffins Creek ≤1750 m in Carruthers Creek	Existing	37% natural land cover 992 m distance to centroid 2.23 average patch size score 1.621 average patch shape score Existing conditions provide good habitat potential, but improvements are needed to achieve biodiversity targets.	28% natural land cover 784 m distance to centroid 2.1 average patch size score 2.02 average patch size shape Existing conditions provide only fair habitat potential.
	• Size	• Average patch size scores	• ≥ 3.87 in Duffins Creek and, ≥ 2.89 in Carruthers Creek	Future (OP)	Not modelled	Not modelled
	• Shape	• Average patch shape scores	• ≥2.79 in Duffins Creek and ≥1.89 in Carruthers Creek	Future (OP) + Enhanced Natural Heritage	48% natural land cover, adjusted to 49% on revised map base. All other results are as per terrestrial system targets. Represents an overall improvement to existing conditions.	27% natural land cover, adjusted to 30% on revised map base. All other results are as per terrestrial system targets. Represents an overall improvement over existing conditions, but as the targeted system was established with implementation constraints in mind, it will not achieve biodiversity targets as fully as opportunities in Duffins Creek watershed will allow.
15. Protect the natural system quality and function from the influence of surrounding land uses	• Matrix influence	• Compatibility of surrounding land uses within 2 km of the edge natural cover patch	• Targeted ratio of urban, natural and rural/agricultural land cover surrounding each cover patch, as defined by the Regional Terrestrial Natural Heritage model matrix influence scores (4 in the Duffins Creek Watershed; 3 in the Carruthers Creek Watershed)	Existing	The average matrix influence score is 2.68.	The average matrix influence score is 2.67.
				Future (OP)	Not modelled	Not modelled
				Future (OP) + Enhanced Natural Heritage	The average matrix influence score is 4.16, which is an improvement over existing conditions. This is due to the increased proportion of natural area relative to urban or rural land uses, and suggests an increased potential for habitat to support sensitive species.	The average matrix influence score is 3.11, which is an improvement over existing conditions. This is due to the increased proportion of natural area relative to urban or rural land uses, and suggests an increased potential for habitat to support sensitive species.

OBJECTIVE	INDICATOR	MEASURE	TARGET	LAND USE/ MGMT. SCENARIO	DUFFINS CREEK WATERSHED STATE/CONDITION	CARRUTHERS CREEK WATERSHED STATE/CONDITION
16. Protect and restore all native vegetation communities and the flora and fauna within them.	• Vegetation type diversity • Species diversity	• Number of vegetation types represented • Number of species represented	• To be determined pending further technical analysis • To be determined pending further technical analysis	Existing	Further study required	Further study required
				Future (OP)	Further study required	Further study required
				Future (OP) + Enhanced Natural Heritage	Further study required	Further study required

Public Use - Recreation

<table>
<tr><th>OBJECTIVE</th><th>INDICATOR</th><th>MEASURE</th><th>TARGET</th><th>LAND USE/ MGMT. SCENARIO</th><th>DUFFINS CREEK WATERSHED STATE/CONDITION</th><th>CARRUTHERS CREEK WATERSHED STATE/CONDITION</th></tr>
<tr><td colspan="7">Goal: To provide appropriate and sustainable public use which promotes environmental awareness and enhancement</td></tr>
<tr><td rowspan="3">17. Create continuous watershed trails in the greenspace system linking Lake Ontario and Oak Ridges Moraine</td><td rowspan="3">• Inter-regional trail network</td><td rowspan="3">• Percent completion of the inter-regional trail network</td><td rowspan="3">• 100% completion</td><td>Existing</td><td>40 km of trails completed, with plans to complete a total of 120 km, which represents a total achievement of 33% of the target.
The demand and use of public trails has increased steadily. With a limited formalized and maintained existing trail network the natural system is being heavily impacted by the random establishment of all types of use trails. Trail widths, side trail use and spread of invasive plants is increasing.</td><td>3 km of trails completed, with plans to complete a total of 33 km, which represents a total achievement of 9% of the target.
The demand and use of public trails has increased steadily. With a limited formalized and maintained existing trail network the natural system is being heavily impacted by the random establishment of all types of use trails. Trail widths, side trail use and spread of invasive plants is increasing.</td></tr>
<tr><td>Future (OP)</td><td colspan="2">If development moves forward without an integrated trail development and maintenance plan, part of the integrity of the natural system will be strongly compromised. The demand for watershed trails will increase. There will be an increase of informal trail blazing, use and spread of non-invasive plants within sensitive watershed areas.
Active membership of trail associations should increase along with casual volunteers for trail maintenance and general clean-up.
Over time municipalities may have increased monetary resources to construct and maintain watershed trails, as a result of the increased tax base associated with urban development.</td></tr>
<tr><td>Future (OP) + Enhanced Natural Heritage</td><td colspan="2">The public will have an enhanced natural experience and a greater chance to make connections with various user groups and communities.
Informal trail blazing, habitat impact and boundary issues will most likely increase, without programs dedicated to greenspace and trail management. Municipalities may have increased monetary resources to support such programs, as a result of the increased tax base associated with urban development.</td></tr>
</table>

OBJECTIVE	INDICATOR	MEASURE	TARGET	LAND USE/ MGMT. SCENARIO	DUFFINS CREEK WATERSHED STATE/CONDITION	CARRUTHERS CREEK WATERSHED STATE/CONDITION
18. Maintain the greenspace system for planned sustainable uses and public enjoyment	• Sustainable public use and enjoyment • Management plans	• Participation in planned uses as defined in the Management Plan • Number of Management Plans completed for areas identified	• Increase participation in planned uses and decrease participation in unplanned uses • 100% completion	Existing	To be determined pending further technical analysis. There is currently a fair variety of outdoor recreation destinations. A great amount of potential exists to improve the number of sites offering outdoor recreation opportunities, considering the extensive amount of land in public ownership inthis watershed.	To be determined pending further technical analysis. There is not currently much variety in the outdoor recreation destinations, indicating that there is a considerable need to improve the number and variety of facilities and destiantions in the watershed.
				Future (OP)	The demand and use of public greenspace for a variety of uses will increase and unplanned uses will increase, creating a need for the expansion of publically owned greenspace lands and for the preperation and implementation of management for public lands.	
				Future (OP) + Enhanced Natural Heritage	The demand and use of public greenspace for a variety of uses will increase and unplanned uses will increase, creating a need for preperation and implementation of management for public lands.	
19. Improve greenspace accessibility while ensuring compatibility between social benefits and ecological health	• Accessible greenspace	• Number of access points to publically owned greenspace as identified in the management plan	• 100% completion of the development of all planned access points	Existing	50% of the total watershed is under ownership of the TRCA, Federal and Provincial governments and regional and local municipalities. The large amount of publicly owned land in the watersheds is very positive and, coupled with private landowner cooperation, provide very good opportunities for achieving an accessible and integrated greenspace system.	Only 25 hectares of public greenspace exists, representing less than 1% of the total watershed area.
				Future (OP)	If urban development proceeds without integrated planning for greenspace and recreation, the available public use opportunities will fail to meet the demands of the increased population base. Furthermore, over use of existing greenspace areas will negatively impact the environment, through over use of existing trails, creation of informal trails, and other impacts, and the quality of the user's experience will deteriorate due to crowding ad user conflicts.	
				Future (OP) + Enhanced Natural Heritage	There will be greater opportunity for the creation of integrated, accessible and extensive greenspace system under this scenario. However, without planning for recreational use opportunities, the potential may fail to be realized and negative impacts from informal, unplanned use may result.	

Human Heritage

OBJECTIVE	INDICATOR	MEASURE	TARGET	LAND USE/ MGMT. SCENARIO	DUFFINS CREEK WATERSHED STATE/CONDITION	CARRUTHERS CREEK WATERSHED STATE/CONDITION
Goal: To preserve and interpret our evolving human heritage resources						
20. Identify and document human heritage resources for protection	• Number of human heritage resources	• Number of registered archaeological sites • Number of designated structures (i.e. built heritage) • Number of listed structures (not yet designated)	• Maintain or increase the number of registered archaeological sites • Maintain or increase the number of designated structures	Existing	Predictive model suggests that many more archaeological sites exist than those that have been identified. Similarly, relatively few archaeological heritage sites have been identified and designated.	
				Future (OP)	As urban development proceeds under this scenario, there will be opportunities through the normal development process to identify archaeological sites and arrange for their protection. There will likely be a reduction in the number of heritage sites, unless the municipal policies and tools for their protection are strengthened.	
				Future (OP) + Enhanced Natural Heritage	Under this scenario, there will be an increase in the number of archaeological sites identified and protected *in situ* (within natural heritage restoration areas). There may be a reduction in the number of built heritage sites identified, as in the OP scenario, but an increase in the level of protection afforded to existing listed sites, where they are located in areas identified for the targeted natural heritage system.	
21. Increase awareness and appreciation of the inherent value of human heritage resources	• Awareness and appreciation	• Percent of population which places value on Human Heritage	• Net increase of awareness and appreciation of Human Heritage	Existing	N/A - need to conduct survey to define baseline.	
				Future (OP)	N/A	
				Future (OP) + Enhanced Natural Heritage	N/A	
22. Apply a standardized approach to protecting human heritage resources at all levels of government *	• Standardized approach	• Number of agencies who agree to applying a standardized approach	• 100% agreement	Existing	No standard beyond that provided in the Heritage Act and individual LACACs	
				Future (OP)	Awareness of the need for a standardized approach may or may not become evident as urban development proceeds.	
				Future (OP) + Enhanced Natural Heritage	Awareness of the need for a standardized approach may or may not become evident as urban development proceeds.	

* (NOTE: currently a MTCR* archaeological standardized approach exists, but not for built heritage sites) Ministry of Tourism, Culture and Recreation

Sustainable Communities

OBJECTIVE	INDICATOR	MEASURE	TARGET	LAND USE/ MGMT. SCENARIO	DUFFINS CREEK WATERSHED STATE/CONDITION	CARRUTHERS CREEK WATERSHED STATE/CONDITION
Goal: To achieve a behavioural shift in lifestyles, community design and resource use in keeping with environmental objectives for the watersheds						
23. Increase awareness of watershed issues and use of available watershed knowledge in decision making to foster sustainability and sustainable living practices	• Awareness • Outdoor Environmental Education	• percent of surveyed population having awareness of watershed issues • Number of students participating in outdoor education programs	• Increase the level of awareness of watershed issues • Increase the number of students participating in outdoor education programs	Existing Future (OP) Future (OP) + Enhanced Natural Heritage	Further studies are required to define baseline conditions and to understand the factors that contribute to change, such that more accurate predictions can be made about the impacts of future land use management strategies.	
24. Promote lifestyles that are ecologically sustainable	• Water efficiency • Materials and resources • Energy efficiency • Renewable energy • urban forests • Naturalization on private lands • Stewardship initiatives	• Amount of water used per capita • Degree of waste generation/diversion • Non-renewable energy consumption • Number of homes and industries using green power • Hectares of urban canopy • Hectares of unaturalized lawns and gardens • Participation in stewardship initiatives	• Reduce the amount of water used per capita • Reduce degree of waste generation and increase diversion • Decrease non-renewable energy consumption • Increase proportional use for renewable green vs. non-renewable energy • Increase urban canopy • Increase hectares of naturalized lawns and gardens • increase participation in stewardship activities	Existing Future (OP) Future (OP) + Enhanced Natural Heritage	Further studies are required to define baseline conditions and to understand the factors that contribute to change, such that more accurate predictions can be made about the impacts of future land use management strategies.	

OBJECTIVE	INDICATOR	MEASURE	TARGET	LAND USE/ MGMT. SCENARIO	DUFFINS CREEK WATERSHED STATE/CONDITION	CARRUTHERS CREEK WATERSHED STATE/CONDITION
25. Use sustainable urban design approaches to guide urban growth and development	• Sustainable communities • Sprawl	• Application of sustainable community principles • Public transit opportunities • Neighborhood mixture of jobs, shops and housing • Density	• Increased % of land developed or redeveloped using sustainable community principles • Increase public transit opportunities • Increase percentage of neighborhoods offering a mixture of jobs, shops and housing	Existing Future (OP) Future (OP) + Enhanced Natural Heritage	Further studies are required to define baseline conditions and to understand the factors that contribute to change, such that more accurate predictions can be made about the impacts of future land use management strategies.	

APPENDIX B

Municipal Land Use Maps and Their Use in Scenario Development

Chapter 3.1 (Land Use and Management Scenarios) of this Technical Summary Report describes three land use scenarios that were developed and analysed within each of the technical studies, as a means of benchmarking the watershed response to existing and future land use states. For the purposes of analysis, land *use* was interpreted as its associated land *cover* type. Various data sources were used in the development of these scenarios, as described in the following sections.

Existing Land Use [Cover] Scenario

Existing land cover mapping was assembled from the 1999 Digital Ortho-photography interpretation. Natural heritage cover was interpreted from the 1999 Ortho-photography using the TRCA's terrestrial natural heritage methodology (TRCA, 2003 Draft).

Future Land Use [Cover] Scenario

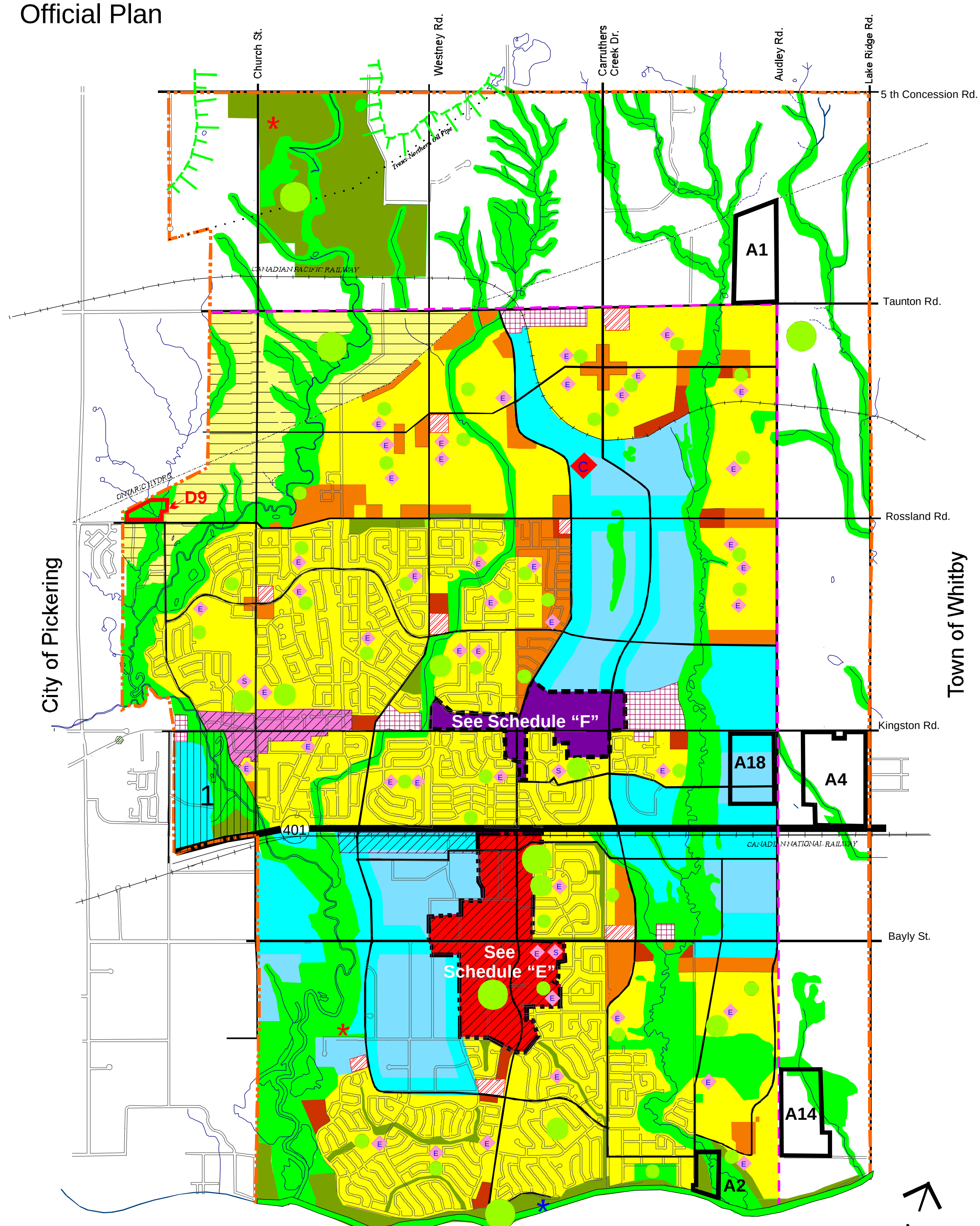
Municipal Official Plan information from the City of Pickering, Town of Ajax, and Community of Stouffville, as shown in Figures B-1, B-2, and B-3, was used to modify the "Existing Land Cover" map, to illustrate where changes would occur with the full implementation of the approved, municipal plans. Municipal plans designate areas for specific land uses, which had to be interpreted in terms of a land cover value. Each municipal plan is somewhat unique in that it uses slightly different land use classifications and codes. Therefore, some interpretation was necessary, based on the TRCA's understanding of the associated municipal policies, as to what the resulting land cover might be.

Land cover on the Oak Ridges Moraine (ORM) was to remain the same as under the "Existing" scenario map, assuming implementation of the ORM Act. TRCA Fill Regulation Mapping was also used, by assuming that Fill regulated areas would remain as natural areas. Given little information at the Official Plan level for the Seaton community, these "urban" designated lands were assumed to be low/medium residential. The federally owned lands being considered as the site of a future airport were classified as "agricultural" with the maintenance of their existing "natural" areas.

Future Land Use [Cover] with Enhanced Natural Heritage System

This scenario was created by increasing the area of natural cover, where revegetation opportunities were expected to exist, such as along stream and valley corridors and adjacent to existing habitat patches. The criteria used in the development of this scenario is more fully described in chapter 3.1.3.

TOWN OF AJAX
Official Plan



Lake Ontario

0 250 500 1000 2000 m

SCHEDULE A
Land Use

Greenlands Framework
- Environmental Protection
- Open Space
- Town-Wide Park
- Community Park
- Neighbourhood Park
- Lake Iroquois Shoreline

Residential Areas
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Future Urban Development
- S Secondary School
- E Elementary School
- C Secondary School Multi-use Campus

Mixed Use Areas
- Downtown Central Area
- Uptown Central Area
- Village Central Area
- Local Central Area
- Mixed Commercial Corridor
- Community Improvement Area
- * Former Landfill Site
- * Water Supply Plant

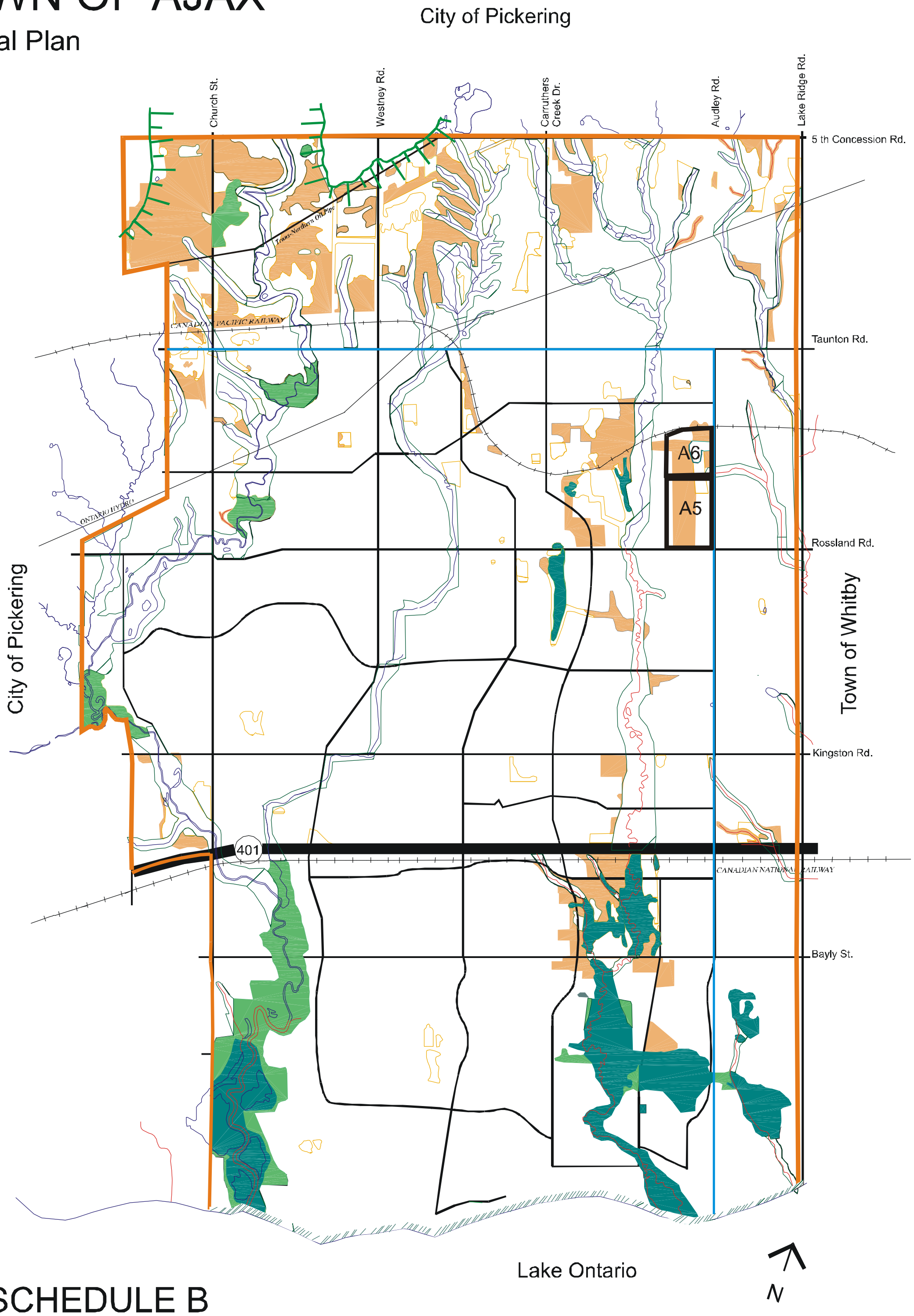
Employment Areas
- Prestige Employment
- General Employment
- Employment Policy Area

Rural Area
- Rural
- Town Boundary
- Urban Area Boundary

FEBRUARY 28, 2002

TOWN OF AJAX

Official Plan



0 250 500 1000 2000 m

SCHEDULE B
Greenlands Framework

Environmental Protection Areas

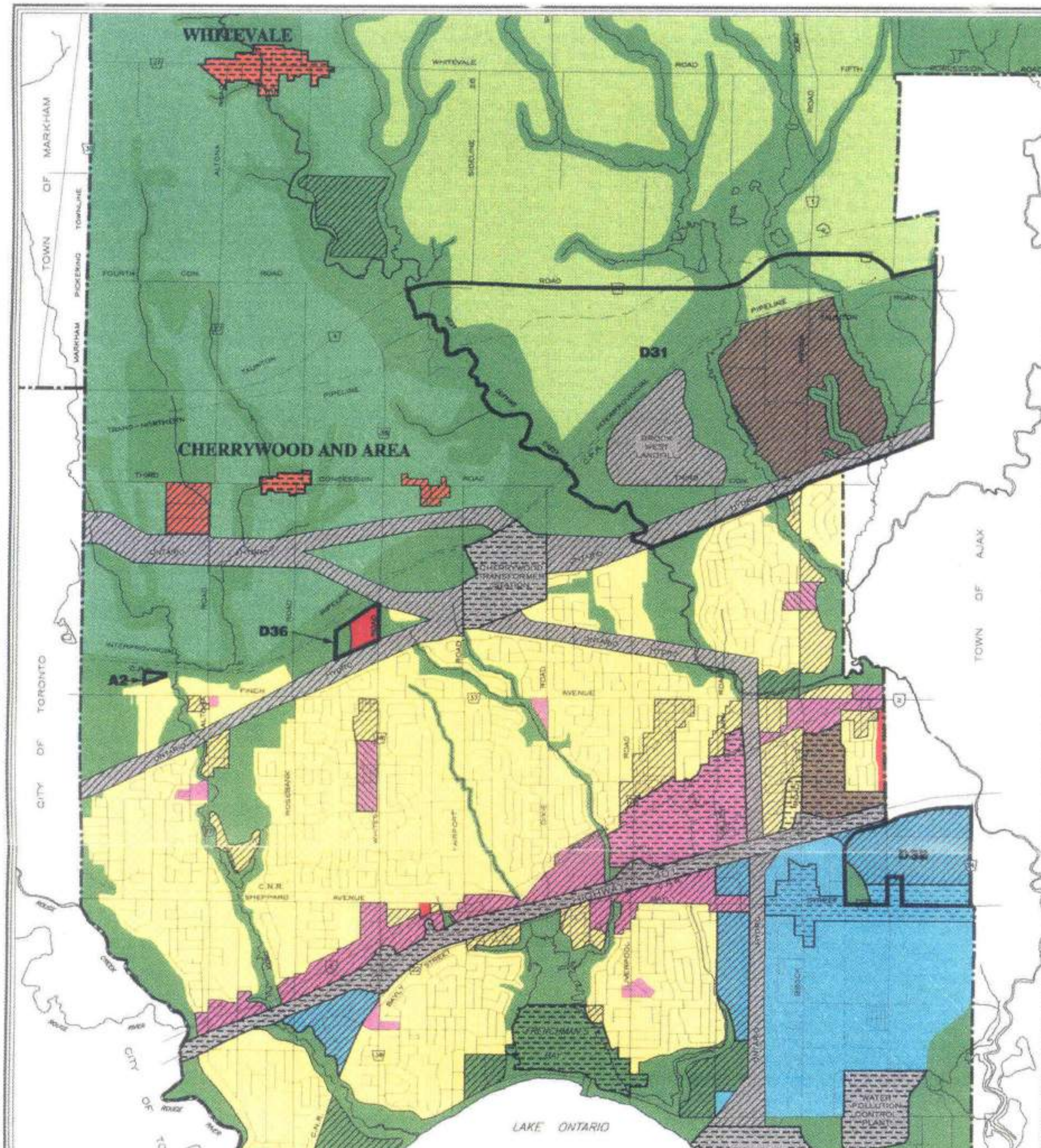
- Valley (Hazard) Systems
- Evaluated Wetlands
- Wetland
- Other Significant Natural Features (ESA's, ANSI's)
- Lake Iroquois Shoreline
- Warm Water Stream
- Cold Water Stream
- Intermittent Cold Water Stream

Environmental Resources Overlay

- Woodlands
- Other Supporting Natural Areas
- Intermittent Warm Water Stream
- Town Boundary
- Urban Area Boundary

Note: The Environmental Protection Areas are outlined in black

FEBRUARY 28, 2002



SCHEDULE I TO THE

PICKERING OFFICIAL PLAN

EDITION 2

SHEET 1 OF 3

CITY OF PICKERING
PLANNING & DEVELOPMENT DEPARTMENT
© SEPTEMBER, 2000
THIS MAP FORMS PART OF EDITION 2 OF THE PICKERING OFFICIAL PLAN AND MUST BE READ IN CONJUNCTION WITH THE OTHER SCHEDULES AND THE TEXT.

LAND USE STRUCTURE

OPEN SPACE SYSTEM
- NATURAL AREAS
- ACTIVE RECREATIONAL AREAS
- MARINA AREAS

MIXED USE AREAS
- LOCAL NODES
- COMMUNITY NODES
- MIXED CORRIDORS
- DOWNTOWN CORE

REGIONAL NODES
- REGIONAL NODE 1
- REGIONAL NODE 2

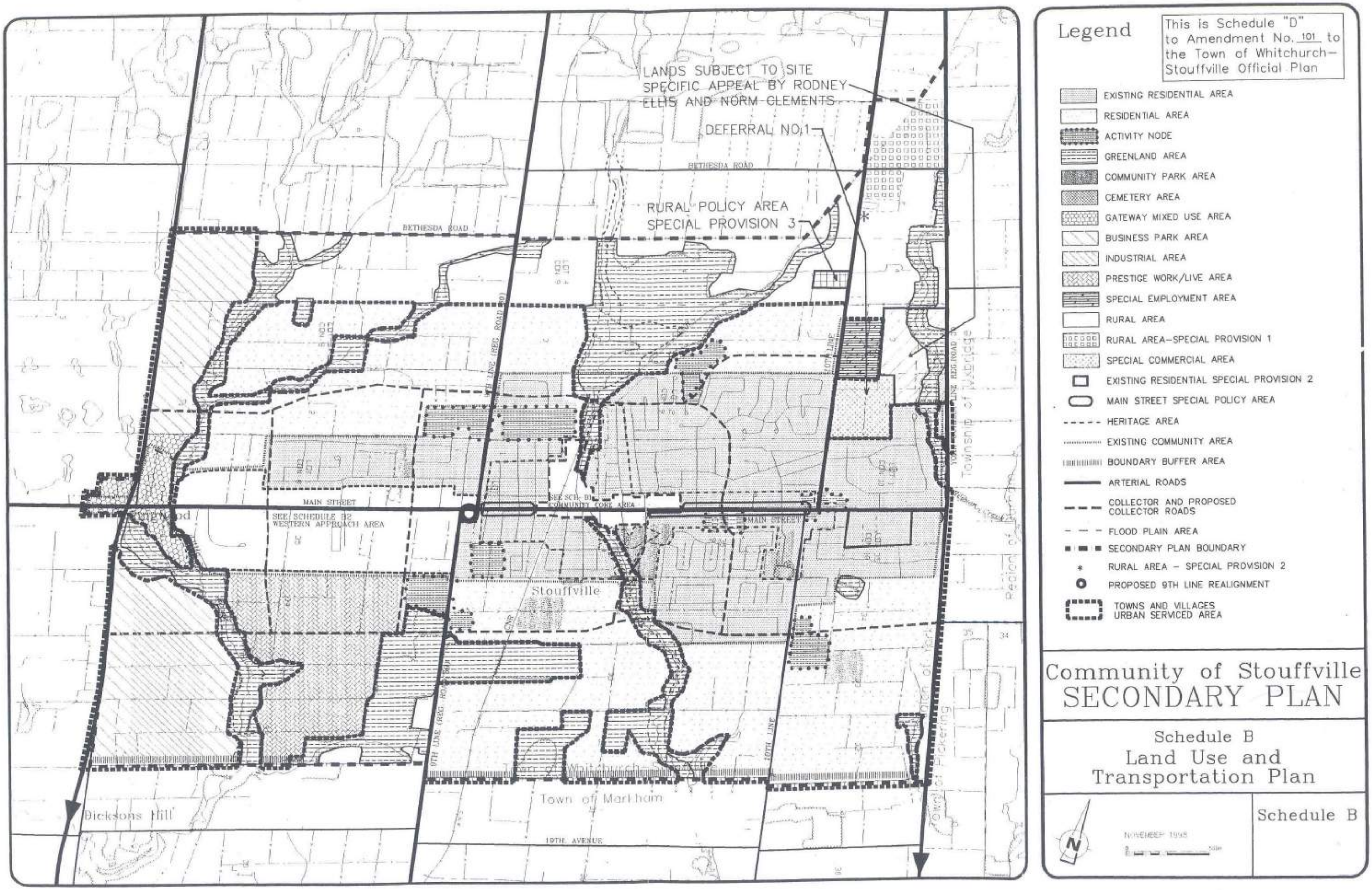
EMPLOYMENT AREAS
- GENERAL EMPLOYMENT
- PRESTIGE EMPLOYMENT
- MIXED EMPLOYMENT

URBAN RESIDENTIAL AREAS
- LOW DENSITY AREAS
- MEDIUM DENSITY AREAS
- HIGH DENSITY AREAS

RURAL SETTLEMENTS
- RURAL CLUSTERS
- RURAL HAMLETS

FREEWAYS AND MAJOR UTILITIES
- POTENTIAL MULTI-USE AREAS
- CONTROLLED ACCESS AREAS

OTHER DESIGNATIONS
- URBAN STUDY AREAS
- SEATON URBAN STUDY AREA
- AGRICULTURAL AREAS
- D1 DEFERRALS
- A1 APPEALS


Legend
This is Schedule "D" to Amendment No. 101 to the Town of Whitchurch-Stouffville Official Plan
EXISTING RESIDENTIAL AREA
RESIDENTIAL AREA
ACTIVITY NODE
GREENLAND AREA
COMMUNITY PARK AREA
CEMETERY AREA
GATEWAY MIXED USE AREA
BUSINESS PARK AREA
INDUSTRIAL AREA
PRESTIGE WORK/LIVE AREA
SPECIAL EMPLOYMENT AREA
RURAL AREA
RURAL AREA-SPECIAL PROVISION 1
SPECIAL COMMERCIAL AREA
EXISTING RESIDENTIAL SPECIAL PROVISION 2
MAIN STREET SPECIAL POLICY AREA
HERITAGE AREA
EXISTING COMMUNITY AREA
BOUNDARY BUFFER AREA
ARTERIAL ROADS
COLLECTOR AND PROPOSED COLLECTOR ROADS
FLOOD PLAIN AREA
SECONDARY PLAN BOUNDARY
RURAL AREA - SPECIAL PROVISION 2
PROPOSED 9TH LINE REALIGNMENT
TOWNS AND VILLAGES URBAN SERVICED AREA
Community of Stouffville
SECONDARY PLAN
Schedule B
Land Use and Transportation Plan
Schedule B
LANDS SUBJECT TO SITE SPECIFIC APPEAL BY RODNEY ELLIS AND NORM CLEMENTS
DEFERRAL NO.1
RURAL POLICY AREA SPECIAL PROVISION 3
BETHESDA ROAD
MAIN STREET
SEE SCHEDULE B2 WESTERN APPROACH AREA
SEE SCH. B1 COMMUNITY CORE AREA
Stouffville
Town of Markham
Dicksons Hill
19TH AVENUE
10TH LINE
Township of Uxbridge
Region of Durham
Town of Pickering

DUFFINS AND CARRUTHERS CREEK WATERSHED PLAN

SUPPORTING DOCUMENTS

Aquafor Beech Ltd. 2002. Duffins Creek Hydrology Update.

Clarifica Inc. 2002. Water Budget in Urbanizing Watersheds: Duffins Creek Watershed.

Gerber Geosciences Inc. 2003. Duffins Creek Watershed Hydrogeology and Assessment of Land Use Change on the Groundwater flow System. Including Appendix on Water Use.

Marshall Macklin Monaghan Ltd. 2002. Duffins Creek Watershed Hydraulic Modelling and Flood Plain Mapping Project.

Stantec Consulting Ltd. and Aquafor Beech Limited. 2003. Dry and Wet Weather Modelling of Water Quality under Alternative Land Use Scenarios in the Duffins and Carruthers Creek Watersheds - A simple Spreadsheet Approach.

TRCA. 2002. Carruthers Creek State of the Watershed Report.

TRCA. 2002. Duffins Creek State of the Watershed Report.

TRCA. 2003. Agricultural Non-Point Source (AGNPS) Modelling of the Duffins and Carruthers Creek Watersheds.

TRCA. 2003. Duffins and Carruthers Creek Watersheds Fisheries Management Plan.

TRCA. 2003. Duffins and Carruthers Creek Low Flow Study and Management Plan.

TRCA. 2003. Ratings Report for the 2003 Duffins and Carruthers Creek Watersheds Report Card.

RATINGS REPORT FOR THE
2002 DUFFINS AND CARRUTHERS CREEK WATERSHEDS
REPORT CARD

February 11, 2003

Prepared by:

Toronto and Region Conservation

For the Duffins and Carruthers Watershed Task Forces

RATINGS REPORT FOR THE
2002 DUFFINS AND CARRUTHERS CREEK WATERSHEDS
REPORT CARD

1.0 Introduction

1.1 Objectives, Indicators, Measures, and Targets

In the process of developing an integrated watershed plan for the Duffins Creek and Carruthers Creek watersheds, the Task Forces have identified management strategies that address the eight technical components of:

- Surface Water Quantity;
- Groundwater Quantity and Quality;
- Surface Water Quality;
- Aquatic Habitat and Species;
- Terrestrial Habitat and Species;
- Public Use - Recreation;
- Human Heritage; and
- Sustainable Communities.

Each management strategy is composed of a set of objectives, which identify the approach necessary to address the key issues associated with each technical component. To better facilitate meaningful and replicable reporting on progress towards full achievement of the management objectives, specific indicators, measures and targets have been defined for each objective. An indicator is a fact or device that provides specific information about the objective of interest. Measures are quantitative or qualitative ways to measure the state of the indicator. Targets represent a numerical threshold or directional aim, associated with each measure, and were chosen as the minimum (or maximum) condition necessary to achieve the desired objective.

In addition to setting management directions, the Task Force has reported on current watershed conditions, thus providing a baseline “Report Card” from which progress can be measured. Reporting on current watershed conditions prior to implementation work being undertaken serves to document the level at which the goals, objectives and targets of the watershed plan are currently being achieved, which will assist in evaluating progress towards implementation of the watershed plan in future reporting periods.

1.2 Ratings Definition

For each goal, objective and measure, a rating has been assigned which represents an evaluation of current watershed conditions. Ratings of current watershed conditions are based on both quantitative and qualitative analyses. To the greatest extent possible, the ratings for each measure are based on a quantitative evaluation of the current level of achievement of the associated target. Ratings for each management objective are based on a qualitative evaluation of the ratings for the measures associated with the objective. The rating for each management goal are based on a qualitative evaluation of the ratings for the associated objectives.

For management objectives where the target is based on a quantitative measure, and where sufficient information regarding that measure is available, current watershed conditions have been evaluated and ratings have been assigned for each measure according to the current level of achievement of the target. The rating system applied to quantitative measures is defined as follows:

Achievement Rating	**% of target achieved**
Excellent	better than 80%
Good	between 70 and 79%
Fair	between 60 and 69%
Poor	between 50 and 59%
Fail	below 50%
Further study required	baseline data not available or insufficient at this time
Not applicable in 2002	not applicable to evaluate % of target achieved in the 2002 reporting period

For some objectives, the chosen indicators and measures are not amenable to quantitative evaluation. In some cases, the target associated with the objective is based on a qualitative condition or directional aim for the measure. In these instances evaluations involved a qualitative evaluation of all available information pertaining to the measure and ratings were assigned based on the best professional judgement of TRCA staff with regard to the current level of achievement of the target.

In some cases, quantitative measures and targets have been established for the objective but the amount of information available pertaining to these measures is insufficient for the purpose of evaluating the level of achievement of the target. In these instances further data collection and analysis is required to fill information gaps. In these instances, no ratings have been assigned in this reporting period and the need for further study has been indicated. Table 3.1 at the end of this document summarizes the information gaps that have been identified through the watershed strategy development process.

In other cases, targets have not yet been established for certain quantitative measures due to limits to our understanding of the conditions required to sustain watershed health and integrity. In these instances, ratings have been assigned based on qualitative comparisons of conditions in the Duffins and Carruthers Creek watersheds to conditions in other watersheds within the TRCA jurisdiction, and the best professional judgement of TRCA staff with regard to the current health of the watershed.

For several management objectives, the target is to maintain or enhance baseline conditions. In many cases, baseline conditions have been defined as those conditions existing in 2002, so it is not applicable to rate the level of achievement of this target in the 2002 reporting period. In these instances, an interim rating has been assigned based on the best professional judgement of TRCA staff with regard to the current health of the watershed. These ratings appear in italics to indicate that future ratings will be based on the quantitative rating method of evaluating the level of achievement of the target in subsequent reporting periods.

The following section contains descriptions of the evaluation method and rationale that supports the ratings assigned for each measure, and the overall rating for each objective.

More detailed descriptions of current conditions on the Duffins and Carruthers Creek watersheds, can be found in the State of the Watershed Reports and the supporting technical documents listed in Appendix A.

2.0 Methodologies and 2002 Ratings

2.1 Surface Water Quantity

GOAL: To maintain the existing hydrologic function of the watershed	Duffins	Carruthers
	Good	**Good**

Objective #1	**Maintain the existing water balance within the watershed**		**Overall Rating**	
			Duffins	**Carruthers**
			Good	*Good*
Indicators	Measures	Targets	2002 Rating	
			Duffins	Carruthers
• watershed hydrology	• total annual infiltration rate (mm/yr)	• maintain or enhance baseline infiltration rates and distribution*†	Not applicable in 2002	Further study required
	• run-off volume (m^3/yr)	• maintain or reduce baseline run-off volume†‡	Not applicable in 2002	Further study required
	• seasonal and annual baseflow (m^3/yr) at indicator sites	• maintain or enhance baseline seasonal and annual baseflows§	Not applicable in 2002	Further study required

References:

*Gerber Geosciences Inc. 2003, Duffins Creek Watershed Hydrogeology and Assessment of Land Use Change on the Groundwater Flow System.
†Clarifica Inc. 2002, Water Budget in Urbanizing Watersheds: Duffins Creek Watershed.
‡Aquafor Beech Ltd. 2002, Duffins Creek Hydrology Update.
§TRCA 2003, Duffins and Carruthers Creek Low Flow Study and Management Plan, Appendix A and B

Comments on the 2002 Ratings

Ratings for this objective will be based on the measures of total annual groundwater infiltration rate, and seasonal and annual baseflow. In 2002, a water balance model was developed for the Duffins Creek watershed and used to describe current conditions pertaining to watershed hydrology with respect to the existing balance between rates of infiltration, evapo-transpiration, and run-off in response to storm events. Values for total annual groundwater infiltration and run-off volume have been calculated for the Duffins Creek watershed based on the output of the water balance model for 2002 conditions. These values will be considered the baseline values that are to be maintained through planning and management measures. In future reporting periods, the water balance model output will be updated and used to recalculate annual infiltration rates and run-off, which will permit evaluations to be made of the level at which this objective is being achieved with respect to maintaining baseline infiltration rates and distribution and run-off volume. Since baseline infiltration rates and distribution and run-off volumes have been defined as the 2002 conditions, and since the target for these measure is to maintain or enhance baseline values, assigning ratings for these measures is not applicable in the 2002 reporting period.

Further technical work is required to fill the information gaps that currently prevent ratings from being assigned with respect to the watershed hydrology of Carruthers Creek. Table 3.1 in the Summary and Recommendations section provides a summary of the areas where further study is required. The water balance model for the Carruthers Creek watershed is not yet complete (scheduled for completion in 2003), and therefore, no baseline infiltration rates can be established at this time. Similarly, no continuous stream flow data is currently available for this watershed and the information on baseflow is limited to two seasons of monitoring field work. A permanent stream gauge was installed in Carruthers Creek in 2002 to address this critical information gap.

The information available on seasonal and annual baseflow in both Duffins and Carruthers Creek, from monitoring field work conducted in 1996 and 2001, provides an initial indication of the status of stream flow in these watersheds during dry periods (defined as periods with no rainfall in the previous 72 hours), yet it is insufficient to properly characterize the natural variability inherent in this type of measure. As additional baseflow measurements are collected and analyzed through on-going seasonal monitoring programs, our understanding of existing baseflow conditions will be improved, which will enable baseline seasonal and annual baseflow volumes to be established for these watersheds, and will permit trends in monitoring data to be identified and interpreted in future reporting periods.

When compared with other watersheds in the TRCA jurisdiction, the hydrologic response and water balance of the Duffins and Carruthers Creek watersheds reflect non-urbanized conditions, or watersheds that are predominantly under a combination of rural/agricultural land use and natural land cover, with a minor amount of urban development, which is the most significant cause of loss of infiltration capacity (see Duffins Creek State of the Watershed Report, Surface Water Quantity section, pgs 146 - 154). Although all existing urban areas in each of these watersheds have been developed without infiltration controls in place, the proportion of each watershed that is impervious (subject to urban land uses with no infiltration controls in place) is much less than all other watersheds in the TRCA jurisdiction. In the Duffins Creek watershed, most of the existing urban development is associated with the reaches of the Lower Duffins, which contribute less than 3% of the estimated total annual baseflow. Based on the predominance of rural, agricultural and natural land cover in both the Duffins and Carruthers Creek watersheds, overall ratings of “Good” have been assigned for this objective, which reflect a qualitative evaluation, based on the best professional judgement of TRCA staff.

Objective #2 Maintain or enhance baseflows			Overall Rating	
			Duffins	**Carruthers**
			Good	***Fair***
Indicators	Measures	Targets	2002 Rating	
			Duffins	Carruthers
• baseflow	• seasonal and annual baseflow (m^3/yr) at indicator sites	• maintain or enhance baseline seasonal and annual baseflows*	Not applicable in 2002	Not applicable in 2002

References:

*TRCA 2003. Duffins and Carruthers Creek Low Flow Study and Management Plan, Appendix A and B.

Comments on the 2002 Ratings

Information available on seasonal and annual baseflow in both the Duffins and Carruthers Creek, from monitoring work conducted in 1996 and 2001, provides an initial indication of the status of stream flow in these watersheds during dry periods (defined as periods with no rainfall in the previous 72 hours), yet it is insufficient to properly characterize the natural variability inherent in this type of measure. As additional baseflow monitoring data is collected and analyzed, our understanding of existing baseflow conditions will be improved, which will enable baseline values for seasonal and annual baseflow volumes to be established for these watersheds, and will permit trends in future monitoring data to be identified and interpreted.

In general, baseflow in Duffins Creek remains continuous for the majority of the reaches in the watershed throughout the year, owing to the small amount of urbanization, the large number of natural features, the predominance of sandy soils and extensive forest cover and wetlands, all of which promote groundwater infiltration and reduce stormwater run-off. A limited number of observations of very low flows in some reaches were made at indicator sites during the driest periods of the summer of 2001. It is also suspected that surface water takings are occurring in this watershed. An overall rating of “Good” has been assigned to Duffins Creek for this objective, based on a qualitative evaluation of historical stream flow data and the limited amount of baseflow monitoring data from indicator sites that is currently available.

Observations of baseflow in Carruthers Creek made in 2001 suggest that baseflow is less consistent than in Duffins Creek. During the driest periods of the summer of 2001, several reaches were observed to have no flow during baseflow monitoring. Surface water takings are occurring in this watershed to a greater extent than in the Duffins. Historical stream flow information for this basin is not sufficient to determine if reaches that were observed to have intermittent baseflow in 2001 have been this way in the past. Continuous stream flow data and additional baseflow monitoring data from indicator sites is needed to better characterize typical low flow conditions in this watershed. A permanent stream flow gauge was installed in Carruthers Creek in 2002 to address this information deficiency. It is suspected that surface water takings are having a significant impact on baseflow in Carruthers Creek. A comprehensive review of the MOE Permit To Take Water database is required to determine the proportion of annual flow that is currently permitted to be withdrawn. An overall rating of “Fair” has been assigned to Carruthers Creek for this objective, based on a qualitative evaluation of the limited amount of baseflow information that is currently available.

Further correlation of baseflow field monitoring data with information on subsurface geology and water takings is required to improve our understanding of the factors and processes affecting baseflow in these systems. There is a need for further integration work to examine seasonal baseflow monitoring data within the context of the regional groundwater flow model that is scheduled to be finished in January 2003 (York-Peel-Durham Groundwater Management Project). Additionally, updated data on surface water and groundwater withdrawals within these watersheds is urgently needed to assess the impacts of current rates of water withdrawals and future water taking proposals on baseflow. The Region of Durham is currently conducting a region-wide assessment of water use, which is scheduled for completion in 2003.

Objective #3	**Minimize or reduce risks to human life and property due to flooding**		**OVERALL RATING**	
			Duffins	**Carruthers**
			Good	***Good***
INDICATORS	MEASURES	TARGETS	2002 RATING	
			Duffins	Carruthers
• number of flood vulnerable areas (FVAs) and flood vulnerable roads (FVRs)	• peak flow rate (unit flows)	• maintain baseline peak flows (2-100 year and Regional control if required)*	Not applicable in 2002	Further study required
	• water level (flood lines)	• maintain baseline water levels (flood lines)†	Further study required	Further study required
	• number of flood vulnerable areas and flood vulnerable roads	• reduce or as a minimum maintain the existing number of flood vulnerable areas and flood vulnerable roads (and the design storm frequency at which they flood)‡	*Good*	*Good*
	• ice jams (frequency and location)	• develop and maintain documentation of the number of sites and frequency of ice jams	Good	Excellent

References:

*Aquafor Beech Ltd. 2002. Duffins Creek Hydrology Update
†Marshall Macklin Monaghan Ltd., 2002. Duffins Creek Watershed Hydraulic Modeling and Flood Plain Mapping Project
‡TRCA 2000. Flood Vulnerable Areas Database; and,
TRCA 2002, Duffins Creek State of the Watershed Report, Figure 7; and,
TRCA 2002, Carruthers Creek State of the Watershed Report, Figure 4.

Comments on the 2002 Ratings
Ratings for this objective will be based on the measures of peak flow rate, water level (flood line elevations), the number of flood vulnerable areas and flood vulnerable roads, and the frequency of ice jams.

For the Duffins Creek watershed, the rating assigned for the measure of peak flow rate is based on the output of the updated Duffins Creek Hydrology Model which was completed in 2002. Peak flow rates that have been calculated using the updated Duffins Creek Hydrology Model will be considered to be the baseline for this measure. In future report cards, peak flow rates will be recalculated using hydrology model input parameters that reflect watershed conditions at that time, and the outputs will be compared with the 2002 results to evaluate progress towards achieving this objective. Since existing peak flow rates have been defined as the 2002 conditions, and since the target for this measure is to maintain existing rates, assigning ratings for the level of achievement with respect to this target is not applicable in the 2002 reporting period.

An update to the existing hydraulic model and associated floodplain mapping for the Duffins Creek watershed is planned over the next two years. This update will be carried out to define the limits of the regional floodplain based on flow information derived from the updated hydrology model. The water level elevations (flood lines) indicated in the updated floodplain maps will be considered the baseline for this measure.

The hydrology model for Carruthers Creek is incomplete at this time due to a lack of stream flow data, which is needed for model calibration. A stream gauge has been installed in the Carruthers Creek watershed in 2002 and continuous monitoring of stream flow is underway to address this deficiency. The Carruthers Creek Hydrology Model is scheduled to be completed in 2003.

Updates to the Flood Vulnerable Areas (FVA) and Flood Vulnerable Roads (FVR) database for each of these watersheds will be carried out as required, once the hydraulic models and floodplain mapping have been updated. The ratings of “Good” for both the Duffins and Carruthers Creek watersheds with respect to the number of FVAs and FVRs reflects the fact that, based on existing records, flood vulnerable sites do exist in both watersheds, but historical accounts of flood events in these watersheds suggest that they occur very infrequently. The rating of “Good” allows for improvement to occur in the future.

In the absence of detailed historical information documenting the frequency of occurrences of ice jams, TRCA staff responsible for flood prediction and response indicate that these types of events occur very infrequently in both the Duffins and Carruther Creek watersheds (see State of the Watershed Reports for Duffins and Carruthers Creek, TRCA 2002). Ratings of “Good” for Duffins Creek, and “Excellent” for Carruthers Creek have been assigned for this measure, based on a qualitative review of available information and the best professional judgement of TRCA staff.

The overall rating of “Good” assigned to both the Duffins and Carruthers Creek watersheds for this objective reflects a qualitative assessment of the current level of risk to human life and property due to flooding, based on the best professional judgement of TRCA staff.

In the future, updated land cover and hydraulic information will be input to the hydrology models for the Duffins and Carruthers Creek watersheds and used to predict peak flow rates, and conduct hydraulic assessments as a part of reviewing the status of floodplain maps. In future report cards, assessments will be made of the number of flood vulnerable areas, flood vulnerable roads, and the number and frequency of ice jam events and compared to the 2002/2003 results to evaluate progress towards achieving this objective.

Objective #4	**Maintain or restore natural stream channel stability**		**OVERALL RATING**	
			Duffins	**Carruthers**
			Further study required	**Further study required**
INDICATORS	MEASURES	TARGETS	2002 RATING	
			Duffins	Carruthers
• in-stream erosion	• erosion index	• maintain the baseline erosion index*	Further study required	Further study required
	• % of developed area that has adequate erosion controls in place (according to 2003 criteria)	• 100% of developed areas with adequate erosion controls in place	Further study required	Further study required
	• rate of erosion at indicator sites	• maintain or reduce the baseline rate of erosion†	Further study required	Further study required

References:

*Cosburn Patterson Mather Ltd., 2001 (1997), Stormwater Management Study - A8 Secondary Plan (OPA 48), Town of Ajax, 2001 Addendum to May 1997 report; and,
Ecotech International Systems Inc., pending approval, Functional Servicing Study - Northeast Quadrant OPA 101 Community of Stouffville, Town of Whitchurch-Stouffville; and,
Parish Geomorphic Ltd., pending review, Erosion Assessment and Fluvial Geomorphic Update for Portions of West Duffins, Whitevale, Ganatsekiagon and Urfe Creeks; and,
Planning and Engineering Initiatives Ltd., 2002, Green Space Project Lands Fluvial Geomorphology Study - Duffins Creek Watershed, Transport Canada, November 2002; and,
URS Cole Sherman Ltd., pending approval, Functional Servicing Study - Southeast Quadrant OPA 101 Secondary Plan, Town of Whitchurch-Stouffville.
† to be defined through the Regional Watershed Monitoring Network.

Comments on the 2002 Ratings

Ratings for this objective are based on the measures of erosion index, % of developed areas within the watershed that have adequate erosion controls in place, and rate of erosion. Modelling work to establish erosion indices for both the Duffins and Carruthers Creek watersheds will be carried out in 2003. The erosion index is a measure that reflects the relative potential for streambank erosion and downcutting of the stream channel due to exposure to flows with erosive capacities that are in excess of the natural cohesiveness strength of the streambank and bed material. When compared with pre-development conditions, the erosion index provides a means of evaluating the effectiveness of stormwater management measures with respect to mitigating the increased potential for erosion that is associated with the expansion of urban areas. Erosion index modelling work requires fluvial geomorphology assessments to be conducted in order to characterize the existing structure and composition of the stream channel and to identify the most sensitive reaches in terms of susceptibility to erosion. Based on modelled stream flow data that is generated by the hydrology model and knowledge of the structure and composition of the stream channel along the most sensitive reaches, erosion threshold values for volume, velocity, and depth of flow are established. The erosion threshold values are used to calculate the erosion index and provide the criteria needed to design stormwater management facilities to provide the necessary level of erosion control (i.e., storage volume and release rate criteria for stormwater management facilities).

Ratings cannot be assigned for the measure of % of developed areas within the watershed with adequate erosion control in place until new erosion control criteria are established. Once erosion indices and stormwater management facility design criteria for erosion control are established for each watershed, the % of developed areas within each watershed that meet the new erosion control criteria will be assessed and quantitative ratings will be assigned for this measure in future reporting periods.

In areas of existing urban development in the Duffins and Carruthers Creek watersheds, monitoring of stream bank erosion will be conducted through the Regional Monitoring Network every three years, starting in 2003. The 2006 data will be compared with the 2003 data and used to establish erosion rates which will be considered the baseline measure to which comparisions will be made in future watershed report cards.

GOAL: To protect groundwater quality and quantity	Duffins	Carruthers
	Good	Fair

Objective #5	**Maintain or enhance groundwater levels and baseflow for watershed functions**		**OVERALL RATING**	
			Duffins	**Carruthers**
			Good	***Fair***
INDICATORS	MEASURES	TARGETS	2002 RATING	
			Duffins	Carruthers
• water table level	• water table level at indicator sites	• establish and maintain baseline water table levels	Not applicable in 2002	Not applicable in 2002
• aquifer water level	• piezometric surfaces at indicator sites	• maintain baseline piezometric surfaces*†	*Good*	*Fair*
• baseflow	• seasonal and annual baseflow	• maintain or enhance baseline seasonal and annual baseflows‡	Further study required	Further study required

References:

*Conservation Authorities Moraine Coalition 2003, York-Peel-Durham-Toronto MODFLOW Groundwater Flow Model - Core Area
†Gerber Geosciences Inc. 2003, Duffins Creek Watershed Hydrogeology and Assessment of Land Use Change on the Groundwater Flow System
‡ TRCA 2003, Duffins and Carruthers Creek Low Flow Study and Management Plan, Appendix A and B.

Comments on the 2002 Ratings
Groundwater levels have been monitored at a number of locations within the Duffins Creek watershed since the late 1970s on a discontinuous basis. A new, continuous groundwater monitoring program has been recently initiated by MOE and TRCA which commenced operation in June of 2001. Groundwater levels and aquifer water levels that will be established in through the monitoring program will be considered baseline measures and will be used to identify and interpret trends in future reporting periods. Since baseline groundwater and aquifer water levels have been defined as the 2002 conditions, and since the target for this measure is to maintain or enhance baseline levels, assigning a rating for this measure is not applicable in the 2002 reporting period.

Despite the discontinuous nature of the available information on historic groundwater levels, it does provide an indication of the extent to which groundwater levels have fluctuated in the past, which will assist in identifying trends in the continuous monitoring data that is now being collected. Annual water table levels within the till and lacustrine deposits situated south of the Oak Ridges Moraine have generally fluctuated between 2 to 3 metres in the past, except for one site (Site 1/94) where fluctuations of up to 5 metres have been observed. Information on water table levels within Oak Ridges Moraine deposits is currently lacking, but fluctuations are expected to be less than those observed in the lower permeability deposits situated to the south. The annual fluctuation of water levels within the deeper aquifers have been observed to be less than 2 metres.

Ratings assigned for this objective with respect to the measure of baseflow are based on a qualitative comparison of results of summer base flow monitoring in 1996 and 2001 with historic stream flow data for the Duffins and Carruthers Creek watersheds (see section 2.1 Surface Water Quantity; Objective #2 for an explanation of the rationale behind these ratings).

Based on consideration of the magnitude of groundwater level fluctuations in the past, the current understanding of baseflow in these watersheds and the best professional judgement of TRCA staff and consultants, overall ratings of “Good” for Duffins Creek and “Fair” for Carruthers Creek have been assigned for this objective. These ratings represent a qualitative review of existing information and the best professional judgement of TRCA staff.

Objective #6	**Protect groundwater quality to ensure provision of safe water supplies and ecological functions**		**OVERALL RATING**	
			Duffins	**Carruthers**
			Good	**Good**
INDICATORS	MEASURES	TARGETS	2002 RATING	
			Duffins	Carruthers
• groundwater chemistry	• Chlorides • Nutrients • Total Organic Carbon (TOC) • Phenols • Conductivity • Metals • pH • Bacteria • parameters in MOE Ontario Drinking Water Standards	• MOE Ontario Drinking Water Standards (mg/L)*	Good	Good

*Ontario Regulation 459/00
www.ene.gov.on.ca for up-to-date information

Comments on the 2002 Ratings
In order to monitor long-term trends in groundwater levels and groundwater quality, the MOE and TRCA have initiated a groundwater monitoring program in June of 2001 which includes the analysis of groundwater samples for various chemical parameters twice per year. Groundwater quality data collected through this program will provide a better understanding of background conditions associated with groundwater quality within the Duffins Creek watershed. No monitoring stations are planned for the Carruthers Creek watershed at this time. Until an additional monitoring station can be established in the Carruthers Creek watershed, monitoring data from the Duffins Creek watershed will be considered to be generally indicative of groundwater quality conditions in the Carruthers Creek watershed.

While long-term data trends for sites within the Duffins Creek watershed are unavailable, there have been a number of studies conducted which provide an indication of background groundwater quality. Groundwater quality within the Duffins Creek watershed does not appear to vary significantly within any of the three aquifers situated within the unconsolidated deposits above bedrock and is generally of good quality for domestic use. Local occurrences of natural high hardness and iron concentrations have been reported along with locally elevated nitrate and chloride concentrations which are above MOE Drinking Water Quality Objectives. Elevated nitrate and chloride levels are believed to indicate contamination from surface applications of nitrate fertilizers and road salt respectively. Groundwater quality concerns at the present time appear to be isolated occurrences of elevated nitrate and bacteria levels associated with septic system effluent entering private wells and occurrences of high chloride concentrations above drinking water criteria (250 mg/L) in private wells situated near salted roadways. Many of the rural residents in the upper parts of the watershed rely on the shallow aquifer system for their potable water supply, and therefore their wells are more susceptible to contamination.

Based on this information, a rating of "Good" has been assigned for both the Duffins and Carruthers Creek watersheds, which reflects a qualitative assessment of the limited monitoring data available at this time.

Development of a source protection plan for these watersheds will begin in 2002, which will especially benefit rural water users on private well systems. It will involve identifying potential contaminant sources, assessing the vulnerability of groundwater systems, and developing a management plan. On-going monitoring work will provide a better understanding of the number of monitoring sites where groundwater chemistry parameters are in excess of Provincial Drinking Water Quality Objectives which will allow quantitative ratings to be established for this objective in future report cards.

Objective #7	**Ensure sustainable rates of groundwater use**		**OVERALL RATING**	
			Duffins	**Carruthers**
			Further study required	**Further study required**
INDICATORS	MEASURES	TARGETS	2002 RATING	
			Duffins	Carruthers
• water table levels	• water table levels at indicator sites	• establish and maintain baseline water table levels	Further study required	Further study required
• aquifer water levels	• piezometric surfaces at indicator sites	• maintain baseline piezometric surfaces*†	Not applicable in 2002	Not applicable in 2002
• baseflow	• seasonal and annual baseflow	• maintain or enhance baseline seasonal and annual baseflows‡	*Good*	*Fair*
• groundwater withdrawals	• maximum annual volume of groundwater withdrawals permitted by active MOE Permits To Take Water	• sustainable rate of groundwater use TBD pending further study	Further study required	Further study required

*Conservation Authorities Moraine Coalition 2003. York-Peel-Durham-Toronto MODFLOW Groundwater Flow Model - Core Area
†Gerber Geosciences Inc. 2002. Duffins Creek Watershed Hydrogeology and Assessment of Land Use Change on the Groundwater Flow System
‡ TRCA 2003. Duffins and Carruthers Creek Low Flow Study and Management Plan, Appendix A and B.

Comments on the 2002 Ratings
Ratings for this objective are based on the measures of groundwater and aquifer water levels at indicator sites, baseflow, and groundwater withdrawals. An explanation of the rationale for the ratings for groundwater and aquifer water levels and baseflow can be found under Objective #5 in this section. An explanation of the rationale for the ratings for baseflow can be found in section 2.1, Surface Water Quantity, under Objective #2.

At this time, a criteria for establishing a targeted "sustainable" rate of groundwater withdrawal has not yet been developed. A comprehensive review and update of the entire MOE Permit To Take Water Database is urgently needed to provide the detail of information needed to assess impacts of current rates of water use on groundwater and aquifer water levels, and to develop criteria for sustainable rates of groundwater withdrawal. The Region of Durham is currently conducting a region-wide assessment of water use, scheduled to be completed in 2003, which will address this information deficiency. Until the water use assessment is complete, it is difficult to determine whether or not current rates of groundwater withdrawal are significantly impacting groundwater quantity on a watershed basis. In future reporting periods ratings will be assigned for this objective by comparing estimates of groundwater recharge derived from the output of the Duffins and Carruthers Creek water budget models and groundwater withdrawal from the water use assessment.

A limited review of information on groundwater withdrawals in the Duffins Creek watershed was conducted as a part of the Duffins Creek Hydrogeology study, which provides an initial indication of the magnitude of groundwater withdrawals occurring in this watershed. The majority of wells within the Duffins Creek watershed are private and provide a household supply of water. Groundwater wells draw from both the shallow and deep aquifers, which makes evaluating the sustainability of current withdrawal rates difficult based on the incomplete understanding of water takings. Active permits to take water on file with the MOE indicate some larger groundwater takings for golf course irrigation, municipal water supply, and commercial uses. The largest permitted taking of groundwater is the municipal water supply for the town of Whitchurch-Stouffville. This water is presently treated and discharged to Stouffville Creek, with some discharge to tile beds. In the future this water will be sent via the York-Durham sewer system to a treatment plant located on the shoreline of Lake Ontario, near the mouth of Duffins Creek. The rate of groundwater withdrawal for the Whitchurch-Stouffville water supply presently totals 4000 m^3/day, which represents 29% of the average total stream flow measured in Stouffville Creek for the seven year period of record (1975 to 1981), and 2% of the average total stream flow measured in Duffins Creek at the Pickering stream gauge station located just upstream from Lake Ontario. Upon decomissioning of the Stouffville Water Pollution Control Plant in 2003, it can be anticipated that average total stream flow in Stouffville Creek will be reduced by approximately one third.

GOAL: To protect and improve surface water quality	Duffins	Carruthers
	Fair	**Fair**

Objective #8	**Manage the quality and quantity of run-off from rural and urban areas to maintain in-stream uses**		**OVERALL RATING**	
			Duffins	**Carruthers**
			Good	**Good**
INDICATORS	MEASURES	TARGETS	2002 RATING	
			Duffins	Carruthers
• in-stream water chemistry	• concentrations of: nutrients (phosphorus, nitrite), suspended solids, bacteria, chloride	• Concentration targets (based on PWQO or other guideline):		
		– Total Phosphorus <0.03 mg/L*	Fail	Fail
		– Nitrite < 0.06 mg/L†	Excellent	Excellent
		– Suspended Solids < 30 mg/L†	Excellent	Excellent
		– Bacteria < 100 counts/100 mL*	Fail	Fail
		– Chloride < 250 mg/L‡	Excellent	Excellent
		– Un-ionized Ammonia < 0.02mg/L*	Excellent	Excellent
	• annual loads of suspended solids and phosphorous	• Maintain annual loadings at or below the targeted " background annual load": Duffins‡‡;		
		Suspended Solids - 2670 tonnes	Excellent	Further study required
		Total Phosphorus - 2.67 tonnes	Poor	Further study required
• stormwater management (SWM)	• percent of developed area within watershed having adequate stormwater controls in place (both quantity and quality control)	• 100% of area having Level 1 water quality control (80% total suspended solids removal) for all new and retrofitted development	Fail	Fair

NOTE: In-stream water chemistry ratings are based on averaged results for each parameter from water quality monitoring conducted between 1988 to 1994, not from sampling conducted in 2002.

‡‡ To be reviewed prior to next Report Card

References:

†Canadian Council of Ministers of the Environment (CCME), 1999. *Canadian Water Quality Guidelines (CWQG)*, Canadian Council of Ministers of the Environment, Winnipeg.

‡Environment Canada and Health Canada, 2001. *Road Salts: Priority Substances List Assessment Report.* Prepared for the Canadian Environmental Protection Act, 1999 Priority Substances List. Internet Publication.

*Ontario Ministry of Environment and Energy (OMOEE), 1994, revised in 1999, *Water Management: Policies, Guidelines, Provincial Water Quality Objectives of the Ministry of Environment and Energy*, Queens Printer for Ontario.

In-stream Water Chemistry: Concentrations

The ratings assigned for in-stream water chemistry concentration targets are based on data collected through the Provincial Water Quality Monitoring Network (PWQMN) between January 1988 to December 1994. Three PWQMN stations located on reaches of Duffins Creek, and one station on Carruthers Creek were active during this period. Six in-stream water chemistry parameters that reflect the major influences affecting water quality in these watersheds were selected as measures for the indicator of in-stream water chemistry. Water quality monitoring data for the parameters of Total Phosphorus, Nitrite, Total Suspended Solids (TSS), Bacteria (faecal coliforms), Chloride, and Un-ionized Ammonia were compiled from the PWQMN records. Monitoring results were compared with Provincial Water Quality Objectives (PWQO) or Interim Guidelines which have been established for the protection of aquatic life and recreation uses of water resources. For each PWQMN station, the number of samples taken between 1988 and 1994 that met PWQOs or Interim Guidelines for the selected parameters were calculated. Ratings based on the quantitative rating system described in section 1.2 were assigned for each in-stream chemistry parameter, according to the percentage of samples that met PWQOs or Interim Guidelines (see Tables 2.3.1 and 2.3.2). For Duffins Creek, the results at each PWQMN station were averaged for each in-stream water chemistry parameter to provide a quantitative rating for the watershed.

The ratings for individual in-stream water chemistry parameters in both Duffins and Carruthers Creek indicate that phosphorus and bacteria concentrations are consistently higher than the targeted condition. It should be noted that the while elevated phosphorus and bacteria levels can pose potential health risks in terms of human contact with water (i.e., recreation uses), they do not necessarily indicate poor water quality conditions in terms of aquatic ecosystem health. It should also be noted that the PWQMN data reflects water quality associated with dry weather stream flow conditions, and does not necessarily capture peak concentrations of these in-stream water chemistry parameters that occur during wet weather.

Table 2.3.1 Duffins Creek In-stream Water Quality Measures and Ratings (PWQMN results from 1988 - 1994)

Parameter	**Target**	**% Samples that meet Target (Stn. #1)**	**% Samples that meet Target (Stn. #28)**	**% Samples that meet Target (Stn. #15)**	**Average**	**Rating**
Total Phosphorus	<0.03 mg/L	63	56	22	47	Fail
Nitrite	<0.06 mg/L	96	100	77	91	Excellent
Total Suspended Solids	<30 mg/L	79	83	87	83	Excellent
Bacteria (faecal coliform)	<100 counts/100 mL	36	66	27	43	Fail
Chloride	<250 mg/L	99	100	100	100	Excellent
Un-ionized Ammonia	<0.02 mg/L	100	98	98	99	Excellent

NB: Station #1 = Duffins Creek at Bayly Street
Station #15 = West Duffins Creek at 8th Concession Road
Station #28 = Brougham Creek

Table 2.3.2 Carruthers Creek In-stream Water Quality Measures and Ratings (PWQMN results from 1988 - 1994)

Parameter	**Target**	**% Samples that meet Target (Stn. #1)**	**Rating**
Total Phosphorus	<0.03 mg/L	34	Fail
Nitrite	<0.06 mg/L	97	Excellent
Total Suspended Solids	<30 mg/L	87	Excellent
Bacteria (faecal coliform)	<100 counts/100 mL	45	Fail
Chloride	<250 mg/L	100	Excellent
Un-ionized Ammonia	<0.02 mg/L	100	Excellent

NB: Station 1 = Carruthers Creek at Bayly Street

Overall, the results for in-stream water chemistry in both Duffins and Carruthers Creek generally indicate "Good" water quality conditions. The low concentrations of Nitrite, Suspended Solids, Chloride, and Un-ionized Ammonia in both watersheds indicate that water quality in these watercourses is generally suitable for supporting a healthy aquatic ecosystem. Overall water quality in these watersheds are likely the best of all the watersheds in the TRCA jursidiction with respect to aquatic ecosystem health. These results are indicative of the small proportion of urban development in these watersheds, as urban areas are often major sources of nutrient and sediment enrichment, and potentially toxic contaminants. Elevated concentrations of Phosphorus in both Duffins and Carruthers Creek highlights the importance of implementing strict stormwater quality controls associated with new urban development, and the need to implement agricultural best management practices to reduce nutrient enrichment in the rural portions of these watersheds. It is expected that in-stream concentrations of Phosphorus and Bacteria will be significantly reduced in the reaches of Duffins Creek that are downstream of the Stouffville Water Pollution Control Plant upon decommissioning of the plant, which is anticipated to occur in 2003.

In-stream Water Chemistry: Annual Loads
Historical stream flow data for the Duffins Creek watershed provides the information necessary to estimate annual loading values for Total Suspended Solids and Phosphorus, which are water quality parameters that are known to be closely correlated with stream flow. Ratings for annual loads were assigned by comparing calculations of existing annual loads for these parameters with estimates of "targeted background annual loads". The rating represents the percentage of the existing condition that meets the targeted condition. "Targeted background annual loads" are defined as the mean total annual flow (as measured by PWQMN stream gauge 02HC006 in Pickering for the monitoring period of 1949 to 1989), multiplied by the targeted in-stream concentration for each parameter (Phosphorus: 0.03 mg/L, Total Suspended Solids: 30 mg/L).

The "targeted background annual load" for Phosphorus in Duffins Creek is 2670 kg, or 2.67 tonnes, based on a mean total annual flow of 88 931 520 cubic metres and a targeted concentration of 0.03 mg/L or 30 mg/m^3. The "targeted background annual load" for Total Suspended Solids in Duffins Creek is 2,670,000 kg, or 2670 tonnes, based on a mean total annual flow of 88 931 520 cubic metres and a targeted concentration of 30 mg/L or 30,000 mg/m^3.

Annual loads of Phosphorus and Total Suspended Solids for Duffins Creek were estimated by multiplying the mean total annual flow (as measured by the stream gauge 02HC006 in Pickering for the period of 1949 to 1989) by the mean concentration for each parameter, based on the results of PWQMN sampling between 1988 and 1994 at station #1 at Bayly Street. The table 2.3.3 summarizes this rating evaluation:

Table 2.3.3 Duffins Creek Existing and Targeted Annual Load Measures and Ratings

Parameter	Existing Annual Load (tonnes/yr.)	Targeted Annual Load (tonnes/yr.)	% of Existing Load that exceeds the Target (x)	% of Existing Load that meets the Target (100 - x)	Rating
Phosphorus	4.7	2.67	43	57	Poor
Total Suspended Solids	3113	2668	14	86	Excellent

NOTE: It is recommended that the methodology for establishing the "targeted background annual loads" and estimating annual loads be reviewed, particularly for phosphorus. The PWQO for phosphorus of 0.03 mg/L is more representative of dry weather conditions. Spreadsheet model calculations under existing conditions in the Duffins Creek watershed indicate phosphorus concentrations are 0.18 and 0.02 mg/L during wet and dry weather, respectively. Since wet weather run-off contributes approximately 46% of the total annual run-off in the Duffins watershed (Stantec and Aquafor Beech, 2003), loading rates exceed the target based on the 0.03 mg/L criteria. Alternative approaches to consider for target setting include: specifying a targeted percent reduction of the existing load; or, specifying separate wet and dry weather targeted loads.

Since no historical stream flow data is currently available for Carruthers Creek, the mean total annual flow for this watercourse cannot be properly characterized. Therefore no calculation of "targeted background annual load" can be made at this time, and the Carruthers Creek was not evaluated for the measures of annual loads for Phosphorus and Total Suspended Solids. A permanent stream flow gauge has been installed on Carruthers Creek in 2002 which will provide the data required to calculate mean total annual flow and annual loads for these parameters in future watershed report cards.

Stormwater Management
The percentage of developed land area with Level 1 stormwater quality control in place (both quality and quantity control) is the measure that will be used to evaluate progress towards this objective in terms of mitigating the impacts of urban stormwater run-off on water quality. Presently in the Duffins Creek watershed, only 31% of developed areas have Level 1 stormwater quality control measures in place. Therefore the Duffins Creek watershed is rated as a "Fail" for this measure. In the Carruthers Creek watershed, 64% of developed areas have Level 1 stormwater quality control measures in place, so it receives a rating of "Fair" for this measure.

It should be noted that prior to 1994, there was no requirement for the provision of Level 1 stormwater quality control in new urban development. While poor ratings for these watersheds in terms of the indicator of stormwater management indicate the need for investment in stormwater management retrofit initiatives for existing urban areas without adequate stormwater control, they do not indicate a lack of compliance with provincial stormwater management criteria because much of the existing urban areas in these watersheds were developed prior to 1994. Since current approvals processes for new urban development require Level 1 stormwater quality control, as development continues, this rating will improve.

Overall Rating
The overall ratings assigned to each watershed for this objective are based on a qualitative review of the ratings for each measure. Both the Duffins and Carruthers Creek watersheds received an overall rating of "Good" for this objective based on the rationale that dry weather water quality conditions (represented by the PWQMN results from 1988 - 1994) in these creeks are generally "Good" in terms of aquatic ecosystem health. The extensive areas of natural vegetation, sandy soils, and significant groundwater discharges to stream baseflow in Duffins Creek and in localized parts of Carruthers Creek play a key role in maintaining the relatively good water quality conditions that exist in these watercourses. The headwater tributaries of Duffins and Carruthers Creek exhibit some of the best water quality conditions of all streams in the Greater Toronto Area.

Considering that the indicator of stormwater management pertains only to the urban portions of the watersheds which at present do not represent a large proportion of the total land area, the rating for this measure should not be weighted equally with the ratings for in-stream water chemistry. Additionally, stormwater retrofit studies are currently underway to address pollutant loads from existing urban areas without Level 1 stormwater control.

Objective #9 Minimize in-stream sediment associated with construction activity			Overall Rating	
			Duffins	Carruthers
			Poor	*Poor*
Indicators	Measures	Targets	2002 Rating	
			Duffins	Carruthers
• compliance with Municipal Erosion and Sediment Control By-laws	• percent of construction permits found to be in compliance with Municipal Erosion and Sediment Control By-laws	• 100% compliance with approved permits under Municipal Erosion and Sediment Control By-laws	*Poor*	*Poor*
	• percent of sediment ponds checked annually	• 100% of sediment ponds checked annually	Further study required	Further study required
	• percent of sediment ponds maintained when required	• 100% of ponds maintained when required	Further study required	Further study required

References:
Clarifica, Inc., 2002, TRCA Model By-law for Erosion and Sediment Control, Litter and Debris Control and Dust Control Relating to Urban Development Activities in the TRCA jursidiction, The Toronto and Region Conservation Authority, April 2002.

Comments on 2002 Ratings

Despite efforts by all agencies, construction activities continue to be a major source of sediment contamination in local watercourses. Ratings of "Poor" for this objective in both Duffins and Carruthers Creek watersheds are based on observations over the past two years and best professional judgement with regard to current levels of implementation of erosion and sediment control best management practices on construction sites. In future reporting periods, information on the number of construction permits found to be in compliance with Municipal Erosion and Sediment Control by-laws will be used to assign a quantitative rating of the level of achievement of the target.

Erosion and sediment impacts on local watercourses associated with construction activities is an important issue that requires further study to develop effective monitoring programs, indices for evaluating levels of impact on aquatic communities, and targets for management measures. The TRCA has recently completed two important initiatives designed to improve the quality and effectiveness of erosion and sediment control measures being implemented on urban construction sites. The first initiative involved the development of a "model" by-law for erosion and sediment control, mud tracking control, litter and debris control, and dust control. Over the upcoming year, TRCA plans to meet with each of the municipalities in the Duffins and Carruthers Creek watersheds to discuss adoption and implementation options. Once new municipal by-laws are implemented, routine inspection of erosion and sediment control practices on active construction sites will be required to provide the information needed to evaluate levels of compliance. The second initiative was to develop a modelling framework to simulate erosion and sediment transport on construction sites and evaluate treatment facility performance. Over the next two to three years, TRCA will be monitoring a sediment and erosion control facility in the Town of Richmond Hill. Data collected from this exercise will be used to calibrate the modelling component. It is anticipated that new sizing criteria for the design of temporary erosion and sediment control ponds will be developed using this information. In the interim, TRCA has adopted a revised, more stringent criteria that requires both a permanent pool and an active storage component for all temporary erosion and sediment control ponds on construction sites. The revised criteria will be a requirement for new development applications until a new criteria is established. Additionally, there is a need to track the number of temporary sediment control ponds that have been designed according to the TRCA's interim sediment control criteria..

Objective #10	Reduce water quality contamination associated with wastewater discharges		Overall Rating	
			Duffins	**Carruthers**
			Poor	**Not applicable***
Indicators	Measures	Targets	2002 Rating	
			Duffins	Carruthers
• in-stream water chemistry	• in-stream phosphorus concentrations due to Sewage Treatment Plant	• in-stream phosphorus concentration due to Sewage Treatment Plant should meet Provincial Water Quality Objectives (0.03 mg/L) for all flow levels upon leaving the sub-catchment (i.e., at 8th Concession and Reesor Creek)	Fail	Not applicable*
• effluent quality	• sewage treatment plant effluent quality	• sewage treatment plant effluent quality meets Certificate of Approval	Fail	Not applicable*
• sewage treatment plant by-passes	• number of sewage treatment plant by-passes	• zero sewage treatment plant by-passes	Excellent	Not applicable*

***Note: There are no point source discharges of Sewage Treatment Plant effluent in Carruthers Creek.**

In-stream water chemistry

Ratings for in-stream water chemistry are based on estimates of in-stream phosphorus concentrations at four locations downstream of the Stouffville Water Pollution Control Plant (WPCP). Dilution ratios and phosphorus concentrations attributed to the Stouffville WPCP under existing conditions were calculated for a range of flows at stream gauging stations downstream of the plant (see Table 2.3.4 for results). The Stouffville WPCP was not found to impact water quality during high flow conditions associated with wet weather conditions. During dry weather conditions on Stouffville Creek, at the stream gauge location immediately downstream of the plant , phosphorus concentrations attributed to the Stouffville WPCP failed to meet the Provincial Water Quality Objective (PWQO) for phosphorus (0.03 mg/L) for at least half of the monthly average flows. Further downstream, at 8th Concession on Reesor Creek, phosphorus concentrations are predicted to be above the PWQO for approximately one quarter of the monthly average flows as a result of plant effluent. During extreme low flow conditions, represented as the minimum observed 7 day flow over a twenty year recurrence interval (7Q20), phosphorus concentrations due to the Stouffville WPCP are predicted to exceeded the phosphorus PWQO as far downstream as Taunton Road. These results suggest that impacts to aquatic life from chlorine levels in plant effluent are also likely. Based on these results, a rating of "Fail" was assigned to Duffins Creek for this objective.

The Stouffville WPCP is scheduled to be decommissioned by the Regional Municipality of York by the end of 2003, which will result in a significant improvement to in-stream water chemistry conditions in Duffins Creek.

Table 2.3.4 Dilution ratios and phosphorus concentrations attributed to the Stouffville WPCP at four downstream locations

Location	**Average streamflow percentiles**	**Dilution ratio**	**P concentration attributed to WPCP (mg/L)**
Stouffville Creek	median 25th percentile 10th percentile 7Q20	3.2 2.3 2 data not available	0.05 0.07 0.09 data not available
Reesor Creek @ 8th Concession Road	median 25th percentile 10th percentile 7Q20	7 5 4 data not available	0.02 0.03 0.04 data not available
West Duffins Creek @ Green River Road	median 25th percentile 10th percentile 7Q20	data not available data not available data not available 2	data not available data not available data not available 0.09
Duffins Creek Mouth @ Kingston Road	median 25th percentile 10th percentile 7Q20	4633259	0.004 0.01 0.01 0.02

NB: Provincial Water Quality Objective for phosphorus is 0.03 mg/L;
7Q20 represents the minimum 7 day flow over a 20 year recurrence interval.

Effluent quality
The rating for effluent quality is based on a review of effluent quality records from the Stouffville WPCP covering the period of January 1998 to December 2001. Effluent quality records were examined to determine the number of monitoring periods during which no parameters were found to exceed the criteria set out in the Certificate of Approval for the Plant. The Certificate of Approval criteria define an exceedance as any instance when the average concentration or loading value for the preceding four month period is in excess of the criteria set out in the Certificate of Approval. These criteria apply to the parameters of Biological Oxygen Demand (B.O.D.), Suspended Solids, and Phosphorus. Special criteria apply to Ammonium, where an exceedance is defined as any observed concentration or loading value that is in excess of the Certificate of Approval criteria between June and September of each year.

During the period of 1998 to 2001, exceedances of Certificate of Approval criteria occurred most frequently for Ammonium (6 of 12 monitoring periods). Exceedances also occurred for B.O.D. (3 of 12 monitoring periods). Only 4 of 12 monitoring periods had no exceedances of any kind, which represents a 33% achievement of the target, and a rating of “Fail”.

Sewage Treatment Plant By-passes
Ratings for this indicator are based on records from the Stouffville WPCP from the period of 1998 to 2001. During this period, no by-pass events occurred, which represents a 100% achievement of the target and a rating of “Excellent”.

Overall Rating
The overall rating of “Poor” assigned to the Duffins Creek watershed for this objective are based on a qualitative review of the ratings for each measure.

GOAL: To protect aquatic habitat and species	Duffins	Carruthers
	Good	**Fair**

Objective #11 Protect and restore native aquatic species and communities			**Overall Rating**	
			Duffins	**Carruthers**
			Good	**Fair**
INDICATORS	MEASURES	TARGETS	2002 RATING	
			Duffins	Carruthers
• fish and invertebrate communities	• invertebrate indices	• to be determined pending further study	Further study required	Further study required
	• Index of Biotic Integrity (IBI)	• minimum IBI of "Good"	Fair	Fair
	• presence and abundance of indicator species	• maintain or achieve historical distribution of targeted indicator species as specified for reaches in the Fisheries Management Plan*	Good	Fair
• in-stream habitat	• percent in-stream woody cover	• to be determined pending further study	Further study required	Further study required
	• percent riffle substrate	• to be determined pending further study	Further study required	Further study required
	• ratio of baseflow to total annual flow	• as specified for reaches in Fisheries Management Plan*	*Good*	*Fair*
• water chemistry	• water temperature	• as specified for reaches in Fisheries Management Plan*	Further study required	Further study required
	• Total Suspended Solids		Good	Good
	• Phosphorus		Fail	Fail
	• Chloride		Good	Good
• fish passage to critical habitat (breeding, rearing, foraging grounds)	• presence of in-stream barriers	• only strategic barriers for fisheries management to remain*	Good	Good

References:

*TRCA 2003. Duffins and Carruthers Creek Watersheds Fisheries Management Plan

Fish and Invertebrate Communities

Evaluating the current condition of the Duffins and Carruthers Creek watersheds in terms of fish and invertebrate communities involves the use of invertebrate indices, Index of Biotic Integrity (IBI) scores, and information on the presence and abundance of indicator species.

At this time there is an insufficient amount of monitoring data available on invertebrates associated with these watercourses to properly characterize these communities. Once more information is obtained through continued monitoring work by the Regional Watershed Monitoring Network, a better understanding of the invertebrate communities associated with the Duffins and Carruthers Creeks will be developed which will allow ratings to be assigned and trends to be identified in future watershed report card processes.

The presence or absence of aquatic communities and/or indicator species are considered to be good indicators of aquatic ecosystem health as they are integrators of a variety of disturbances to their environment. The Index of Biotic Integrity (IBI) is a method for evaluating aquatic ecosystem health based on fish community associations that is widely used in North America. In this method, IBI scores and ratings are calculated for individual monitoring stations based on measurements related to the diversity of fish species present, the presence of indicator species, an evaluation of the fish communities, and the abundance of fish. For example, in many Southern Ontario watersheds, the presence of brook trout is an indicator of a healthy coldwater ecosystem, while a high abundance of longnose dace or blacknose dace generally indicates a degraded aquatic ecosystem. Overall IBI ratings are assigned by examining the frequency and distribution of IBI scores over the entire watershed. Using a standard method such as IBI for assessing general aquatic ecosystem health allows the results to be compared over time to identify changes and monitor trends, and allows comparisons to be made with other watersheds in the Greater Toronto Region.

Based on IBI scores from 32 monitoring stations on Duffins Creek and 6 stations on Carruthers Creek, both the Duffins and Carruthers Creek receive overall Index of Biotic Integrity scores of “Fair”. The rating of “Fair” indicates that there are a significant number of opportunities for improving aquatic habitat and fish communities in these watersheds.

The presence of cold water fish species such as brook trout and slimy and mottled sculpin are indicators of healthy aquatic ecosystems in these watersheds. In terms of the presence and abundance of indicator species, the Duffins Creek watershed is rated as “Good”, based on the number and diversity of cold water species of fish that have been observed through monitoring work, and the presence of brook trout at several monitoring stations. Monitoring results from the Carruthers Creek watershed indicate a lower diversity of cold water fish species and no evidence of brook trout being present, and so it is rated as “Fair” for this measure. In both the Duffins and Carruthers Creek watersheds there is evidence suggesting that more reaches would have supported brook trout in the past than what has been observed at present. These ratings also reflect the fact that Atlantic salmon, which historically would have migrated into these creeks from Lake Ontario, have been extirpated.

In-stream habitat

Ratings assigned for in-stream habitat are based on assessments of in-stream woody cover, riffle substrate, and baseflow as a percent of total annual flow for individual reaches. At this time, information on in-stream woody cover and riffle substrate is not sufficiently detailed for setting targets and assigning ratings for these measures. Fluvial geomorphology work that is scheduled to be undertaken in 2003 will provide this type of detailed information about in-stream conditions that will allow targets and ratings to be established in the near future.

Ratings for the measure of baseflow as a percentage of total annual flow are based on Habitat Suitability Indices developed in the United States which utilize annual baseflow as a percentage of average annual flow to determine habitat suitability for trout species. This ratio provides an indication of the stability of stream flow throughout the year. Higher ratios indicate more stable flows which provide more suitable conditions for sensitive coldwater species of fish. Ratios greater than 50% are considered to be excellent for trout production, ratios between 25 to 50% are good for trout production, and ratios less than 25% are poor for trout production. Ratios of baseflow to total annual flow for the thirty reaches, or sub-basins of Duffins Creek were calculated based on outputs of the water balance model which estimates annual evapo-transpiration, groundwater infiltration and run-off for each sub-basin. Annual baseflow volumes were calculated based on the work by Gerber (2003). Total annual flow for each of the thirty sub-basins was calculated as the sum of baseflow volume plus run-off volume.

The ratings of "Good" for Duffins Creek and "Fair" for Carruthers Creek for the ratio of baseflow to total annual flow represent qualitative assessments of the overall results for individual reaches because information available at this time is insufficient to properly establish quantitative targets for each of the overall watersheds. A detailed breakdown of the results for individual reaches can be found in the Duffins and Carruthers Creek Fisheries Management Plan.

Water Chemistry

Ratings assigned for water chemistry parameters are based on the percent of samples tested through the Provincial Water Quality Monitoring Network that meet Provincial Water Quality Objectives (PWQO) or Interim Guidelines (see section 2.3 Surface Water Quality; Objective #8 for a breakdown of the results). These guidelines have been established for the protection of aquatic life and recreation uses of water resources. In terms of aquatic ecosystem health, water quality conditions in both watersheds are generally good, with the exceptions of reaches immediately downstream of the Stouffville Water Pollution Control Plant on Duffins Creek, and locations along and downstream of Miller's Creek, and the lower portions of the Duffins and Carruthers Creek watersheds, where suspended solids contamination from urban development activities is currently a problem. It should be noted that the in-stream water chemistry results are based on a limited number and frequency of samples and therefore will not reflect peak concentrations typically associated with the spring run-off or the "first flush" of stormwater run-off. Additionally, the PWQMN in-stream water chemistry results reflect conditions at monitoring stations that are located on higher order tributaries and do not provide any indication of the potential for elevated impacts on lower order, headwater streams. The health of lower order, headwater streams is being tracked by the Regional Watershed Monitoring Network through the use of biological monitoring indicators, rather than water chemistry indicators, which is a more cost-effective approach that integrates the cumulative effects of the presence of multiple contaminants.

Fish Passage to Critical Habitat

The measure for this indicator is the number of in-stream barriers to fish migration that are present in each watershed. Ratings of "Good" have been assigned to both watersheds, which reflects the fact that although many fish barriers exist in both Duffins Creek and Carruthers Creeks, they do not limit fish movement as severely as in other watersheds in the TRCA jurisdiction. However, some barriers are present that could be preventing fish from accessing critical habitat in the headwaters areas, and opportunities exist to improve fish passages in each of these watersheds. Concern over competition between resident populations of trout (native brook trout and naturalized brown trout) and migratory trout (rainbow trout and chinook salmon) necessitates maintenance of a partition between these two fish communities. The existing barriers on West Duffins Creek north of Whitevale Road, and north of Highway 7 on East Duffins Creek fulfill this role and should be maintained as fisheries management structures.

Overall Rating

The overall rating of "Good" assigned to Duffins Creek, and "Fair" for Carruthers Creek for this objective are based on a qualitative review of the ratings for each measure.

Objective #12 Protect and restore the riparian zone and associated functions			**OVERALL RATING**	
			Duffins	**Carruthers**
			Fair	**Fair**
INDICATORS	MEASURES	TARGETS	2002 RATING	
			Duffins	Carruthers
• riparian zone vegetation	• percent of total stream bank length with riparian vegetation cover	• 100% coverage with riparian vegetation	Good	Good
	• percent of total stream bank length with woody riparian vegetation cover	• minimum of 75% coverage with woody riparian vegetation	Fair	Poor

Comments on the 2002 Ratings

The ratings for this objective are based on assessments of riparian vegetation cover and the woody component of vegetation along stream banks. The total stream length for each watershed was calculated with the aid of a Geographic Information System (GIS), and the value was multiplied by two to provide the total length of stream bank. Information on riparian vegetation cover was derived by interpreting 1999 aerial photographs. Areas of riparian vegetation cover were delineated and classified according to the following five categories: forest; successional; meadow; wetland; and bare.

Table 2.4.1 Riparian Vegetation Cover Category Definitions and Results of 2002 Assessment

Riparian Vegetation Cover Category	**Definition**	**Duffins**		**Carruthers**	
		Length of Stream Bank (m)	**% of Total**	**Length of Stream Bank (m)**	**% of Total**
Forest	Areas having a woody component of greater than 25%, and a minimum of 3 trees wide	377990	50	47986	38
Successional	Sparsely vegetated areas having a minor woody component (10 - 25% woody vegetation)	6908	1	4626	4
Meadow	Areas dominated by uncultivated grasses (does not include fallow fields, pastures, or manicured grass)	120140	16	33800	27
Wetland	Areas dominated by wetland: marsh; bog (Difficulty exists in distinguishing between swamp and forest due to the canopy cover)	70534	9	7832	6
Bare	Areas lacking riparian vegetation where it is either dominated by cropped grasses or is devoid of any vegetation at the time of the air photo	175492	23	30412	24
Total		751064	99	124656	99

Based on the delineation and classification of riparian vegetation cover, calculations were made of the length of stream bank, and percent of the total length under each riparian cover category. Table 2.4.1 describes the characteristics that define each of the riparian vegetation cover categories and the results of the assessments of length of stream bank under each type of riparian vegetation cover for each watershed.

Ratings for the measure of percent of total stream length with riparian vegetation cover are based a quantitative evaluation of the current level of achievement of the target. Values for the percent of total stream length with riparian vegetation cover were calculated by adding the results in Table 2.4.1 for all riparian vegetation cover categories except for the “Bare” category, for each watershed. In the Duffins Creek watershed, 76% of the total stream bank length has riparian vegetation cover which corresponds to an achievement rating of “Good”. In the Carruthers Creek watershed, it was found that 75% of the total stream bank length has riparian vegetation cover, which also corresponds to an achievement rating of “Good”.

Ratings for the measure of percent of total stream bank length with woody riparian vegetation cover are also based on a quantitative evaluation of the current level of achievement of the target. Values for this measure were calculated by adding the Table 2.4.1 results for the categories of Forest and Successional, which are the only categories that contain a woody vegetation component. In the Duffins Creek watershed, it was found that 51% of the total stream bank length has riparian vegetation with a woody component, which corresponds to a 68% achievement of the target and an achievement rating of “Fair”. Similarly, in the Carruthers Creek watershed, it was found that 42% of the total stream bank length has riparian vegetation cover with a woody component, which corresponds to a 56% achievement of the target and an achievement rating of “Poor”. Tables 2.4.2 and 2.4.3 summarize the results for Duffins and Carruthers Creek, respectively.

Table 2.4.2 Duffins Creek Riparian Vegetation Target and Achievement Ratings in 2002

Measure	Existing (2002)	Target	% of Target Achieved	Achievement Rating
% of total stream bank length with riparian vegetation cover (includes all categories except Bare)	76	100	76	Good
% of total stream length with woody riparian vegetation cover (Forest and Successional categories only)	51	75	68	Fair

Table 2.4.3 Carruthers Creek Riparian Vegetation Target and Achievement Ratings in 2002

Measure	Existing (2002)	Target	% of Target Achieved	Achievement Rating
% of total stream bank length with riparian vegetation cover (all categories except Bare)	75	100	75	Good
% of total stream length with woody riparian vegetation cover (Forest and Successional categories only)	42	75	56	Poor

Overall ratings for this objective were assigned based on a qualitative review of the ratings for each measure and the best professional judgement of TRCA staff with regard to the overall state of riparian zones in each watershed. These results indicate that riparian vegetation coverage on stream banks is generally good in each watershed. However there is a need to continue with restoration plantings of woody species along stream banks in order to improve the proportion of woody riparian vegetation, which will benefit the food chain of the stream ecosystem, improve the stability of the stream banks and, as the woody vegetation matures, will help to regulate water temperature by providing shade to the stream channel.

Objective #13	Maintain or restore the natural variability of annual and seasonal stream flow		OVERALL RATING	
			Duffins	**Carruthers**
			Further study required	**Further study required**
INDICATORS	MEASURES	TARGETS	2002 RATING	
			Duffins	Carruthers
• stream hydrograph (annual and seasonal variation in hydrological regimes)	• flow events (timing, duration, frequency, and rate of change)	• to be determined with consideration for maintaining or restoring historical variability of the hydrograph, and consideration of the timing of low flows with respect to sensitive life cycle requirements of aquatic communities	Further study required	Further study required
	• ratio of baseflow to total annual flow		*Good*	*Fair*
	• ratio of seasonal baseflow to total seasonal flow		Further study required	Further study required

Comments on the 2002 Ratings
At this time, more detailed examination of historical stream flow data with consideration of the requirements of aquatic communities is required for both watersheds in order to improve our understanding of the relationship between the stream hydrograph and aquatic community health. An evaluation of the stream hydrographs of the Duffins and Carruthers Creeks with respect to the life cycle requirements of aquatic communities will be provided in the forthcoming Duffins and Carruthers Creek Fisheries Management Plan.

An explanation of the rationale behind the ratings for the measure of ratio of baseflow to total annual flow can be found under Objective #11 in this section.

GOAL: To protect and enhance terrestrial habitat and species	Duffins	Carruthers
	Good	**Fair**

Objective #14	**Increase the percent natural cover to a quantity which provides targeted biodiversity and supports recreational uses**		OVERALL RATING	
			Duffins	**Carruthers**
			Good	**Fair**
INDICATORS	MEASURES	TARGETS	2002 RATING	
			Duffins	Carruthers
• quantity	• percent natural land cover	• ≥49% in Duffins Creek and ≥30% in Carruthers Creek	Good	Excellent
• distribution	• distribution of the natural land cover in relation to total watershed area (as measured by distance-to-centroid)	• distance-to-centroid ≤2350 m for Duffins Creek and ≤1750 m for Carruthers Creek	Excellent	Excellent
• size	• average patch size scores	• ≥3.87 in Duffins Creek, ≥2.89 in Carruthers Creek	Poor	Good
• shape	• average patch shape scores	• ≥2.79 in Duffins Creek, ≥1.89 in Carruthers Creek	Poor	Excellent

Reference:

TRCA Terrestrial Natural Heritage Strategy (under development)

Comments on the 2002 ratings
To monitor and evaluate progress towards this objective, TRCA staff have selected four indicators that address critical aspects of terrestrial ecosystems: quantity of natural cover; distribution of natural cover; size of natural cover patches; and shape of natural cover patches. Quantity of natural cover was measured by calculating the percent of the total watershed area that is under natural land cover, which includes forest, meadow, wetland and successional land cover types. The measure of “distance-to-centroid” was used to evaluate the distribution of natural cover over the watershed. For this measure, a GIS is used to determine the Cartesian coordinates of the centroid (the theoretical “centre of mass”) of the mosaic of patches of natural cover that make-up the existing terrestrial system, and the Cartesian coordinates of the centroid of the watershed. The measure of “distance-to-centroid” is the distance that separates the two sets of coordinates. The ideal condition for this measure is a distance of zero, which occurs when the patches of natural cover that make up the terrestrial system are distributed evenly across the watershed. Similarly, the existing and targeted terrestrial systems were evaluated in terms of size and shape indicators by using a GIS to quantify the area of each patch of natural land cover (size indicator), and to establish the ratio of patch area to perimeter length (shape indicator) which provides a means of quantifying the extent to which each natural land cover patch is being influenced by “edge effects”. These values were transformed into patch size and shape scores which are based on a scale of 0 to 5. Patches that score high are considered to be quality habitats capable of supporting a variety of sensitive species, mid-scoring patches are considered to be in fair condition, and low scoring patches support only the most robust species.

Ratings for each indicator were assigned by comparing existing natural land cover conditions to the targeted terrestrial system. The results of these assessments and the associated ratings are provided in table 2.5.1, and table 2.5.2.

Table 2.5.1 Duffins Creek Watershed Terrestrial Natural Heritage Targets and 2002 Ratings

Measure	Existing (2002)	Target*	% of Target Achieved	Achievement Rating
Percent natural land cover	37	≥48	77	Good
Distance to centroid (metres)	992	≤2351	100	Excellent
Average patch size score	2.23	≥3.87	58	Poor
Average patch shape score	1.621	≥2.79	58	Poor

* The technical analyses conducted to develop these targets utilized the Duffins Creek watershed boundary that was derived from 1:50 000 scale topographic mapping data. Subsequent technical studies utilized a new watershed boundary that was derived using higher resolution data (1:10 000 scale digital elevation model). This discrepancy accounts for the difference between the target for natural cover indicated here (48% using the lower resolution watershed boundary) and the target indicated in the watershed plan (49% using the higher resolution watershed boundary). In this reporting period, the technical analyses required to calculate the targets were not repeated using the new watershed boundary. These targets will be updated in the next reporting period.

The targeted condition for the terrestrial natural heritage system of the Duffins Creek watershed represents a net increase in area under natural land cover in such a way that also improves the average size and shape scores for natural land cover patches. In the targeted condition, increases to natural land cover are concentrated in the northern portions of the watershed, which results in a greater distance-to-centroid value, and represents a less-desirable condition for the distribution of natural land cover over the watershed. However, the benefits to other scores (i.e., average patch size and shape), and to the connectivity of the natural system as a whole that are associated with this change makes this condition a preferable option. When the measure of distance-to-centroid is examined independently of other measures, the 2002 scores are more preferable than those associated with the targeted condition, so they are considered to represent a 100% achievement of the target.

Table 2.5.2 Carruthers Creek Terrestrial Natural Heritage Targets and 2002 Ratings

Measure	Existing (2002)	Target	% of Target Achieved	Rating
% of watershed under natural land cover	28	≥27	100	Excellent
Distance-to-centroid (metres)	784	≤1750	100	Excellent
Average patch size score	2.1	≥2.89	73	Good
Average patch shape score	2.02	≥1.89	100	Excellent

* The technical analyses conducted to develop these targets utilized the Carruthers Creek watershed boundary that was derived from 1:50 000 scale topographic mapping data. Subsequent technical studies utilized a new watershed boundary that was derived using higher resolution data (1:10 000 scale digital elevation model). This discrepancy accounts for the difference between the target for natural cover indicated here (27% using the lower resolution watershed boundary) and the target indicated in the watershed plan (30% using the higher resolution watershed boundary). In this reporting period, the technical analyses required to calculate the targets were not repeated using the new watershed boundary. These targets will be updated in the next reporting period.

The targeted condition for the terrestrial natural heritage system of the Carruthers Creek watershed incorporates a net loss in natural land cover associated with the expansion of urban settlement areas, while improving the average size of natural land cover patches. While improvements to the size of existing natural cover patches will contribute to shifting the centroid of all natural land cover patches further away from the centroid of the watershed and decreasing the average patch shape score, this change is still considered to be the most preferable option in consideration of constraints associated with future plans for urban development. When the measures of both distance-to-centroid and average patch shape are examined independently of other measures, the 2002 scores are more preferable than those associated with the targeted condition. Therefore the existing (2002) conditions for these measures are considered to represent full achievement of the target (100%).

It is important to acknowledge that the target for natural land cover in the Carruthers Creek watershed was established with consideration of the constraints associated with existing developed areas and lands that are designated for development in the future. Fewer opportunities exist for restoring natural land cover in the Carruthers Creek watershed, than in the Duffins Creek watershed because the proportion of the watershed in public ownership is much less.

It is acknowledged that the target for natural land cover in the Carruthers Creek watershed does not reflect conditions required to achieve biodiversity targets (i.e., support species-of-concern) or to significantly enhance recreational use opportunities to the same extent that the targets for the Duffins Creek watershed do. However, the target does represent a significant improvement from existing conditions and is believed to be the best condition that could be achieved within the constraints to regeneration that currently exist.

The overall ratings reflect a qualitative assessment of the current level of achievement of this objective which is based on a review of individual ratings for each measure and the best professional judgement of TRCA staff. The overall rating of “Good” for the Duffins Creek watershed reflects the fact that the existing amount of natural land cover provides a good basis on which to build a healthy and functioning terrestrial system, although improvements to the size, shape and distribution of natural land cover patches are needed to provide the conditions necessary to achieve biodiversity targets (i.e., support species-of-concern). The overall rating of “Fair” for the Carruthers Creek watershed reflects the fact that although a large percent of the target has already been achieved, the terrestrial system remains in a “Fair” state of health in terms of ability to support species-of-concern (biodiversity targets) and to provide the land base needed for outdoor recreation uses.

Objective #15	Protect the natural system quality and function from the influence of surrounding land uses		OVERALL RATING	
			Duffins	Carruthers
			Fair	**Fair**
INDICATORS	MEASURES	TARGETS	2002 RATING	
			Duffins	Carruthers
• matrix influence	• compatibility of surrounding land uses within 2 km of the edge of each natural cover patch	• targeted ratio of urban, natural and rural/agricultural land cover surrounding each natural cover patch, as defined by the Regional Terrestrial Natural Heritage model matrix influence scores	Fair	Excellent

Comments on the 2002 Ratings

Ratings for this objective are based on a landscape analysis that considers the influence of adjacent land uses on the status of individual patches of natural land cover as viable habitat areas. Matrix influence scores are assigned to each natural land cover patch and an average score is calculated for each watershed. The targeted condition for the terrestrial system of the Duffins Creek watershed involves increasing natural land cover from 37% to 48%. The average matrix influence score in the targeted condition is 4.16. The average matrix influence score for existing conditions on the Duffins Creek watershed is 2.68, which represents an achievement of 64% of the target and a rating of “Fair”.

In order to accommodate plans for future urban development in accordance with the Regional Official Plan, the targeted condition for the terrestrial system of the Carruthers Creek watershed involves a small increase in natural land cover from 29% to 30%. The average matrix influence score for the targeted condition is 3.11. The average matrix influence score for existing conditions on the Carruthers Creek watershed is 2.67, which represents and achievement of 86% of the target and a rating of “Excellent”.

Based on the state of health of the terrestrial system in the Carruthers watershed, and in consideration of the surrounding land uses which impose similar impacts to those in the Duffins, a “Fair” rating is more appropriate. It is recommended that application of the matrix influence score on a watershed scale be reviewed prior to the next report card and consideration be given to developing a variation of this score that may be more appropriate for watershed scale applications.

Objective #16	**Protect and restore all native vegetation community types and species to targeted levels**		**OVERALL RATING**	
			Duffins	**Carruthers**
			Further study required	**Further study required**
INDICATORS	MEASURES	TARGETS	2002 RATING	
			Duffins	Carruthers
• vegetation type diversity	• number of vegetation types represented	• to be determined pending further technical analysis	Further study required	Further study required
• species diversity	• number of species represented	• to be determined pending further technical analysis	Further study required	Further study required

Comments on the 2002 Ratings
In order to establish targets for these measures further inventory work and technical analysis of information on flora and fauna abundance and distribution in the Duffins and Carruthers Creek watersheds is required.

GOAL: To provide appropriate sustainable public use which promotes environmental awareness and enhancement	Duffins	Carruthers
	Good	Poor

Objective #17 Create continuous watershed trails in the greenspace system linking Lake Ontario and the Oak Ridges Moraine			Overall Rating	
			Duffins	**Carruthers**
			Fair	**Fair**
Indicators	Measures	Targets	2002 Rating	
			Duffins	Carruthers
• Inter-regional trail network	• Percent completion of the inter-regional trail network	• 100% completion	Fail	Fail

Comments on the 2002 Ratings
Ratings for this objective are based on a quantative evaluation of the total length of trails that have been completed in each watershed, compared to the target condition, which represents fully implemented plans by local municipalities to extend the Trans Canada Trail, the Oak Ridges Moraine Trail, the Waterfront Trail through these watersheds.

In the Duffins Creek watershed, there are currently 40 km of trails completed, with plans to complete a total of 120 km, which represents a total achievement of 33% of the target, and a rating of "Fail".

In the Carruthers Creek watershed, there are currently 3 km of trails completed, with plans to complete a total of 33 km, which represents a total achievement of 9% of the target, and a rating of "Fail".

The overall ratings of "Fair" reflects the fact that there are significant opportunities to extend the current trail network into a more continuous system linking the Lake Ontario waterfront to the Oak Ridges Moraine. Although ratings for this objective are low based on the proportion of proposed trails that have been completed to date, there are strong efforts being put towards planning and implementing the remaining sections of the inter-regional trails by municipalities in each watershed. Therefore significant improvements with regard to the achievement of this objective are anticipated in the near future.

Objective #18	Manage the greenspace system for planned sustainable uses and public enjoyment		Overall Rating	
			Duffins	**Carruthers**
			Good	**Poor**
Indicators	Measures	Targets	2002 Rating	
			Duffins	Carruthers
• Sustainable public use and enjoyment	• Participation in planned uses as defined in the Management Plan	• Increase participation in planned uses and decrease participation in unplanned uses	Further study required	Further study required
• Management Plans	• Number of Management Plans completed for areas identified	• 100% completion	Further study required	Further study required

Comments on the 2002 Ratings
Despite the fact that information is not available to quantitatively rate the selected indicators and measures, adequate local knowledge is available to provide a basis for a qualitative evaluation of the overall objective.

Within the Duffins watershed, the following factors were considered: number of completed management plans for public lands (e.g., Greenwood Mgmt Plan, Headwaters Mgmt. Plan, Duffins Marsh Restoration Plan, etc.); available public use opportunities (e.g., Seaton Trail, Oak Ridges Trail,); and municipal parks and recreation strategic plans.

Within the Carruthers watershed, the Town of Ajax Parks and Recreation Department has been proactive in developing Management and Trails Plans, and the Waterfront Regeneration Trust has established the waterfront trail, yet there are still opportunities to be realized in the middle and upper reaches of that watershed.

There is a need to ensure that environmental management system-based approaches to the management of publicly-accessible greenspace be employed to minimize impacts associated with public use.

Objective #19	Improve greenspace accessibility while ensuring compatibility between social benefits and ecological health		OVERALL RATING	
			Duffins	**Carruthers**
			Good	**Poor**
INDICATORS	MEASURES	TARGETS	2002 RATING	
			Duffins	Carruthers
• Accessible greenspace	• Number of access points to publically owned greenspace as identified in the management plan	• 100% completion of the development of all planned access points	Further study required	Further study required

Comments on the 2002 Ratings

Ratings for this objective are based on qualitative comparisons of the amount of accessible publicly-owned greenspace land in the Duffins and Carruthers Creek watersheds with other watersheds in the TRCA jurisdiction, most notably, the Humber River watershed which received an overall rating of "Good" in the Watershed Report Card of 2000.

In the Duffins Creek watershed, a rating of "Good" reflects the fact that over 50% of the total watershed area is under ownership and care of the TRCA, Federal and Provincial governments and regional and local municipalities, providing great potential to increase the amount of publicly owned and accessible greenspace as development proceeds and population densities increase in each watershed. At the present time, publicly accessible greenspace still remains fragmented and the number of year round access points needs improvement.

In the Carruthers Creek watershed, a rating of "Poor" has been assigned due to the fact that only 25 hectares of public greenspace exists, that being the lands around the Carruthers Creek Marsh, at the mouth of Carruthers Creek, which represents less than 1% of the total watershed area..

The overall ratings reflect the fact that in both watersheds, the current greenspace network is somewhat fragmented, and that opportunities exist to significantly increase the value of individual areas of greenspace by linking them together into a continuous, integrated, and accessible system. Future initiatives to link these areas include proposed extensions to the Trans Canada Trail, the Oak Ridges Moraine Trail, the Waterfront Trail and other trail planning initiatives proposed by local municipalities.

2.7 Human Heritage

GOAL: To preserve and interpret our evolving human heritage resources	**Duffins**	**Carruthers**
	Fair	**Fair**

Objective #20 Identify and document human heritage resources for protection			**Overall Rating**	
			Duffins	**Carruthers**
			Fair	***Fair***
Indicators	Measures	Targets	2002 Rating	
			Duffins	Carruthers
• number of human heritage resources	• number of registered archaeological sites	• maintain or increase the number of registered archaeological sites	*Fair*	*Fair*
	• number of Designated structures (i.e., built heritage)	• maintain or increase the number of Designated structures	*Fair*	*Fair*
	• number of Listed structures (not yet Designated)	• maintain or increase the number of Listed structures	*Fair*	*Fair*

Comments on the 2002 Ratings
The rating for this objective represents a qualitative assessment of the number of human heritage resources (archaeological sites and Designated and Listed structures) that have been identified within these two watersheds as compared with other watersheds in the TRCA jurisdiction. The ratings of "Fair" for individual measures and the overall rating reflect the fact that relatively few built heritage sites have been Designated, and also that there are large areas within these two watersheds that have not yet been surveyed for archaeological sites. This situation is due in part to the extensive amounts of land in public ownership and, therefore, relatively small portions of each watershed have been subject to urban development which would prompt the required studies.

Archaeological sites are most often identified through investigations initiated by the development approvals process. Attention has been focused primarily on the Airport lands, and to some degree the Seaton lands, to the exclusion of the Oak Ridges Moraine, the eastern subwatersheds of the Duffins, and the Carruthers Creek watershed as a whole. These ratings suggest that there is significant room for improvement in the initiation of archaeological site investigations.

The current assessment of the numbers of built heritage structures is a compilation of the separate inventories held by each of the five municipal Local Architectural Conservation Advisory Committees (LACACs) or equivalent heritage agencies. Their ability to conduct inventories and research, and to designate structures (under the Ontario Heritage Act) varies, depending upon priorities and funding within each municipality. These ratings suggest that there is significant room for improvement regarding the updated listing and designation of heritage structures across these two watersheds.

Objective #21	Increase awareness and appreciation of the inherent value of human heritage resources		OVERALL RATING	
			Duffins	**Carruthers**
			Fair	**Poor**
INDICATORS	MEASURES	TARGETS	2002 RATING	
			Duffins	Carruthers
• awareness and appreciation	• percent of population which places value on human heritage	• net increase of awareness and appreciation of human heritage	Fair	Poor

Comments on the 2002 Ratings
At this time, no public opinion survey has been conducted to gauge the percent of watershed residents who place value on Human Heritage resources. The ratings for this objective reflect a qualitative evaluation of the status of current levels of public awareness and appreciation of human heritage resources that is based on the best professional judgement of TRCA staff.

In future reporting periods, consideration should be given to the use of other surrogate measures to evaluate progress towards this objective such as the number of visitors to human heritage interpretive facilities, public events that promote local history, or amount of funding contributed to heritage programs from public and private sources.

Objective #22	Apply a standardized approach to protecting human heritage resources at all levels of government		Overall Rating	
			Duffins	Carruthers
			Fair	***Fair***
Indicators	Measures	Targets	2002 Rating	
			Duffins	Carruthers
• standardized approach	• number of agencies who agree with applying a standardized approach	• 100% agreement	*Fair*	*Fair*

References:

TRCA, 2002, *Archaeological Resource Management Procedures: Guidelines*

Comments on the 2002 Ratings

At this time, no standardized approach to protecting human heritage resources has been adopted by all levels of government. The ratings for this objective reflect a qualitative evaluation of current levels of agreement on a standardized approach by local agencies, based on the best professional judgement of TRCA staff.

GOAL: To achieve a behavioural shift in lifestyles, community design and resource use in keeping with environmental objectives for the watersheds	**Duffins**	**Carruthers**
	Fair	**Fair**

Objective #23	**Increase awareness of watershed issues and use of available watershed knowledge in decision making to foster sustainability and sustainable living practices**		**Overall Rating**	
			Duffins	**Carruthers**
			Further study required	**Further study required**
Indicators	Measures	Targets	2002 Rating	
			Duffins	Carruthers
• Awareness	• percent of surveyed population having awareness of watershed issues	• increase the level of awareness of watershed issues	Further study required	Further study required
• Outdoor Environmental Education	• number of students participating in outdoor education programs	• increase the number of students participating in outdoor education programs	Further study required	Further study required

Comments on the 2002 Ratings
At this time, no surveys on public awareness of watershed issues, nor student participation in outdoor education programs have been conducted. There is a need to conduct a survey of public awareness in the near future, in order to establish the current level of awareness, which will permit progress towards achieving this objective to be meaningfully evaluated in the next reporting period in 2005.

In the absence of information with regard to the current level of public awareness of watershed issues in these watersheds, no overall ratings have been assigned for this objective in this reporting period. Results of the forthcoming surveys of public awareness will provide the information needed to rate the current level of achievement of this objective for each of these watersheds.

Objective #24	**Promote lifestyles that are ecologically sustainable**	**Overall Rating**	
		Duffins	**Carruthers**
		Further study required	**Further study required**

Indicators	Measures	Targets	2002 Rating	
			Duffins	Carruthers
• water efficiency	• amount of water used per capita	• reduce the amount of water used per capita	Further study required	Further study required
• materials and resources	• degree of waste generation/diversion	• reduce degree of waste generation and increase diversion	Further study required	Further study required
• energy efficiency	• non-renewable energy consumption	• decrease non-renewable energy consumption	Further study required	Further study required
• renewable energy	• number of homes and industries using green power	• increase proportional use for renewable green vs. non-renewable energy	Further study required	Further study required
• urban forests	• hectares of urban canopy	• increase urban canopy	Further study required	Further study required
• naturalization on private lands	• hectares of naturalized lawns and gardens	• increase hectares of naturalized lawns and gardens	Further study required	Further study required
• stewardship initiatives	• participation in stewardship initiatives	• increase participation in stewardship activities	Further study required	Further study required

Comments on the 2002 Ratings
During this reporting period no information has been collected to document the current condition of each of these measures.

Objective #25	**Use sustainable urban design approaches to guide urban growth and development**	**OVERALL RATING**	
		Duffins	**Carruthers**
		Fair	**Fair**

INDICATORS	MEASURES	TARGETS	2002 RATING	
			Duffins	Carruthers
• Sustainable Communities • sprawl	– application of sustainable community principles.	– increased % of land developed or redeveloped using sustainable community principles.	Further study required	Further study required
	– public transit opportunities	– increase public transit opportunities	Fair	Fair
	– neighborhood mixture of jobs, shops and housing	– increase percentage of neighborhoods offering a mixture of jobs, shops and housing	Further study required	Further study required
	– density	– increase percentage of urban area that are high density	Further study required	Further study required

Comments on the 2002 Ratings
The ratings of "Fair" that have been assigned for the measure of public transit opportunties are based on the qualitative observation that currently, the public transit system within these watersheds is very underdeveloped. The existing condition of extreme traffic congestion on the 401, 407, and Highway 7 is evidence of a heavy reliance on the automobile as the primary means of transporation in this area. The rating of "Fair" suggests that considerable improvement to access and use of public transit and overall urban design to provide more opportunities for residents to adopt alternative means of transportation (e.g., biking, walking) is necessary to achieve the principles of Sustainable Communities in these watersheds.

During this reporting period no information has been collected to document the current condition of the remainder of these measures.

Overall ratings of "Fair" have been assigned to both the Duffins and Carruthers Creek watersheds based on a qualitative review of the limited amount of available information pertaining to the measures associated with this objective and the best professional judgement of TRCA staff.

3.0 Summary and Recommendations

The results of the watershed report card process for the Duffins and Carruthers Creek watersheds has provided an indication of "baseline" conditions with respect to the current level of achievement of the goals, objectives, and targets of the Duffins and Carruthers Creek Watershed Plan. These ratings will better enable progress to be monitored and evaluated in future report card processes. This rating process has highlighted the need for further data collection and analysis to provide the detail of information required to evaluate each watershed with respect to all of the indicators and measures that have been chosen for each objective of the plan. The following table (Table 3.0.1) provides a summary of the types of data collection and technical analysis that should be completed for these watersheds to provide the information needed to prepare the next watershed report card.

Table 3.0.1 Summary of Management Strategies and Ratings

TOPIC	GOAL		OBJECTIVES		RATINGS	
	Duffins	Carruthers			Duffins	Carruthers
Surface Water Quantity	Good To maintain the existing hydrologic function of the watershed.	Good	Objective #1	Maintain the existing water balance within the watershed	*Good*	*Good*
			Objective #2	Maintain or enhance baseflows.	*Good*	*Fair*
			Objective #3	Minimize or reduce risks to human life and property due to flooding	*Good*	*Good*
			Objective #4	Maintain or restore natural stream channel stability	Further study required	Further study required
Groundwater Quality and Quantity	Good To protect groundwater quality and quantity	Fair	Objective #5	Maintain or enhance groundwater levels and baseflow for watershed functions	*Good*	*Fair*
			Objective #6	Protect groundwater quality to ensure provision of safe water supplies and ecological functions	Good	Good
			Objective #7	Ensure sustainable rates of groundwater use	Further study required	Further study required
Surface Water Quality	Fair To protect and improve surface water quality	Fair	Objective #8	Manage the quality and quantity of run-off from rural and urban areas to maintain in-stream uses.	Good	Good
			Objective #9	Minimize in-stream sediment associated with construction activity.	*Poor*	*Poor*
			Objective #10	Reduce water quality contamination associated with wastewater discharges	Poor	Not applicable
Aquatic Habitat and Species	Good To protect aquatic habitat and species	Fair	Objective #11	Protect and restore native aquatic species and communities	Good	Fair
			Objective #12	Protect and restore the riparian zone and associated functions	Fair	Fair
			Objective #13	Maintain or restore the natural variability of annual and seasonal stream flows	Further study required	Further study required
Terrestrial Habitat and Species	Good To protect and enhance terrestrial habitat and species	Fair	Objective #14	Increase the percent natural cover to a quantity which provides targeted biodiversity and supports recreational uses	Good	Fair
			Objective #15	Protect the natural system quality and function from the influence of surrounding land uses	Fair	Fair
			Objective #16	Protect and restore all native vegetation community types and species to targeted levels	Further study required	Further study required

TOPIC	GOAL		OBJECTIVES		RATINGS	
	Duffins	Carruthers			Duffins	Carruthers
Public Use - Recreation	Good To provide appropriate sustainable public use which promotes environmental awareness and enhancement	Poor	Objective #17	Create continuous watershed trails in the greenspace system linking Lake Ontario and the Oak Ridges Moraine	Fair	Fair
			Objective #18	Manage the greenspace system for sustainable uses and public enjoyment	Good	Poor
			Objective #19	Improve greenspace accessibility while ensuring compatibility between social benefits and ecological health	Good	Poor
Human Heritage	Fair To preserve and interpret our evolving human heritage resources	Fair	Objective #20	Identify and document human heritage resources for protection	Fair	Fair
			Objective #21	Increase awareness and appreciation of the inherent value of human heritage resources	Fair	Poor
			Objective #22	Apply a standardized approach to protecting human heritage resources at all levels of government	Fair	Fair
Sustainable Communities	Fair To achieve a behavioural shift in lifestyles, community design and resource use in keeping with the environmental objectives for the watersheds	Fair	Objective #23	Increase awareness of watershed issues and use of available watershed knowledge in decision making to foster sustainability and sustainable lifestyle practices	Further study required	Further study required
			Objective #24	Promote lifestyles that are ecologically sustainable	Further study required	Further study required
			Objective #25	Use sustainable urban design approaches to guide urban growth and development	Fair	Fair

Table 3.0.2 Data and Information Needs for Future Reporting

Component	Areas for further study	Duffins	Carruthers
Surface Water Quantity	establish total annual infiltration rates by sub-catchment	completed	x
	collection and analysis of baseflow data at indicator sites	x	x
	documenting occurrences of flood events and ice jams	x	x
	erosion index technical analysis	x	x
	inventory of surface water withdrawals	x	x
	stream flow monitoring - average annual stream flow data	completed	x
	water budget analysis	completed	x
Groundwater	groundwater modelling and analysis	completed	x
	correlation of subsurface geology information with baseflow	x	x
	inventory of groundwater withdrawals	x	x
	establishing “sustainable” rates of groundwater withdrawal	x	x
	inventory of potential sources of groundwater contamination	x	x
	further correlation and analysis of groundwater quality data	x	x
Surface Water Quality	average annual loading values - TSS and TP	completed	x
	% of construction projects found to be in compliance with the new Municipal Erosion and Sediment Control By-law	x	x
	% of temporary sediment ponds checked annually	x	x
	% of temporary sediment ponds maintained as required	x	x
Aquatic Habitat and Species	establish an invertebrate index	x	x
	fluvial geomorphology assessment (percent in-stream woody cover and percent riffle substrate)	x	x
	water temperature monitoring and analysis	x	x
Terrestrial Natural Heritage	inventory and mapping of vegetation type and species diversity	x	x
	establish biodiversity indices	x	x
Recreational Use	% public greenspace maintained using an Environmental Management System approach	x	x
	% public greenspace maintained in naturalized conditions	x	x
	# of publically-accessible recreation facilities and destinations	x	x
Human Heritage	survey of public awareness and appreciation of human heritage resources	x	x
	survey of government agencies in support of a standardized approach	x	x
Sustainable Communities	survey on public awareness of watershed issues	x	x
	assessment of levels of participation in stewardship activities	x	x
	assessment of public transit use	x	x

Appendix A - SUPPORTING DOCUMENTS

Aquafor Beech Ltd. 2002, Duffins Creek Hydrology Update.

Canadian Council of Ministers of the Environment (CCME), 1999. *Canadian Environmental Quality Guidelines (CWQG)*, Canadian Council of Ministers of the Environment, Winnipeg.

Clarifica, Inc., 2002, TRCA Model By-law for Erosion and Sediment Control, Litter and Debris Control and Dust Control Relating to Urban Development Activities in the TRCA jursidiction, The Toronto and Region Conservation Authority, April 2002.

Clarifica Inc. 2002, Water Budget in Urbanizing Watersheds: Duffins Creek Watershed.

Conservation Authorities Moraine Coalition 2003, York-Peel-Durham-Toronto MODFLOW Groundwater Flow Model - Core Area

Cosburn Patterson Mather Ltd., 2001 (1997), Stormwater Management Study - A8 Secondary Plan (OPA #48), Town of Ajax, 2001 Addendum to May 1997 report.

Ecotech International Systems Inc., pending approval, Functional Servicing Study - Northeast Quadrant OPA 101 Community of Stouffville, Town of Whitchurch-Stouffville.

Environment Canada and Health Canada, 2001. *Road Salts: Priority Substances List Assessment Report*. Prepared for the Canadian Environmental Protection Act, 1999 Priority Substances List. Internet Publication.

Gerber Geosciences Inc. 2003, Duffins Creek Watershed Hydrogeology and Assessment of Land Use Change on the Groundwater flow System. Including Appendix on Water Use.

Marshall Macklin Monaghan Ltd. 2002, Duffins Creek Watershed Hydraulic Modelling and Flood Plain Mapping Project.

Ontario Ministry of Environment and Energy (OMOEE), 1994, revised in 1999, *Water Management: Policies, Guidelines, Provincial Water Quality Objectives of the Ministry of Environment and Energy*, Queens Printer for Ontario.

Parish Geomorphic Ltd., pending review, Erosion Assessment and Fluvial Geomorphic Update for Portions of West Duffins, Whitevale, Ganatsekiagon and Urfe Creeks.

Planning and Engineering Initiatives Ltd., 2002, Green Space Project Lands Fluvial Geomorphology Study - Duffins Creek Watershed, Transport Canada, November 2002.

Stantec Consulting Ltd. and Aquafor Beech Ltd. 2003, Dry and Wet Weather Modelling of Water Quality under Alternative Land Use Scenarios in the Duffins and Carruthers Creek Watersheds - A Simple Spreadsheet Approach.

TRCA 2002, Carruthers Creek State of the Watershed Report.

TRCA 2002, Duffins Creek State of the Watershed Report.

TRCA 2003, Agricultural Non-Point Source (AGNPS) Modelling of the Duffins and Carruthers Creek Watersheds.

TRCA 2003, Duffins and Carruthers Creek Watersheds Fisheries Management Plan.

TRCA 2003, Duffins and Carruthers Creek Low Flow Study and Management Plan.

TRCA 2003, Duffins Creek Headwaters Management Plan.

TRCA 2003, Duffins Creek Marsh Restoration Plan.

TRCA 2003, Ratings Report for the 2002 Duffins and Carruthers Creek Watersheds Report Card.

TRCA 2003, Terrestrial Natural Heritage Program Methodology Report.

URS Cole Sherman Ltd., pending approval, Functional Servicing Study - Southeast Quadrant OPA 101 Secondary Plan, Town of Whitchurch-Stouffville.

Water Quality Modelling Based on Changes in Water Quantity

Final report

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Water Use and Supply Project

Water Quality Modelling Based on Changes in Water Quantity

1.0 INTRODUCTION

This research represents a pilot project that is being carried out to establish a methodology for assessing the sensitivity of watershed stream water quality to changes in water quantity caused by climate change. The pilot watershed is the Duffins Creek watershed, which is located in the east of Toronto. It falls under the jurisdiction of the Toronto and Region Conservation Authority. It was selected because of the large existing data and knowledge base that has been developed over the years. In addition, new watershed strategies have been developed that have been supported by a number of technical studies. A surface water quality study evaluated water quality conditions during dry and wet weather (Stantec/Aquafor Beech). The Agricultural Non-Point Source model (AGNPS) model was calibrated for the Duffins Creek Watershed (Leon et al. 2002) and a wet weather event-based evaluation (TRCA, Jan. 2003) was carried out using the AGNPS model.

2.0 STUDY AREA

The Duffins Creek watershed is 293 km^2 in area and drains into Lake Ontario at Ajax, 10 km east of Metropolitan Toronto. Duffins Creek watershed can be divided into subwatershed units, including Reesor, West Duffins Creek, Ganatsekiagon Creek, Urfe Creek, East Duffins Creek and Millers Creek, as shown in Figure 1. The headwaters originate in the northern regions of the watershed in the Oak Ridges Moraine where sub-surface drainage predominates (Bowen *et al.*, 1995). The digital elevation model (DEM) and the drainage for Duffins Creek watershed are shown in Figure 2. In the DEM, the lighter colours represent the higher elevations. The soil type coverage is shown in Figure 3 along with the current land use. The land use is mainly non-intensive agricultural with growing urban areas in the lower parts of the watershed at Pickering and Ajax. Only 10% of the watershed is developed. Agricultural practices in the watersheds have changed over the past 30 years in response to expropriation to build a new international airport in the 1970's by the Provincial and Federal governments. Current agricultural practices include cash crops, market gardens, sod farms, diary and beef operations, and orchards. Also scattered throughout the watershed are riding stables and hobby farms. A large percentage of the operations in the watershed are based on tenant farming.

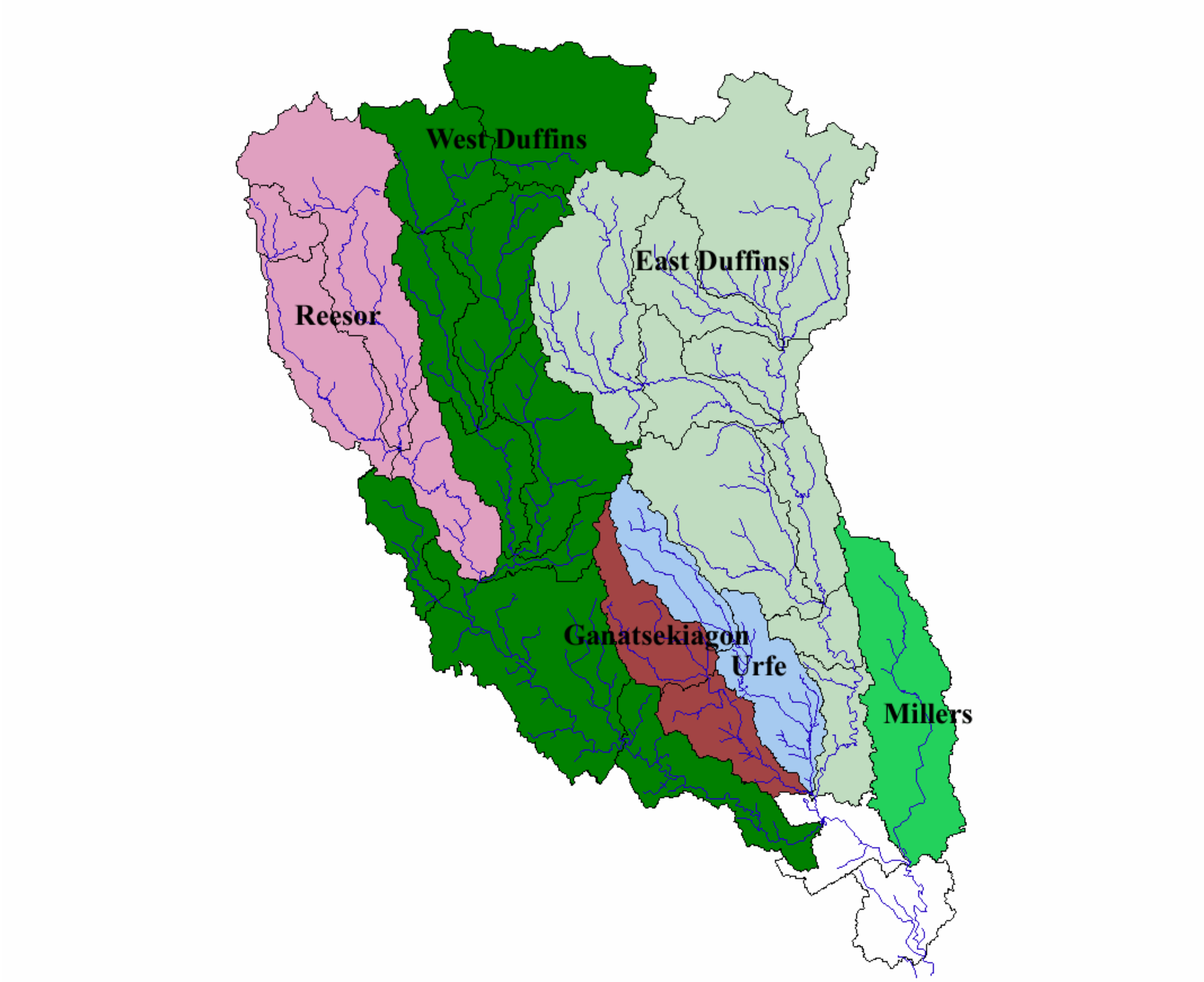


Figure 1. Duffins Creek subwatersheds

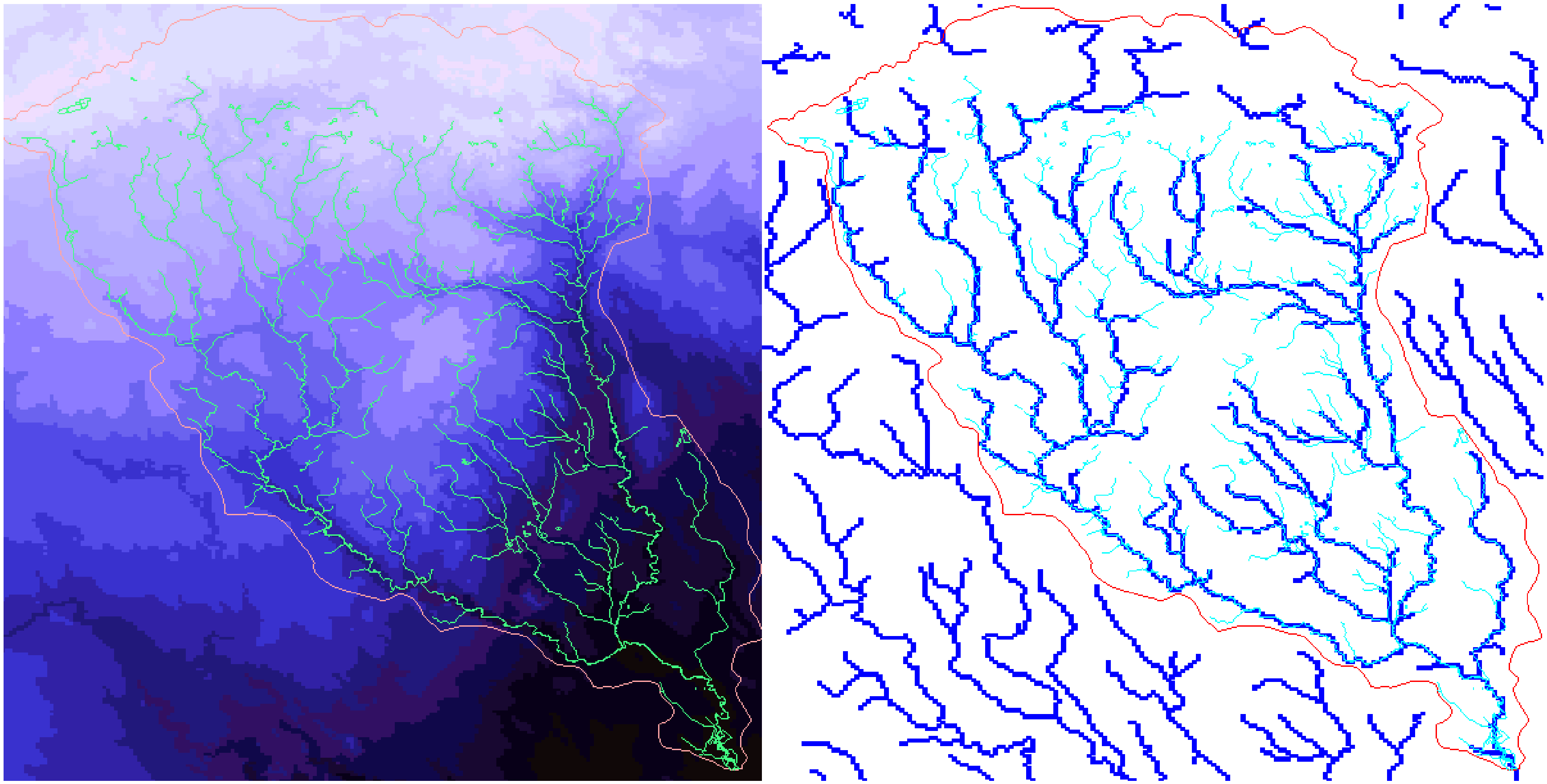
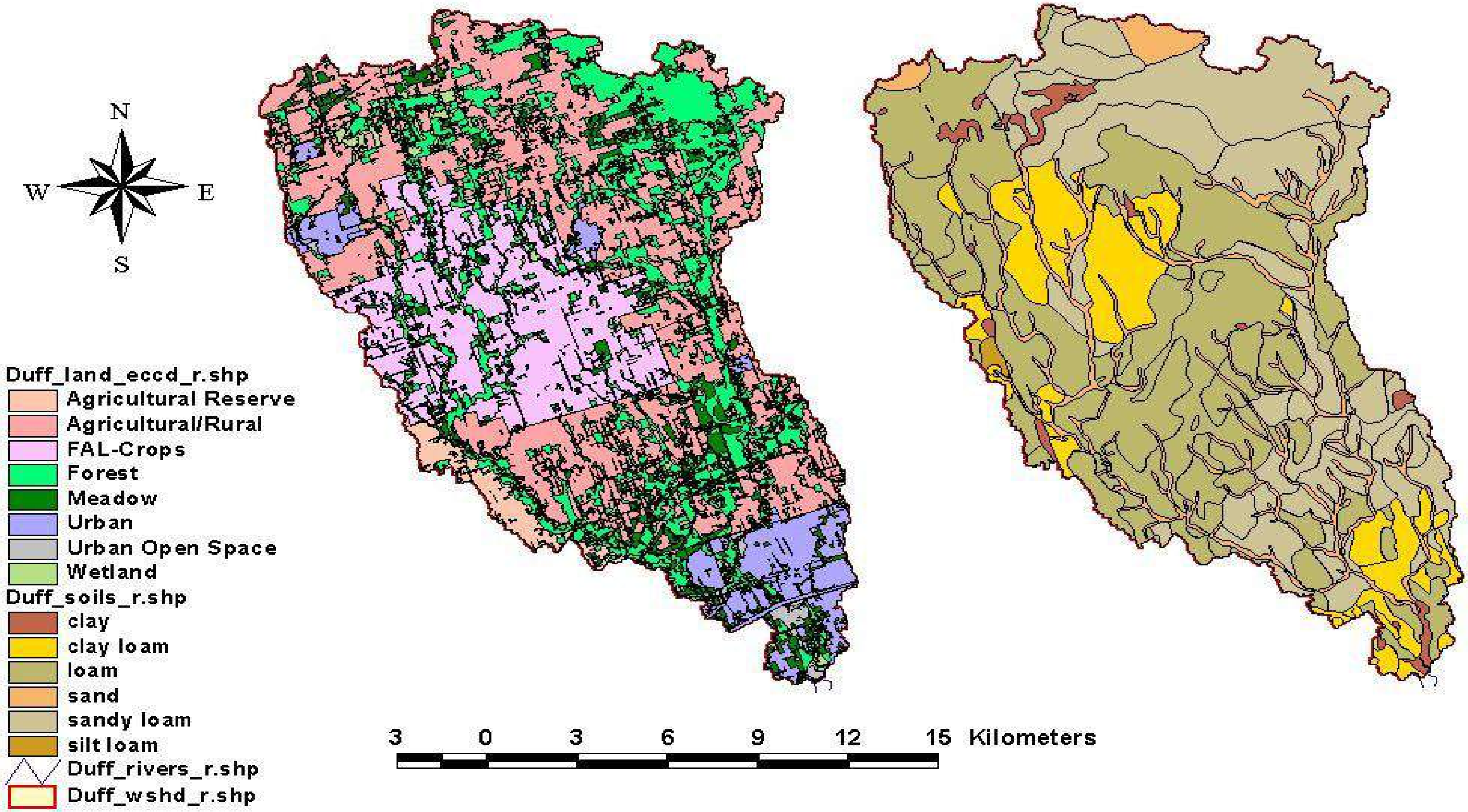


Figure 2 DEM (left) and DEM flow accumulation/drainage (right) for Duffins Creek watershed

Figure 3 Duffins Creek watershed landuse and soil coverage maps



2.1 Current Surface Water Quality

Water quality data from Ontario's Provincial Water Quality Monitoring Network (PWQMN) was used by the TRCA as a basis for their analysis discussed here. Data were available for six monitoring stations for a period of approximately 20 years. Data for the period of 1988 to 1993 were considered to represent "current conditions". This information was augmented with baseflow chemistry data collected at 110 stations during 1995 and 1996 by the Geological Survey of Canada. The TRCA assessment focused on selected water quality parameters: phosphorus, nitrogen compounds, suspended solids, chlorides, bacteria (E. *coli* and faecal coliform), biological oxygen demand, and dissolved oxygen. Although heavy metals and persistent organic pollutants are also of interest, an accurate assessment of these parameters was not possible with the data provided by the above-mentioned sources.

The nutrients phosphorus and nitrate are elevated in the watershed. Trends and effects are similar for both. Median phosphorus concentrations meet the interim provincial phosphorus guideline of 0.03 mg/L throughout the watershed, except in the Urfe Creek, lower Stouffville Creek and the West Duffins. These tributaries are impacted by local agricultural and/or urban runoff and effluent from the Stouffville sewage treatment plant (STP). Sources of phosphorus and nitrate include lawn, garden and agricultural fertilizers and eroded soil particles from construction sites, stream banks and agricultural fields. The relationship between nitrate levels and land use is a good indicator of anthropogenic impacts to the overall aquatic system. Ammonia is a component of human and animal sewage and also forms from the microbial decomposition of organic material. Ammonia levels meet Provincial Water Quality Objectives (PWQO) virtually all of the time, with only one exceedence in the data collected during the period 1988 to 1994 at monitoring stations on the West Duffins, and Ressor Creek tributaries. Overall, water quality studies in the Duffins Creek watershed have found lower phosphorus and nitrate loads in tributaries flowing from the more well forested catchments.

Biological oxygen demand (BOD) is elevated in Stouffville Creek, lower West Duffins, Ganatsekiagon and Urfe Creeks relative to other Duffins tributaries. Organic loads generated by effluent from the Stouffville STP represent the primary cause of BOD. Farm runoff or septic leachate is the cause of increased BOD levels in the Ganatsekiagon and Urfe Creeks.

Chloride concentrations have been increasing over the years. Current levels remain low in the rural portions of the watershed. Road salt with runoff from transportation networks is the primary source of chlorides although septic fields, STPs and landfill leachates are also minor sources (Bowen and Hinton, 1998). At this time there is no guideline level for chloride concentrations.

Total suspended sediment (TSS) concentrations are low in the upper portions of the watershed due to significant areas of forested lands, good riparian vegetation and stabilized streambanks. In the lower watersheds, the streams pass through the Iroquois Shoreline and enter urban areas, which represent increased sources of sediment. Over time, there has been little change in mean suspended sediment levels. TSS levels increase during wet periods and decrease in drier periods. TSS levels in Reesor Creek during 28 rain events sampled in 1997-1998 (NWRI and TRCA, 2000) were an order of magnitude higher than those levels measured through the PWQMN (median of 65 mg/L compared to 7 mg/L), the latter of which is biased towards monitoring during dry weather conditions. In 2000-2001 a sampling program was undertaken by the Ministry of Environment to provide more reliable data for a number of heavy metals and trace organic contaminants (e.g. organochlorine pesticides, chlorobenzene, PAHs, and volatile organic compounds) in the Duffins Creek. Preliminary results indicate that the majority of organic parameters evaluated were not detected, and of the few organic parameters that were detected, all occurred in very trace amounts (less than a few parts per billion). Metals concentrations were found to be within normal background levels. Based on other biological indicators there is no evidence of toxic organic contaminants problems.

3.0 METHODS

The following section describes a methodology for examining the sensitivity of the watershed's stream water quality to potential changes in water quantity resulting from climate change stressors.

3.1 Climate Change Scenarios

Scenarios of climate change analyzed in this project were drawn from two internationally recognized climate models: the Canadian Centre for Climate Modelling and Analysis (CCCma) CGCM1 and the Hadley Centre HadCM2. Respective model details and specifications are discussed in Boer et al. (2000a, 2000b) and Johns et al. (1997). Output from 3 (HadCM2) or 4 (CGCM1) non-lake grid cells for the study area was averaged to develop the final scenario change factors. The monthly temperature and precipitation values are shown in Table 1. These are the same values that are being used in the groundwater sensitivity studied being carried out as part of the Water Use and Supply Project (Piggott, personal correspondence).

Table 1. Table of monthly 2080s[a] scenario factors applied to base climate data

	Temperature Change Factor (°C)[b]		Precipitation Change Factor (%)[a]	
MONTH	CGCM1	HadCM2	CGCM1	HadCM2
January	6.8	3.2	9.9	16.9
February	9.5	3.6	23.8	25.9
March	6.8	2.3	27.8	4.1
April	6.9	2.0	17.5	14.4
May	5.6	2.3	6.5	12.1
June	4.7	2.1	1.2	4.7
July	3.9	2.7	-2.3	23.3

August	3.9	2.2	-9.9	21.7
September	4.1	1.2	9.7	15.1
October	4.1	2.9	6.9	32.4
November	4.1	2.7	3.6	23.5
December	2.5	2.8	-1.4	13.8

Notes: [a] commonly referred to as the '2080s' scenario; [b] relative to simulated 1961-90 average

The precipitation scenario values were used in the AGNPS non-point source model to generate stream flow and water chemistry data for the climate change conditions.

3.2 AGNPS Model

The AGNPS model (Young *et al*., 1994) is a distributed model that simulates agricultural watersheds for a single storm event assuming uniform precipitation patterns. Version 5.0 of the AGNPS model was used in this study. Watersheds modeled by AGNPS must be divided into homogenous square working areas called cells. The hydrology in the model is calculated by the Soil Conservation Service (SCS) curve number approach. With this method, the infiltration is calculated simply by subtracting the runoff from the amount of rainfall with the runoff being calculated using the SCS curve numbers for each cell.

The Universal Soil Loss Equation (USLE) is used for predicting soil erosion, which is predicted for five different particle sizes (sand, silt, clay, small and large aggregates). The AGNPS model simulates the soil loss and sediment yield in a two-step process. First, the soil erosion is calculated and then compared to the sediment transport capacity of the flow. The eroded sediment is then routed based on a steady-state continuity equation for sediment transport and deposition described by Foster *et al*. (1980). Among the factors in the USLE, the soil erodibility factor is a measure of potential erosion of the soil and is a function of the soil texture; the vegetative cover factor estimates the effect of ground cover conditions and accounts for the effect of vegetation and land management on erosion rates resulting from canopy protection (reduction of rainfall energy effect).

The pollutant transport part of the model estimates transport of nitrogen, phosphorous and chemical oxygen demand (COD) throughout the watershed. It is divided into one part handling soluble pollutants and another part for sediment based pollutants. The methods used to predict nitrogen and phosphorus yields were developed by Frere et al. (1980).

As in most nonpoint source pollution models, the equations are based on the CREAMS model (Knisel, 1980). The nitrogen and phosphorus estimates are performed using relationships between chemical concentration, sediment yield and runoff volume. Soluble nitrogen and phosphorus in runoff waters represent the effects of rainfall, fertilization, solid waste and leaching from the soil in each cell. The contributions of soluble nutrients from each cell are calculated first within the cell and routed downstream. Once soluble nutrients reach concentrated flow, they are assumed to remain as constants. That is, the amount arriving in the overland flow from any particular cell is simply added to what is already present in the channel, with no losses of soluble nutrients allowed, except for the nutrient decay within the cell.

Nitrogen concentration occurring in precipitation varies between 0.8 and 1.2 ppm, which is not agronomically significant for cropland but could be for unfertilized and forested areas. The value used in the model is the recommended value in the AGNPS documentation (Young *et al.*, 1994) of 1 ppm. Other sources of nutrients are the fertilizers. Normally nitrogen fertilizers are quite water-soluble and phosphate fertilizers are moderately soluble. Consequently, water from the soil and light rain dissolves the granules. Only part of the rainfall leaves the field as runoff. The part of the rain that does not run off fills the surface layer and leaches soluble nutrients deeper into the soil. In the AGNPS model a leaching rate is calculated through the use of extraction coefficients for soil and runoff.
The AGNPS model was conceived on the basis of the CREAMS model, which was developed with the intention of minimizing the calibration efforts. The model has been applied and validated in many parts of the United States. Validation of the model for sediment and runoff was shown by Koelliker and Humber (1989) for five watersheds in Kansas. Sugiharto *et al.* (1994) applied the AGNPS model to evaluate 20 management practices dealing with sediment and phosphorus yields from 4 ha fields in a watershed dominated by dairy farms. Best management practices were evaluated for watersheds in southern Iowa (Tim *et al.* 1994) and coastal watersheds in South Carolina (Choi and Blood, 1999). It has being used in different circumstances to calculate sediment and nutrient loading due to nonpoint source pollution in watersheds (Bingner *et al.*, 1989, Young *et al.*, 1989, Finney *et al.*, 1995, Mostaghimi *et al.*, 1997).

In Canada, the AGNPS model has had much less use. Perrone and Madramootoo (1999) evaluated the model in a small Quebec watershed for its applicability and performance with respect to hydrologic conditions in that province. As part of collaboration between the National Water Research Institute and the Ontario Ministry of Environment, the AGNPS model was modified and a new interface was developed. It was applied to the Duffins Creek watershed and calibrated for conditions in southern Ontario (Leon et al., 2002). Guidelines were developed in order to properly run the AGNPS model and select the appropriate values for the parameters and coefficients.

3.3 The AGNPS Model Interface

The AGNPS is a robust and well-tested model. Mostaghimi *et al.*, (1997) found that, based on several simulations, the AGNPS model was suitable for a watershed scale simulation. At the same time, they also noted that the most difficult task was the input data preparation for the model, a very time consuming process and pointed out the difficulties for determining the accuracy of such input values. The AGNPS model has previously been interfaced with GIS systems such as GRASS (He et al. 1993), SPANS (Rode and Frede, 1997) and ARC/INFO (Hession and Huber, 1989). However, these GIS systems have a large learning curve to master and we wanted a system that would allow rapid and easy training for a wide range of users.

Data needed for the model is classified into two categories: *Watershed Data* include information applying to the entire watershed such as watershed size, number of cells, and if running for a single event, the storm type, duration and intensity. *Cell Data* includes information on the parameters based on soil type, land use, and management practices within the cell.

Any attempts to improve NPS modelling capabilities need to be combined with the application of new technologies to resolve problems associated with ease of model use. This will allow the user to track the decision-making processes through the model to obtain a better understanding of the simulation. An integrated approach is achieved in this research with the linkage of the AGNPS model with the RAISON decision support system. Interactive programs were created to assist in processing data, initiating model simulations, and analyzing model results.

Interfaces were built (Leon, 1999) to allow interaction with the model by intercepting input and output and to connect them to the database in the system. Work was done to create communication links between the AGNPS model and RAISON. The interface created in the present research, drastically reduces the time required to prepare input data for the model based on automatically extracting parameter values from digital information of the watershed.

The pre-processing tools provide easy data compiling for the models. Using DEM (Digital Elevation Model), soil type, and land use maps in vector formats, procedures are designed to automate as much input of data as possible. Design of a control panel for model operation helps in the setup and operation of the simulation process. Actually this also triggers the model to run by creating a shell that activates the model and controls the mode of operation. Post-processing for output data by means of graphical and statistical tools also assists with the interpretation of model results. Such a generic application is very useful for applying the model to different watersheds in order to validate the hydrologic and water quality components. Also, techniques to analyze the sensitivity associated to the model were evaluated and included in the system.

3.4 Baseline AGNPS Model Conditions

The Toronto and Region Conservation Authority (TRCA Jan. 2003) have applied the AGNPS model to the Duffins and Carruthers Creek watershed in support of their watershed management strategy. They used the AGNPS model as an event evaluation tool to examine watershed responses to alternative land use and management scenarios. The existing land use runs were used as the baselines for this study.
The grid size employed was 1 km^2 for the East and West branch subwatersheds while grid sizes of 500 m^2 was used for the Urfe and Ganatsekiagon and 750 m^2 for the Miller and Reesor subwatersheds. Two representative storm types were selected from measured data. The first was a 25 mm storm with a 12 hour duration. The second was a 15 mm storm with a 9 hour duration. Both were type II storms, with a rainfall intensity and distribution typical for this area (Leon et al., 2002) and average antecedent moisture conditions. In subwatersheds with extensive natural cover (forests, meadows or wetlands) or coarse textured soils, it was necessary to run larger volume rain events in order to generate runoff. Fertilizer application rates and suggested availability factors were based on the results of a survey conducted for the Duffins Creek watershed in 1997 (JDE Ventures, 1998). The subwatershed characteristics are presented in Table 2. A summary

of the AGNPS modelling results for the existing conditions scenario in each subwatershed are presented in Table 3. These outputs will be used as the baseline values for comparing with the results generated for the various climate change scenarios.

Table 2 Duffins Creek Subwatershed characteristics

Subwatershed	East	Ganatsekiagon	Miller	Reesor	Urfe	West
Area (ha)	9,202	1,305	1,698	3,986	1,437	13,539
Percent Agricultural	51	58	38	41	54	64
Percent Natural	45	40	25	23	45	32
Percent Urban	4	2	38	36	1	4

Table 3 Existing condition model outputs

Subwatershed	Storm Event	Nitrogen (mg/L)	Phosphorus (mg/L)	COD (mg/L)	Peak Flow (m^3/s)
Reesor	25 mm 12hr	4.33	0.18	26.87	0.60
West Duffins	25 mm 12 hr	3.67	0.03	20.01	0.44
East Duffins	30 mm 12 hr	3.01	0.07	21.15	0.50
Ganatsekiagon	40 mm 12 hr	2.67	0.10	41.97	0.97
Urfe	38 mm 12 hr	2.48	0.02	26.25	0.71
Miller	25 mm 12 hr	4.78	0.14	6.35	0.40

4.0 APPLICATION OF CLIMATE CHANGE SCENARIOS

The impacts of the climate change scenarios were examined by multiplying the baseline storm event precipitation values by the maximum and minimum monthly values generated by each of the two climate change models. The monthly precipitation factors are shown in Table 4, with the values used in bold. The CGCM1-based scenario is much warmer throughout the year and somewhat drier, especially from May through December, than the HadCM2-based scenario.

Table 4 Climate change precipitation factors

Month	CGCM1	HadCM2
January	1.09944	1.169273
February	1.238461	1.259401
March	**1.278223**	**1.041153**
April	1.174727	1.143941
May	1.065138	1.121209
June	1.012484	1.046791
July	0.977347	1.23317
August	**0.901482**	1.217241
September	1.097181	1.150584
October	1.069443	**1.323755**
November	1.0359	1.235055
December	0.986129	1.3825

A summary of the results for the base case and the maximum and minimum climate change scenarios for selected water quantity and quality parameters at the outlets of the Duffins Creek subwatersheds are presented in Table 5.

Table 5 AGNPS Model outputs for base case and two climate change scenarios

Subwatershed	Scenario	Nitrogen (mg/L)	Phosphorus (mg/L)	COD (mg/L)	Peak Flow (m^3/s)
East Duffins	ExCond	3.01	0.07	21.15	0.50
	HadCM2wet	2.2	0.05	21.92	5.34
	HadCM2dry	2.9	0.06	21.43	0.85
	CGCM1wet	2.3	0.05	21.98	4.43
	CGCM1dry	3.28	0.08	20.25	0.036
Ganatsekiagon	ExCond	2.67	0.1	41.97	0.97
	HadCM2wet	1.77	0.06	38.98	3.82
	HadCM2dry	2.52	0.09	41.54	1.21
	CGCM1wet	1.85	0.06	39.29	3.33
	CGCM1dry	3.13	0.12	42.93	0.48
Miller	ExCond	4.78	0.14	6.35	0.40
	HadCM2wet	4.21	0.12	6.49	1.84
	HadCM2dry	4.69	0.14	6.36	0.53
	CGCM1wet	4.27	0.12	6.47	1.61
	CGCM1dry	4.98	0.14	6.34	0.18
Reesor	ExCond	4.33	0.18	26.87	0.60
	HadCM2wet	3.83	0.18	33.16	3.15
	HadCM2dry	4.29	0.18	27.96	0.82
	CGCM1wet	3.92	0.15	28.79	3.80
	CGCM1dry	4.39	0.17	24.01	0.24
Urfe	ExCond	2.48	0.02	26.25	0.71
	HadCM2wet	1.6	0.02	24.59	3.20
	HadCM2dry	2.33	0.02	26.0	1.04
	CGCM1wet	1.69	0.02	24.77	2.74
	CGCM1dry	2.88	0.03	26.75	0.30
West Duffins	ExCond	3.67	0.03	20.01	0.44
	HadCM2wet	2.94	0.03	21.79	5.16
	HadCM2dry	3.58	0.03	20.37	0.76
	CGCM1wet	3.03	0.03	21.67	4.31
	CGCM1dry	3.85	0.03	18.95	0.04

ExCond – Existing Condition (2002)
HadCM2 – Hadley Centre HadCM2 model
CGCM1 - Canadian Centre for Climate Modelling and Analysis CGCM1 model

Overall, it can be seen that both of the two wet climate change conditions result in slightly lower concentrations of nitrogen and phosphorus and elevated peak flows, as compared to the existing condition, for most of the sub-watersheds. The dry climate change scenarios predict slightly higher concentrations of nitrogen and phosphorus than those predicted for the wet climate change scenarios, and lower peak flows, as expected. In the Urfe and West Duffins Creek subwatersheds, the phosphorus concentrations are not predicted to change under the various scenarios despite the significant changes predicted in associated peak flows. The COD concentrations do not change consistently with the wet and dry conditions in the different sub-watersheds and the relative changes in COD are very small.

Under the HadCM2dry scenario, in all of the sub-watersheds it is predicted that the nitrogen and phosphorus concentrations will be slightly lower, but very similar to the existing conditions. The CGCM1dry scenario generates nitrogen and phosphorus concentrations that are slightly higher than the existing condition concentrations. The peak flow for the HadCM2dry scenario is predicted to be slightly higher than the existing condition whereas the CGCM1dry scenario generates a substantially smaller peak flow rate than the existing condition.

So it can be seen that even within the same watershed, different subwatersheds can show different levels of sensitivity to changes in climate (precipitation) with respect to impacts of water quantity on water quality. The same can be said for the relative impacts of water quantity changes on specific water quality parameters.

5.0 CLIMATE CHANGE vs. LANDUSE CHANGE

In order to put the impacts of climate change into perspective with respect to other changes taking place in the watersheds, we can compare the TRCA study results for projected land use changes (notably urban expansion) up to the year 2020, as planned by Regional and Local governments.

In Table 6, the relative percent changes in the parameters as compared to the existing base case are presented. No overall statement can be made as each subwatershed has a different response to the various scenarios.

In the East Duffins subwatershed, the largest changes in nitrogen and phosphorus concentrations (reductions) are predicted by the wet climate change scenarios, which also predict larger flows. The landuse changes are predicted to cause a reduction in flows, as are the dry climate change scenarios, along with increases in nitrogen and phosphorus concentrations.

In Ganatsekiagon subwatershed, the wet climate change scenarios are predicted to cause the largest changes in nitrogen concentrations (reductions), as well as the largest increases in flows. However, the land use change is predicted to generate the largest reduction in phosphorus concentrations as well as COD. Only the CGCM1dry scenario is predicted to generate increased concentrations of nitrogen, phosphorus, and COD.

The Miller Creek subwatershed stream chemistry is predicted to be much more significantly affected by the landuse changes than by the climate change scenarios.

In the Ressor Creek subwatershed, all but the CGCM1dry scenario are predicted to cause the nitrogen concentrations to decrease, as compared to the existing base case. Neither the 2020 landuse nor the HADCM2 climate change scenarios are predicted to have any impact on the phosphorus concentrations. Both of the CGCM1 scenarios are predicted to cause reduction in phosphorus concentrations. All but the CGCM1dry scenario are predicted to cause increases in the COD concentrations.

The Urfe Creek subwatershed is predicted to have a reduction in the nitrogen concentrations for all of the scenarios except the CGCM1dry. The 2020 landuse scenario and the CGCM1dry scenarios are both seen to result in elevated phosphorus concentrations while the others result in no changes. The COD concentration is seen to be most significantly impacted under the 2020 landuse scenario.

For West Duffins Creek subwatershed, all of the climate change scenarios except the CGCM1dry are predicted to cause decreases in nitrogen concentration in the streamwater. The 2020 landuse and the CGCM1dry scenarios are both expected to cause increases in nitrogen concentrations. None of the scenarios are predicted to have any effect on phosphorus concentrations as compared to the existing base condition. The 2020 landuse scenario is predicted to cause the most significant impact on COD concentrations.

In conclusion, it is quite apparent that each subwatershed has unique responses and sensitivities to the various scenarios. The larger flow events almost always result in decreases in stream water nitrogen and phosphorus concentrations. This is mainly a dilution effect. The 2020 landuse scenarios typically result in much smaller changes in peak flows than are predicted by for the climate change scenarios, especially the wet climate change scenarios. However, it can be seen that the large changes in peak flows do not always result in significantly large changes in stream flow chemistry.

Table 6 Comparison of climate change and landuse impacts on stream chemistry and flows.

Subwatershed	Scenario	% change Nitrogen	% change Phosphorus	% change Peak Flow	% change COD
East Duffins	HadCM2wet	-26.9	-28.6	962	3.6
	HadCM2dry	-3.6	-14.3	69.8	1.5
	CGCM1wet	-23.6	-28.6	781	3.9
	CGCM1dry	9.0	14.3	-93.0	-4.3
	2020 Landuse	15.1	22.2	-12.3	-10.2
Ganatsekiagon	HadCM2wet	-33.7	-40.0	293.3	-7.1
	HadCM2dry	-5.6	-10.0	25.1	-1.0
	CGCM1wet	-30.7	-40.0	242.8	-6.4
	CGCM1dry	17.2	20.0	-50.9	2.3
	2020 Landuse	-13.3	-66.7	-47.1	-63.3
Miller	HadCM2wet	-11.9	-14.3	356.4	2.2
	HadCM2dry	-1.9	0.0	31.1	0.16
	CGCM1wet	-10.7	-14.3	299.0	1.9
	CGCM1dry	4.2	0.0	-55.0	-0.16
	2020 Landuse	-49.2	100	-97	-17.2
Reesor	HadCM2wet	-11.5	0.0	421.7	23.4
	HadCM2dry	-0.9	0.0	35.5	4.1
	CGCM1wet	-9.5	-16.7	530	7.1
	CGCM1dry	1.4	-5.6	-60.7	-10.6
	2020 Landuse	-11.6	0.0	-38.0	8.3
Urfe	HadCM2wet	-35.5	0.0	350	-6.3
	HadCM2dry	-6.0	0.0	30.0	-1.0
	CGCM1wet	-31.9	0.0	286	-5.6
	CGCM1dry	16.1	50.0	-58.2	1.9
	2020 Landuse	-29.3	200	-79.8	-72.1
West Duffins	HadCM2wet	-19.9	0.0	1073	8.9
	HadCM2dry	-2.5	0.0	71.7	1.7
	CGCM1wet	-17.4	0.0	879	8.3
	CGCM1dry	4.9	0.0	-91.1	-5.3
	2020 Landuse	12.7	0.0	-32.1	19.4

The relative sensitivities of the subwatershed parameters to the climate change scenarios are shown in Table 7. The absolute values of the changes for each parameter have been used to break the results into 3 classes (low, medium, and high). At this point it is not possible to predict what the ranges should be for a generic ranking system that would apply for Ontario level four watersheds. These would have to be adjusted as the process proceeds. The ranges shown in Table 7 for nitrogen are: (low: 0 – 11.7; medium: 11.8 - 23.3; high: 23.4 - 35.0). The ranges for phosphorus are: (low: 0 – 16.7; medium: 16.8 – 33.3; high: 33.4 – 50.0). Peak flow ranges are: (low: 0 – 337; medium: 338 – 675; high: 676 – 1073). Finally, the ranges for COD are: (low: 0 – 7.8; medium: 7.9 – 15.6; high: 15.7 – 23.4). The results are also shown in Figures 4-19 for each of the parameters for the different climate change scenarios.

Under both the wet and dry climate change scenarios, Ganatsekiagon and Urfe Creek subwatersheds appear to be the most sensitive to changes in streamwater nitrogen and phosphorus concentrations. This is despite the fact that they show the smallest changes in peak flow rates for the wet and dry climate change scenarios. Despite having a high sensitivity to changes in nitrogen concentrations, Urfe Creek subwatershed has a low sensitivity to changes in COD.

These results illustrate why a deterministic watershed model that combines the complex interactions of processes, such as the AGNPS model, is required to understand the behaviour of watersheds to stressors rather than relying on simple, non-interconnected functions.

Table 7 Relative Sensitivity of subwatersheds to climate change scenarios

Subwatershed	Scenario	Nitrogen Sensitivity	Phosphorus Sensitivity	Peak Flow Sensitivity	COD Sensitivity
East Duffins	HadCM2wet	High	Medium	Low	Low
	HadCM2dry	Low	Low	Low	Low
	CGCM1wet	High	Medium	High	Low
	CGCM1dry	Low	Low	Low	Low
Ganatsekiagon	HadCM2wet	High	High	Low	Low
	HadCM2dry	Low	Low	Low	Low
	CGCM1wet	High	High	Low	Low
	CGCM1dry	Medium	Medium	Low	Low
Miller	HadCM2wet	Medium	Low	Medium	Low
	HadCM2dry	Low	Low	Low	Low
	CGCM1wet	Low	Low	Low	Low
	CGCM1dry	Low	Low	Low	Low
Reesor	HadCM2wet	Low	Low	Medium	High
	HadCM2dry	Low	Low	Low	Low
	CGCM1wet	Low	Medium	Medium	Low
	CGCM1dry	Low	Low	Low	Medium
Urfe	HadCM2wet	High	Low	Medium	Low
	HadCM2dry	Low	Low	Low	Low
	CGCM1wet	High	Low	Low	Low
	CGCM1dry	Medium	High	Low	Low
West Duffins	HadCM2wet	Medium	Low	High	Medium
	HadCM2dry	Low	Low	Low	Low
	CGCM1wet	Medium	Low	High	Medium
	CGCM1dry	Low	Low	Low	Low

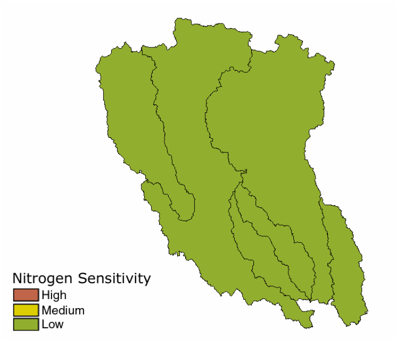


Figure 4: Nitrogen (HadCM2 - Dry)

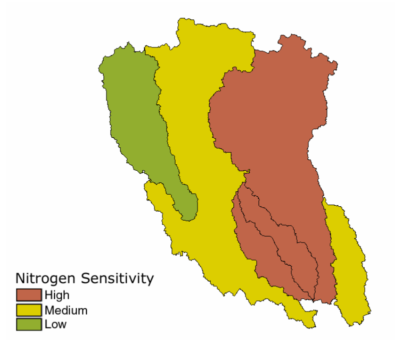


Figure 5: Nitrogen (HadCM2 - Wet)

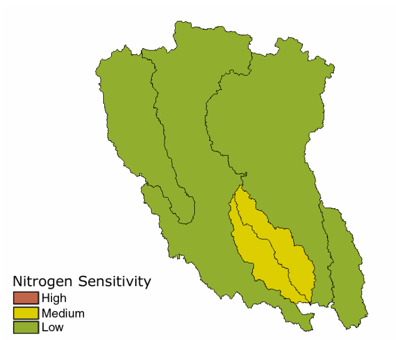


Figure 6: Nitrogen (CGCM1 - Dry)

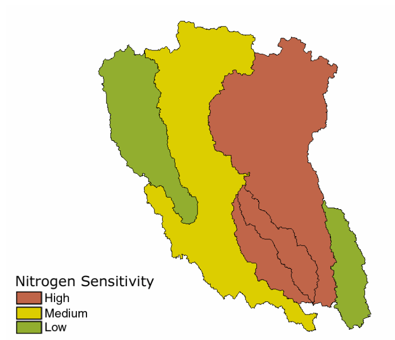


Figure 7: Nitrogen (CGCM1 - Wet)

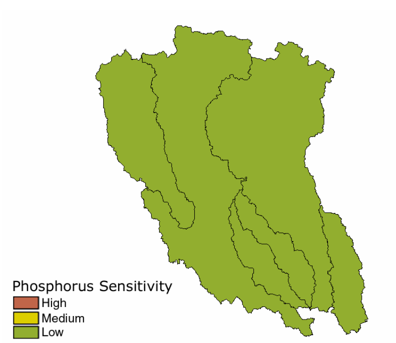


Figure 8: Phosphorus (HadCM2 - Dry)

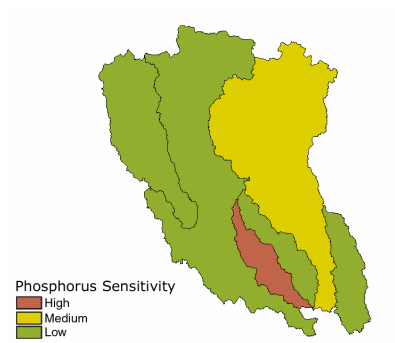


Figure 9: Phosphorus (HadCM2 - Wet)

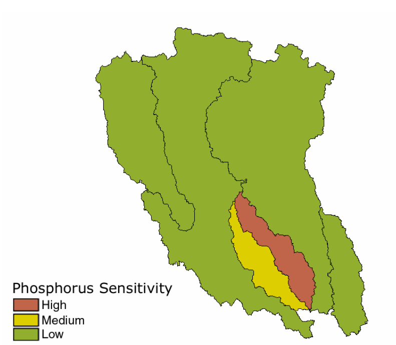


Figure 10: Phosphorus (CGCM1 - Dry)

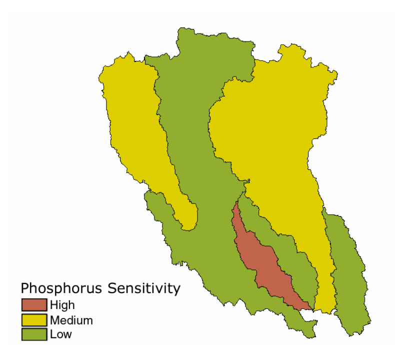


Figure 11: Phosphorus (CGCM1 - Wet)

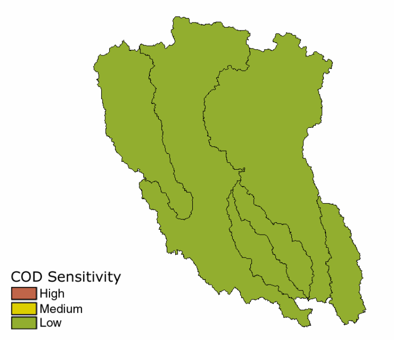


Figure 12: COD (HadCM2 - Dry)

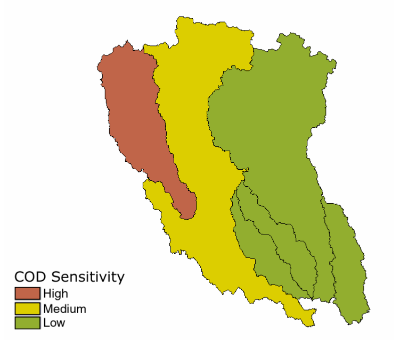


Figure 13: COD (HadCM2 - Wet)

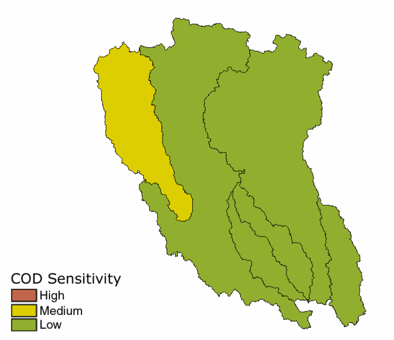


Figure 14: COD (CGCM1 - Dry)

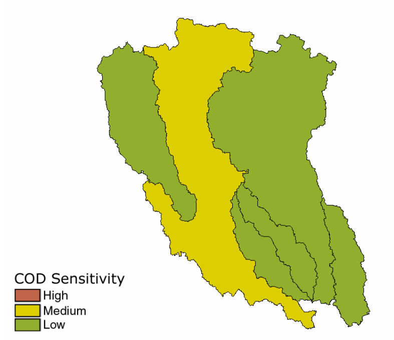


Figure 15: COD (CGCM1 - Wet)

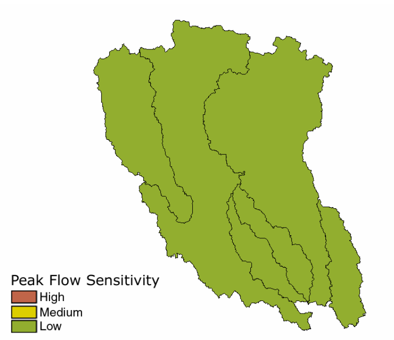


Figure 16: Peak Flow (HadCM2 - Dry)

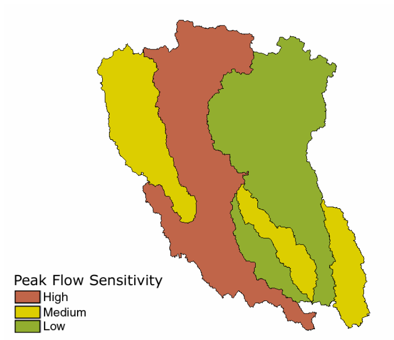


Figure 17: Peak Flow (HadCM2 - Wet)

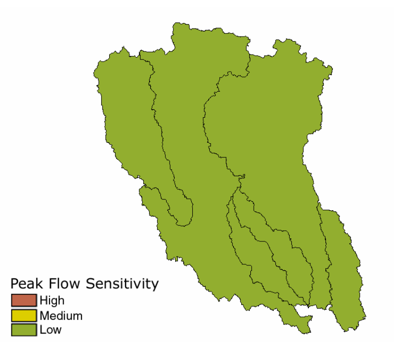


Figure 18: Peak Flow (CGCM1 - Dry)

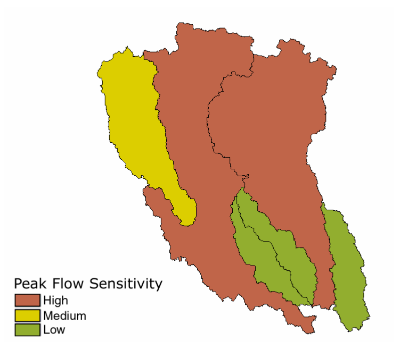


Figure 19: Peak Flow (CGCM1 - Wet)

6.0 COMPARISON OF SUBWATERSHED TO WHOLE WATERSHED RESPONSE

In Table 8 the results of running the AGNPS model for the entire Duffins Creek watershed are presented. The percent changes as compared to the existing conditions are shown in Table 9. The absolute average changes for all of the subwatersheds have been calculated and are shown in Table 10. Also in Table 10 are the results for the absolute averages calculated for the data in Table 8 for the entire Duffins Creek run. Converting these to the relative sensitivity ranges employed in Table 7, it can be seen that the results are the same for the water quality parameters. However, the peak flow is predicted to be more sensitive for the whole Duffins Creek application. This is likely due to the lower portion of the Duffins Creek watershed represented in white in Figure 1, which is a highly urbanized area.

Table 8 Entire Duffins Creek AGNPS Model outputs

Scenario	Nitrogen (mg/L)	Phosphorus (mg/l)	COD (mg/l)	Peak Flow (m^3/s)
ExCond	3.09	0.07	9.7	0.42
HadCM2wet	2.46	0.06	10.85	7.9
HadCM2dry	3.0	0.07	9.9	0.86
CGCM1wet	2.53	0.06	10.75	6.48
CGCM1dry	3.29	0.08	9.15	0.0006

Table 9 Entire Duffins Creek relative changes between existing conditions and climate change scenarios

Scenario	% change nitrogen	% change Phosphorus	% change COD	% change Peak Flow
HadCM2wet	-20.4	-14.3	11.9	1780
HadCM2dry	-2.9	0.0	2.06	110
CGCM1wet	-18.1	-14.3	10.8	1443
CGCM1dry	6.5	14.3	-5.7	-99.9

Table 10 Average sensitivity of subwatersheds as compared to sensitivity of Duffins Creek as a whole

	Nitrogen Sensitivity	Phosphorus Sensitivity	COD Sensitivity	Peak Flow Sensitivity
Subwatersheds	Medium	Low	Low	Low
Whole Duffins	Medium	Low	Low	Medium

7.0 STRENGTHS AND LIMITATIONS OF THE APPROACH

The approach used in this study provides a quantitative, scientifically defendable method for evaluating the sensitivity of watershed stream water quality to changes in water quantity for a select number of chemical parameters. The data required as input to the model is available for most of Ontario. There is no need to perform a calibration of the model as this work has already been undertaken in previous research (Leon et al. 2002).

The system has the capability of also examining pesticides, although it has not yet been tested.
One of the limitations of the approach using this version of the AGNPS model is that it does not currently simulate winter conditions. The model also does not calculate a groundwater mass balance so only changes in surface water quantity can be examined. The model also does not currently have the ability to examine metals, pathogens and many persistent organic pollutants.

8.0 APPLICATION TO OTHER WATERSHEDS

The pre-processing tools provided through the AGNPS interface facilitate easy data compiling for the models. Using DEM (Digital Elevation Model), soil type, and land use maps in vector formats, procedures are designed to automate as much input of data as possible (Leon, 1999). Design of a control panel for model operation helps in the setup and operation of the simulation process. Post-processing for output data by means of graphical and statistical tools also assists with the interpretation of model results. Such a generic application is very useful for applying the model to different watersheds in order to validate the hydrologic and water quality components.
The application of this methodology to other watersheds in Ontario could be tied in with the current AGNPS-based studies being carried out by the Conservation Authorities. As part of a joint project between NWRI, OMOE and the Great Lakes Sustainability Fund, numerous Conservation Authorities (South Nation, Raisin, Toronto and Region, Halton, Hamilton, Niagara, and Grand River) have already been trained in the use of the AGNPS system and have applied it to their watersheds. These Conservation Authorities are currently calibrating the model to stream flows and chemistry data measured for their watersheds. Once that has been completed, they would develop their existing condition scenario, as has been done by the TRCA. In the beginning the time to reach this point has been 6 months. However, most of the spatial data is easily available and there is a network of CA support groups. The application of the model will then require the use of the appropriate climate change values for the area being considered and the methodology described in this report may then be followed.

9.0 ACKNOWLEDGEMNTS

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REFERENCES

Bingner, R.L., Murphree, C.E. and Mutchler, C.K. 1989. Comparison of sediment yield models on watersheds in Mississippi. Transactions of the ASAE 32(2): 529-534.

Boer, G.J., Flato, G., Reader, M.C., and Ramsden, D. 2000a. A transient climate change simulation with greenhouse gas and aerosol forcing: experimental design and comparison with the instrumental record for the 20th century, Climate Dynamics, 16(6):405-425.

Boer, G.J., Flato, G., and Ramsden, D. 2000b. A transient climate change simulation with greenhouse gas and aerosol forcing: projected climate for the 21st century, Climate Dynamics, 16(6):427-450.

Bowen, G.S. and Hinton, M.J. 1998. The Temporal and Spatial Impacts of Road Salt on Steams Draining the Greater Toronto Area. In: Proceedings of the Groundwater in a Watershed Context Symposium, December 2-4, 1998, Canadian Water Resources Association.

Bowen, G.S., Kay, D., Lam, D.C.L., and Booty, W.G. 1995. Environmental Databases Duffins Creek Watershed. Duffins Creek Project Technical Report 95-2, MOEE.

Choi, K.S. and Blood, E. 1999. Modeling developed coastal watersheds with the Agricultural Non-Point Source Model. Journal of the American Water Resources Association. Vol. 35(2): 233-244.

Finney, V.L., Cocke, M.A., Moorhead, S.T., Klug, J. (1995). Nutrient Analysis of the Malibu Watershed Using the AGNPS Model. Animal Waste and the Land-Water Interface, Ed. Kenneth Steele, Lewis Publishers, pp. 305-312.

Foster, G.R., Lane, L.J., Nowlin, J.D., Laflen, J.M., and Yountg, R.A., (1980). A Model to Estimate Sediment Yield from Field-Sized Areas: Development of the Model. In: Knisel, W.G. (ed.) 1980. CREAMS: A Field Scale Model for Chemicals, Runoff, and Erosion from Agricultural Management Systems, USDA, Cons. Research Report No. 26, pp. 36-63.

Frere, M.H., Ross, J.D., and Lane, L.J. 1980. The nutrient Submodel. In Knisel W. Ed. CREAMS, A Filed Scale Model for Chemicals, Runoff and Erosion from Agricultural Managed Systems. U.S. Dept. Agric. Conser. Res. Rep. 26, Vol. 1.

He, C., Riggs, J.F., and Kang, Y.T. 1993. Integration of Geographic Information Systems and a Computer Model to Evaluate Impacts of Agricultural Runoff on Water Quality. Water Resources Bulletin, Vol. 29, No. 6, 891-900.

Hession, W.C. and K.L. Huber. 1989. BMP effectiveness using AGNPS and a GIS. American Society of Agricultural Engineers, 1989 International Winter Meeting. Paper No. 89-2566.

JDE Ventures, 1998. 1998 Survey of Farming Practices and Fertilizer use in the Stouffville and Reesor Creeks Watershed for AGNPS Model Application, A final report to the Ontario Ministry of Environment, Standards Development Branch and the Toronto Region Conservation Authority, 15p

Johns, T.C., Carnell, R.E., Crossley, J.F., Gregory, J.M., Mitchell, J.F.B., Senior, C.A., Tett, S.F.B. & Wood, R.A. 1997. The second Hadley Centre couple ocean-atmosphere GCM: model description, spinup and validation, Climate Dynamics, 13, 103-134

Knisel, W.G., (1980). CREAMS: A Field Scale Model for Chemicals, Runoff, and Erosion from Agricultural Management Systems, Conservation Research Report No. 26, U.S. Department of Agriculture, Washington, D.C.

Koelliker, J.K. and Humbert, C.E. (1989). Application of AGNPS Model for Water Quality Planning, ASAE Paper No. 89-2042, American Society of Agricultural Engineers, USA.

Leon, L.F., Booty, W.G., Bowen, G.S. and Lam, D.C.L. 2002. Calibration of the AGNPS Model for Duffins Creek Watershed in Southern Ontario. (in print).

Leon, L.F. 1999. AGNPS Interface for RAISON/Windows: Tutorial Guidelines. University of Waterloo, Department of Civil Engineering.

Mostaghimi, S. Park, S.W., Cooke, R.A., and Wang, S.Y. 1997. Assessment of Management Alternatives on a Small Agricultural Watershed. Wat. Res. Vol. 31(8): 1867-1878.

National Water Research Institute and Toronto and Region Conservation Authority. 2000. Reesor Creek Events sampling 1997-1998 Database.

Perrone, J. and Madramootoo, C.A. 1998. Improved curve number selection for runoff prediction, Ca. J. Civil Eng. 25:728-734.

Rode, M. and Frede, H.G. 1997. Modification of AGNPS for Agricultural Land and Climate Conditions in Germany, J. Environ. Qual., 26:165-172.

Stantec Consutling Ltd./Aquafor Beech Ltd. 2002. Spreadsheet Model for Wet and Dry Weather Flow. Ref. 22714.1. Submitted to Toronto and Region Conservation, Toronto.

Sugiharto, T. McIntosh, T.H., Uhrig, R.C. and Lardinois, J.J. 1994. Modeling alternatives to reduce dairy farm and watershed nonpoint source pollution. J. Environ. Qual. 23:18-24.

Tim. U.S. and Jolly, R. 1994. Evaluating agricultural nonpoint-source pollution using integrated geographic information systems and hydrologic/water quality model. J. Environ. Qual. 23:25-35.

TRCA Jan. 2003. Agricultural Non-Point Source (AGNPS) Modelling of the Duffins and Curruthers Creek Watersheds.

Young, R.A., Onstad, C.A., Bosch, D.D. and Anderson, W.P. 1994. Agricultural Nonpoint Source Pollution Model, Version 4.03, AGNPS User's Guide. St. Paul, Minn. Polution Control Agency and USDA-ARS, Washington DC.

Young, R.A., Onstad, C.A., Bosch, D.D., and Anderson, W.P. 1989. Agricultural nonpoint source pollution model for evaluating agricultural watershed. Journal of Soil and Water Conservation 44(2):168-173.




A WATERSHED PLAN

FOR DUFFINS CREEK AND CARRUTHERS CREEK

EXECUTIVE SUMMARY

A Report of the Duffins Creek and
Carruthers Creek Watershed Task Forces

AUGUST, 2003

Duffins and Carruthers Watersheds

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E X E C U T I V E   S U M M A R Y

The Duffins and Carruthers Creek watersheds lie to the east of Toronto and drain into the north shore of Lake Ontario. These two river systems connect communities across Durham Region and York Region including the City of Pickering, the Towns of Ajax, Markham and Whitchurch-Stouffville, and the Township of Uxbridge. They are among the healthiest of watersheds in the Greater Toronto Region, yet they are also exhibiting signs of stress from land use activities. Although the "footprint" of the proposed Pickering Airport and the Seaton land development was not available during the time this Plan was written, we do know these two watersheds will face pressure from this future urban growth, road widenings, and construction. The Management Actions contained within the Watershed Plan and its associated technical reports provide a watershed perspective and clear direction for these undertakings. However, these watersheds also hold the potential for innovative management associated with their extensive public land holdings and position relative to the protection afforded by the newly enacted Oak Ridges Moraine Act (2001).

This Watershed Plan is a blueprint for action. The Plan includes a brief summary of current watershed conditions and identifies the issues to be addressed and the opportunities that exist. It sets out a vision for the future, a management philosophy, and a framework of management strategies including watershed management goals, objectives, and the required actions. It outlines a set of effective implementation mechanisms, and provides guidance for implementation priorities at a subwatershed scale and areas within the watershed where initial implementation activities should focus.

This Watershed Plan comes from a commitment by Toronto and Region Conservation (TRCA) in its 1989 Greenspace Strategy to guide the preparation of a watershed management strategy for each of the nine watersheds in its jurisdiction. Building upon commitments made in the Greenspace Strategy, and with over 45 years experience in protecting and restoring the environmental health of one of the most rapidly expanding city regions in the world, TRCA has defined a new vision for its work, The Living City:

> ***The Living City Vision***
> *The quality of life on Earth is being determined in the rapidly expanding city regions. Our vision is for a new kind of community, The Living City, where human settlement can flourish forever as part of nature's beauty and diversity.*

The Living City is a way of living in city regions that promotes a healthy coexistence between economy and nature. In a Living City, the ecosystem is seen as the foundation for the City Region. Nature is protected and enhanced for its ability to sustain the health of its important functions in the regional ecosystem; a system in which all living things are interdependent and exist in a delicate balance.

The Living City vision has three objectives: healthy rivers and shorelines, regional biodiversity, and sustainable communities. In support of The Living City vision and building upon the experience gained from previous watershed planning initiatives, TRCA has advanced its community-based process and technical approaches in the development of this Watershed Plan.

TWO TASK FORCES AND ONE PLAN

TRCA continued its very successful model for empowering watershed stakeholders and formed two Watershed Task Forces in 2000. Membership of the two Task Forces included elected municipal representatives, watershed residents, and representatives from key stakeholder groups and agencies.

The Task Forces were charged with the responsibility of developing this Watershed Management Plan. Despite their difference in size, the Duffins Creek and Carruthers Creek watersheds are diverse and contrasting landscapes that share many of the same opportunities and challenges. Therefore, the Task Forces prepared one management plan for the two watersheds.

VISION

The Duffins and Carruthers Creek Watersheds Task Forces hold the following vision for the future of these watersheds:

> ***The Vision***
> *Duffins Creek and Carruthers Creek watersheds will be healthy, dynamic, and sustainable watersheds that continue to have clean, safe water. These watersheds will have functioning wetlands and be diverse with self-sustaining communities of native plants, fish and wildlife, where natural and human heritage features are protected and valued. Residents will recognize the watersheds as essential community resources that enhance their quality of life. All stakeholders will participate in the stewardship of the watersheds and growth and development will reflect this vision and the importance of protecting and enhancing this priceless legacy.*

MANAGEMENT PHILOSOPHY

The vision for the Duffins Creek and Carruthers Creek watersheds is supported by a management philosophy that promotes five key elements.

Net Gain
- Improve upon existing features and functions throughout the watersheds.
- Use the unique opportunities provided by extensive public land holdings in the watersheds.

Environment First

- Manage the watersheds as a "system," considering the environmental function first.
- Protect and enhance the natural features and functions as a first step in a hierarchy of other management approaches.
- Emphasize prevention over remediation, recognizing that prevention is more cost efficient than remediation.

Balance Land Use

- These watersheds, adjacent to one of the largest cities in Canada, must support a combination of natural, urban and agricultural land uses and systems.
- Apply the principles of Smart Growth.
- Recognize through land use actions, the concept of balance, thus ensuring integrity of watershed functions.

Human Health and Safety

- Recognize linkages between human health and the health of the environment.
- Minimize risk to human health and safety.

Everyone Counts – Ownership, Commitment and Follow Through

- Demonstrate sustainable living and sustainable community design.
- Build upon existing leadership, stewardship, and good decision making practices.
- Strengthen existing and develop new partnerships.
- Make the appropriate lifestyle choices, change behaviours, and encourage innovation in thoughts, words, and actions.

TECHNICAL FOUNDATION FOR THE PLAN

State-of-the-art watershed management today not only addresses a broader range of issues than previous initiatives, but also considers the interrelationships among these issues. Issues are considered in both the current and future planning context, in order to take a more proactive approach to management. Given the rich information base existing within the Duffins and Carruthers Creek watersheds, and the extensive experience of TRCA and its partners with watershed planning, the Task Forces were able not only to employ, but advance, state-of-the-art methodologies for watershed planning.

To understand key functions and issues operating within the watersheds, the Task Forces and the technical support team defined and evaluated three land use scenarios in terms of the effects they would impose on watershed health. The three scenarios included: existing land use, future land use (as per the approved Official Plans), and future land use with enhanced natural cover. These scenarios reflected the primary drivers of change expected in the watersheds, including urban growth and opportunities for natural area protection. The results of the evaluation enabled the Task Forces to benchmark the watersheds' response along a continuum.

Recognizing that the watershed ecosystem is a complex network of interrelated features and functions, the task forces reduced the watershed ecosystems to a set of simpler component systems in order to understand the response to each of the three land use scenarios. Studies were undertaken within the following technical areas:

- surface water quantity;
- groundwater quantity and quality;
- surface water quality;
- aquatic habitat and species;
- terrestrial habitat and species;
- human heritage; and
- public use – outdoor recreation.

An innovative aspect of this work was the degree to which the findings of each technical study component were integrated and interpreted from the perspective of other interrelated components. A watershed response model guided the integration and interpretation of results arising from each individual technical component study. For example, increases in vegetative cover predicted changes in groundwater levels and stream baseflow, which in turn predicted an effect on the aquatic community composition in certain stream reaches. Details of this approach and each of the technical component studies are summarized in the Technical Analysis and Integration Process Summary Report (TRCA, 2003) and in the full set of supporting technical reports. These reports build upon information previously published in the Duffins and Carruthers Creek State of the Watershed Reports (TRCA, 2002).

MANAGEMENT APPROACH

The Task Forces have recommended that the most effective approach for managing the Duffins and Carruthers Creek watersheds involves achievement of an enhanced natural heritage system, together with the application of best management practices in all aspects of land use activities. The concept of an enhanced natural heritage system at a watershed scale is described in the "Future Land Use (as per Official Plans) with Enhanced Natural Heritage Cover" scenario.

Implementation of this management approach will involve a review and realization of opportunities for achieving an enhanced natural heritage system at subwatershed and site scales.

The selection of this approach was based on the following considerations:

- its consistency with the Task Forces' Management Philosophy;
- its effectiveness for meeting multiple watershed management benefits;
- its ability to provide the foundation for a sustainable watershed;
- its feasibility; and
- its consistency with other provincial and federal basin management objectives.

GOALS, OBJECTIVES, AND BASELINE REPORT CARD

A set of eight goals and 25 objectives make up the overall management strategy of this Watershed Plan (Table E-1). A rating has been assigned to each goal and objective, based on an evaluation of the state of current watershed conditions in relation to the management direction provided by the specific goal and objectives. These ratings form a baseline "Watershed Report Card" from which the effectiveness of implementing the Watershed Plan can be measured. Details of the rating analysis are documented in the Ratings Report for the 2003 Duffins and Carruthers Creek Watersheds Report Card (TRCA, 2003).

MONITORING AND REPORTING

A formal, coordinated multi-agency monitoring program is not intended to be the sole form of watershed monitoring in the Duffins and Carruthers Creek watersheds. Many of the recommendations tabled in Chapter Six of this Plan are in fact initiatives that require frequent performance assessments. These performance assessments are considered to be elements of watershed monitoring. It is also recognized that observations of stream and terrestrial ecosystem health by residents, stakeholders, and non-government organizations are important metrics of the effectiveness of this Watershed Plan.

Periodic reviews of this Watershed Plan are an integral component of TRCA's watershed management process and allow for: systematic improvements to the plan, the incorporation of new scientific understandings of the watersheds, and emerging initiatives such as "sustainability". At the same time, the original assumptions of the Watershed Plan can, if necessary, be adjusted. Timing of major reviews should be coordinated with the preparation of a Watershed Report Card, in advance of major land use changes in the watershed.

TABLE E-1: Summary of management goals, objectives and ratings

TOPIC	GOAL		OBJECTIVES		RATINGS	
	Duffins	**Carruthers**			**Duffins**	**Carruthers**
Surface Water Quantity	**Overall Rating:** **Good**	**Good**	Objective #1	Maintain the existing water balance within the watershed.	Good	Good
	To maintain the existing hydrologic function of the watershed.		Objective #2	Maintain or enhance baseflows.	Good	Fair
			Objective #3	Minimize or reduce risks to human life and property due to flooding.	Good	Good
			Objective #4	Maintain or restore natural stream channel stability.	Further study required	Further study required
Groundwater Quality and Quantity	**Overall Rating:** **Good**	**Fair**	Objective #5	Maintain or enhance groundwater levels and discharge for watershed functions.	Good	Fair
	To protect groundwater quality and quantity groundwater levels and discharge for watershed functions.		Objective #6	Protect groundwater quality to ensure provision of safe water supplies and ecological functions.	Good	Good
			Objective #7	Ensure sustainable rates of groundwater use.	Further study required	Further study required

TOPIC	GOAL	OBJECTIVES		RATINGS	
	Duffins **Carruthers**			**Duffins**	**Carruthers**
Surface Water Quantity	**Overall Rating:** **Fair** **Fair** To protect and improve surface water quality.	Objective #8	Manage the quality and quantity of run-off from rural and urban areas to maintain in-stream uses.	Good	Good
		Objective #9	Minimize in-stream sediment associated with construction activity.	Poor	Poor
		Objective #10	Reduce water quality contamination associated with wastewater discharges.	Poor	Not Applicable
Aquatic Habitat and Species	**Overall Rating:** **Good** **Fair** To protect aquatic habitat and species.	Objective #11	Protect and restore native aquatic species and communities.	Good	Fair
		Objective #12	Protect and restore the riparian zone and associated functions.	Fair	Fair
		Objective #13	Maintain or restore the natural variability of annual and seasonal stream flows.	Further study required	Further study required

TABLE E-1: Summary of management goals, objectives and ratings

TOPIC	GOAL		OBJECTIVES		RATINGS	
	Duffins	**Carruthers**			**Duffins**	**Carruthers**
Terrestrial Habitat and Species	**Overall Rating:** **Fair**	**Fair**	Objective #14	Increase the per cent of natural cover to a quantity that provides targeted biodiversity and supports recreational uses.	Good	Fair
	To protect and enhance terrestrial habitat and species.		Objective #15	Protect the natural system quality and function from the influence of surrounding land uses.	Fair	Fair
			Objective #16	Protect and restore all native vegetation community types and species to targeted levels.	Further study required	Further study required
Public Use - Recreation	**Overall Rating:** **Good**	**Fair**	Objective #17	Create continuous watershed trails in the greenspace system linking Lake Ontario and the Oak Ridges Moraine.	Fair	Fair
	To provide appropriate sustainable public use that promotes environmental awareness and enhancement.		Objective #18	Manage the greenspace system for sustainable uses and public enjoyment.	Good	Poor
			Objective #19	Improve greenspace accessibility while ensuring compatibility between social benefits and ecological health.	Good	Poor

TOPIC	GOAL	OBJECTIVES		RATINGS	
	Duffins **Carruthers**			**Duffins**	**Carruthers**
Human Heritage	**Overall Rating:** **Fair** **Fair** To preserve and interpret our evolving human heritage resources.	Objective #20	Identify and document human heritage resources for protection.	Fair	Fair
		Objective #21	Increase awareness and appreciation of the inherent value of human heritage resources.	Fair	Fair
		Objective #22	Apply a standardized approach to protecting human heritage resources at all levels of government.	Fair	Further study required
Sustainable Communities	**Overall Rating:** **Good** **Fair** To achieve a behavioural shift in lifestyles, community design, and resource use in keeping with the environmental objectives for the watersheds.	Objective #23	Increase awareness of watershed issues and use of available watershed knowledge in decision making to foster sustainability and sustainable lifestyle practices.	Further study required	Further study required
		Objective #24	Promote lifestyles that are ecologically sustainable.	Further study required	Further study required
		Objective #25	Use sustainable urban design approaches to guide urban growth and development.	Fair	Fair

TEN INTEGRAL MANAGEMENT ACTIONS

The Task Forces recommended a detailed set of management activities for the achievement of each objective. A number of these actions are common, in that they contribute toward the fulfillment of numerous objectives. Certain benefits are considered especially important because they can happen well beyond their site of application. These particular management actions are so important that they are integral to the overall health of the watersheds and should be afforded top priority for implementation. The Integral Management Actions are:

1. Protect existing meadows, wetlands, and forests identified in the enhanced terrestrial natural heritage system and secure lands to be restored.

2. Actively restore areas within the enhanced natural heritage system, which contribute multiple watershed benefits, and allow passive restoration to occur in the remaining areas.

3. Provide stormwater quantity and quality controls for new and existing development, including transportation corridors.

4. Manage land uses and water withdrawals to maintain or enhance infiltration patterns, groundwater pathways, and resultant baseflows.

5. Eliminate the remaining point source of pollution (i.e. Stouffville Water Pollution Control Plant) and manage non-point sources of pollution, in particular stormwater runoff and infiltration from urban land uses, transportation corridors, and rural contributions.

6. Enforce stringent erosion and sediment controls for construction and infrastructure maintenance activities.

7. Protect and restore natural streams and stream processes by managing runoff and sediment loss at source, protecting valley and stream corridors, and naturalizing altered streams.

8. Remove and/or mitigate human-built barriers to fish passage and sediment transport, including on-line ponds, where recommended by the Fisheries Management Plan.

9. Maintain self-sustaining, resident/migratory fish and wildlife populations as barometers of a healthy natural heritage system.

10. Identify and raise awareness of past and present human influences on the watersheds and the strong link between human heritage, watershed recreation, and human and environmental health.

MULTIPLE BENEFITS OF NATURAL COVER

The protection and enhancement of terrestrial natural heritage cover through the achievement of the enhanced natural heritage system is central to the Task Forces' management approach. Technical analysis of the watersheds' response to the "Future Land Use (as per the Official Plans) with Enhanced Natural Heritage System" scenario repeatedly demonstrated the multiple watershed benefits that can be realized by achieving an enhanced natural heritage system. In addition to benefits associated with terrestrial habitat and species objectives, a natural heritage system would contribute to the management of hydrological, hydrogeological, water quality, aquatic resource, recreation, and human heritage concerns.

At a watershed scale, the protection of a viable natural heritage system will provide the foundation for a sustainable watershed. By protecting the ability of natural systems to carry out watershed functions, there will be less need for costly maintenance of infrastructure, less risk with unproven technological solutions to watershed management, and cost savings in taking a preventative approach rather than a reliance on remedial or "end-of-the-pipe" solutions. In addition, choices made at the community and site scales within the watershed will contribute to overall watershed sustainability.

IMPLEMENTATION FRAMEWORK

A Tool Kit of Implementation Mechanisms

Common to many watershed plans in Ontario, the key implementation mechanisms include: policy and planning, regulations and permits, stewardship and regeneration activities, land acquisition/securement, and education and awareness.

Both the province, under the Oak Ridges Moraine Act (2001) and Conservation Plan (2002), and Justice O'Connor in his Part Two Report of the Walkerton Inquiry (2002) have endorsed the important role municipal land use planning and other government permitting processes play in implementing a watershed plan. The Duffins and Carruthers Watershed Task Forces have also recognized the importance of developing a model policy framework to assist in the transition between the watershed plan and its implementation through these other planning and policy tools. Initial work has been completed in developing model policy framework; further work is a priority implementation activity.

GIS-based mapping has been prepared for each watershed to identify the areas targeted for active stewardship, regeneration, land acquisition and securement.

Subwatershed Scale Direction

A more detailed identification of key management considerations and actions has been provided at the subwatershed level. For this purpose, the Duffins Creek watershed was divided into six drainage areas including: West Duffins Creek, East Duffins Creek, Ganatsekiagon Creek, Urfe

Creek, Millers Creek, and the Lower Duffins Creek. The Carruthers Creek Watershed makes up the seventh area. Opportunities have been illustrated on a map for each subwatershed.

Community Action Sites

The task forces have identified six sites within the watersheds as potential "Community Action Sites". Sites were selected to demonstrate the implementation of many aspects of the watershed plan; the expected interest, enthusiasm, and support of implementation partners; and the feasibility of design and implementation at the site level. Community Action Sites have been successful in other watersheds as a means of facilitating the transition from plan to ground level action and in providing a sense of early accomplishment for partners implementing the plan.

Roles and Responsibilities

Implementation of the Watershed Plan requires the involvement of everyone, including residents, businesses, schools, and all levels of government. Specific recommendations are provided as to a role for each partner.

TOWARD FULFILLMENT OF NEW PROVINCIAL DIRECTIONS

The release of this report could not come at a better time as it complements recent recommendations of the Walkerton Inquiry, the Oak Ridges Moraine Act and Conservation Plan, and the proposed North Pickering Land Exchange and its principles for development of the Seaton lands. These decisions, combined with planning for the extensive federal government land holdings for a proposed regional airport in the Duffins watershed, suggest that we are at a point in time when critical decisions concerning the protection and enhancement of these areas need to be made.

Walkerton Inquiry Call for Source Protection

The Walkerton Inquiry's Part Two Report, A Strategy for Safe Drinking Water, was released by the Ontario Government in May 2002 and contains 93 recommendations for improved public policy and programs that will ensure the safety of Ontario's drinking water supply. The report focuses considerable attention on the importance of protecting drinking water sources as the first step in a multi-barrier approach to drinking water supply management. Specifically, the report calls for the preparation of watershed-based source protection plans and outlines the role of conservation authorities in this effort.

Drinking water sources within the Duffins Creek and Carruthers Creek watersheds include both lake-based (urban portions of the City of Pickering and the Town of Ajax) and groundwater-based supplies. The regional municipalities of Peel, York, and Durham have been assembling information to address components of groundwater source protection, and TRCA is committed to a program of coordinating the integration of all of this information within an integrated watershed management and source protection plan.

The preparation of source protection plans for watersheds that are predominantly served by Lake Ontario may require a slightly different approach than areas influenced mostly by local sources. Although the Duffins Creek and Carruthers Creek watersheds affect the nearshore Lake Ontario environment, contaminant sources also arise from upstream in the Great Lakes Basin and from "imported" sources, such as atmospheric deposition.

Toronto and Region Conservation is working with Conservation Ontario and its representatives on the Provincial Advisory Committee that has been established to recommend a framework for the preparation of Source Protection Plans in Ontario.

Oak Ridges Moraine Act and Conservation Plan

After a six month moratorium that froze development on the Oak Ridges Moraine, and during which time a strategy was developed and public consultation undertaken, (Bill 122, The Oak Ridges Moraine Conservation Act) was passed in the Ontario Legislature and received Royal Assent on December 14, 2001. On April 22, 2002 the Oak Ridges Moraine Conservation Plan was approved and filed as a Ministers Regulation (O. Reg. 140/02). The purpose of the Plan is to provide land use and resource management planning direction to ensure the protection and ecological and hydrological integrity of the Oak Ridges Moraine.

The Conservation Plan provides for four land use designations. The first two are Natural Core Areas and Natural Linkage Areas, where very limited new land uses are being permitted. The Countryside Areas are largely identified for agricultural, rural, recreational, and resource areas and, finally, the Settlement Areas are restricted to existing urban or settlement area boundaries.

Municipalities are directed in the plan to recognize these land use designations, setbacks, and further study requirements in their Official Plans and zoning by-laws within set timeframes. In addition, it requires that detailed water management studies (i.e., watershed plans, water budgets, and conservation plans) be completed and their results be incorporated into municipal Official Plans before any major development proposals may be approved.

In summary, the Conservation Plan was written and designed to be implemented by municipal governments. Many of the requirements of the Plan involve tasks or studies that conservation authorities have traditionally undertaken for their member municipalities.

Prior to the enactment of the Oak Ridges Moraine Act and Plan, the nine conservation authorities with watersheds on the Oak Ridges Moraine formed a coalition to advocate for the protection of the Moraine. This Conservation Authorities Moraine Coalition has prepared a proposal to be submitted to its member municipalities outlining the aspects of the Conservation Plan, which could be delivered by conservation authorities. The preparation of watershed plans like this one, water budgets, and mapping of environmental features are among the items being proposed by the coalition.

WORKING TOGETHER FOR THE FUTURE DUFFINS AND CARRUTHERS WATERSHEDS

This Watershed Plan will be successful if it remains a living document, one that is revisited and implemented when and where appropriate. We will know that we have made a difference if we strive to meet multiple objectives during implementation and continue to further understanding of the technical work that supports management strategies and their direction.

What is Success?

As we move forward and evolve with the times and the places that are unique to these two watersheds we should be able to look back and say that we have:

- protected and enhanced the natural systems and sustainability of communities within the Duffins Creek and Carruthers Creek watersheds;
- strengthened foundations for managing the watersheds using a formal monitoring and reporting system in place;
- improved water quality in Carruthers Creek and Duffins Creek for improved habitats and the provision of safe drinking water;
- increased our knowledge of human and natural heritage resources in these watersheds and developed educational and outreach programs that support and apply this new knowledge base in the two watersheds and beyond;
- provided opportunities for watershed residents and stakeholders to have a greater say in how these watersheds are used and managed;
- expanded our knowledge and refined our planning and management practices to sustain these river systems;
- built on existing and established new watershed partnerships that reflect the importance of the Duffins Creek and Carruthers Creek watersheds in the Regional Municipalities of Durham and York and beyond; and
- encouraged private landowners to manage and exercise good stewardship of their lands to promote watershed sustainability.

Good decision making is based on sound science and an accurate, reliable knowledge base. This Watershed Plan identifies a series of actions that are based on sound science. These actions have emerged as a result of detailed analysis and consultation. For practical purposes, these management strategies are to be initiated and monitored over the next five years. Many of these actions will be completed during this time. For those actions that require implementation over a longer time period, significant progress will be made during the next five years and a foundation established for continued action.

Periodic reviews of this Watershed Plan are an integral component of TRCA's watershed management process allowing for systematic improvements to the Plan, and the incorporation of new scientific understandings of the watersheds and emerging initiatives, such as "sustainability". At the same time, the original assumptions of the Watershed Plan, if necessary, can be adjusted. Timing of major reviews should be coordinated with the release of Watershed Report Cards, or advanced, if unanticipated major changes in land use occur.

Many individuals and groups have collaborated to develop this strategy. Many more will be involved in its implementation. But its success hinges on the vigour with which each partner pursues the vision, management philosophy, and accompanying management strategies. Two healthy, dynamic and sustainable watersheds are attainable for Duffins Creek and Carruthers Creek.

EXECUTIVE SUMMARY APPENDIX

This appendix includes three figures taken from A Watershed Plan for Duffins and Carruthers Creek as well as the membership of the Carruthers Creek Task Force and the Duffins Creek Task Force.

The following three figures are appended:

Federal and Provincial Land Holdings

This figure illustrates the location of the five local and two regional municipalities within the Duffins and Carruthers watersheds including York and Durham Regions and all five local municipalities.

The southern boundary of the Oak Ridge Moraine is shown in red and therefore, the headwaters of Duffins Creek are subject to special policies and legislation as a result of the Oak Ridges Moraine Act and Conservation Plan.

The Duffins Creek watershed contains some of the largest land holdings for Toronto and Region Conservation in their jurisdiction and those lands are shown in green.

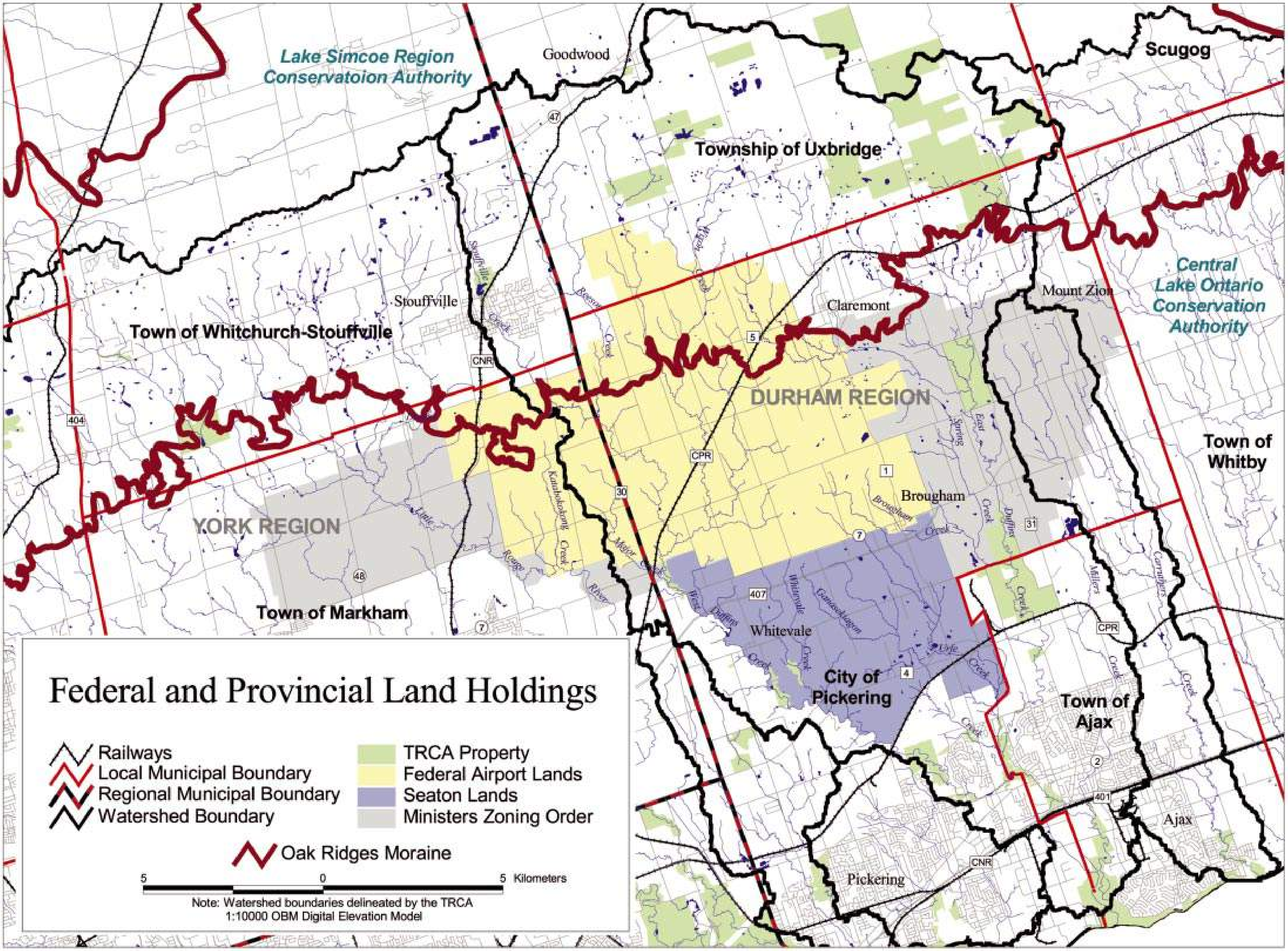
The yellow region is the Federal Pickering Lands and the blue area is the Provincial Seaton Lands. Shown in grey are the areas under Provincial Minister's zoning orders which restrict development in areas adjacent to the potential airport site. The Agricultural Assembly Lands occur on the west side of Duffins Creek and zoning controls were put in place to protect these agricultural lands.

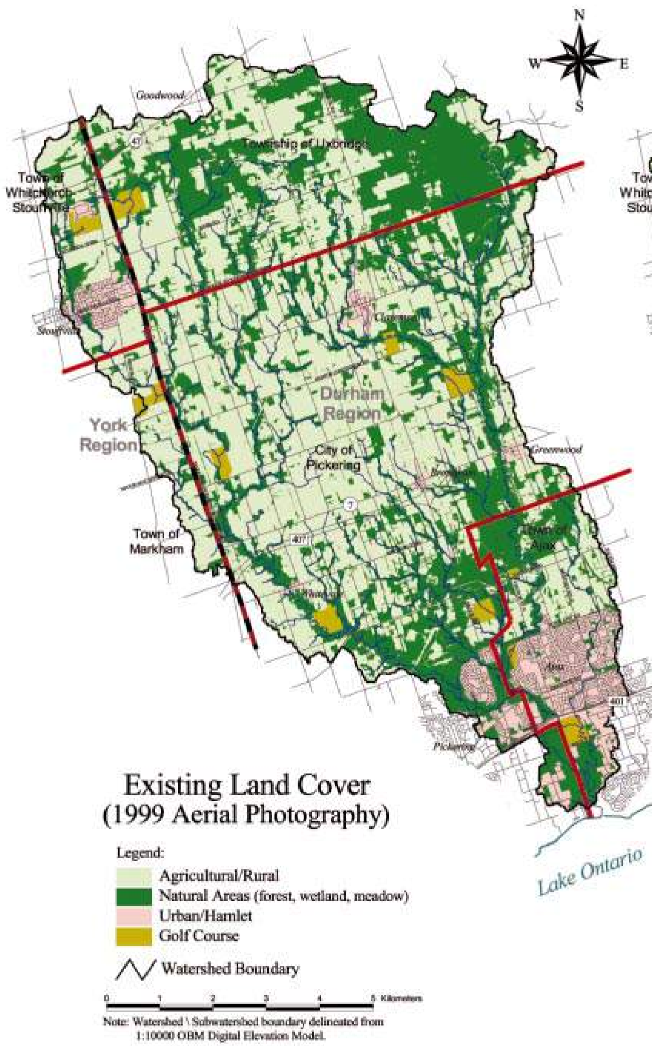
With over 50 per cent of the Duffins Creek watershed in public ownership there is a unique opportunity to implement this watershed plan.

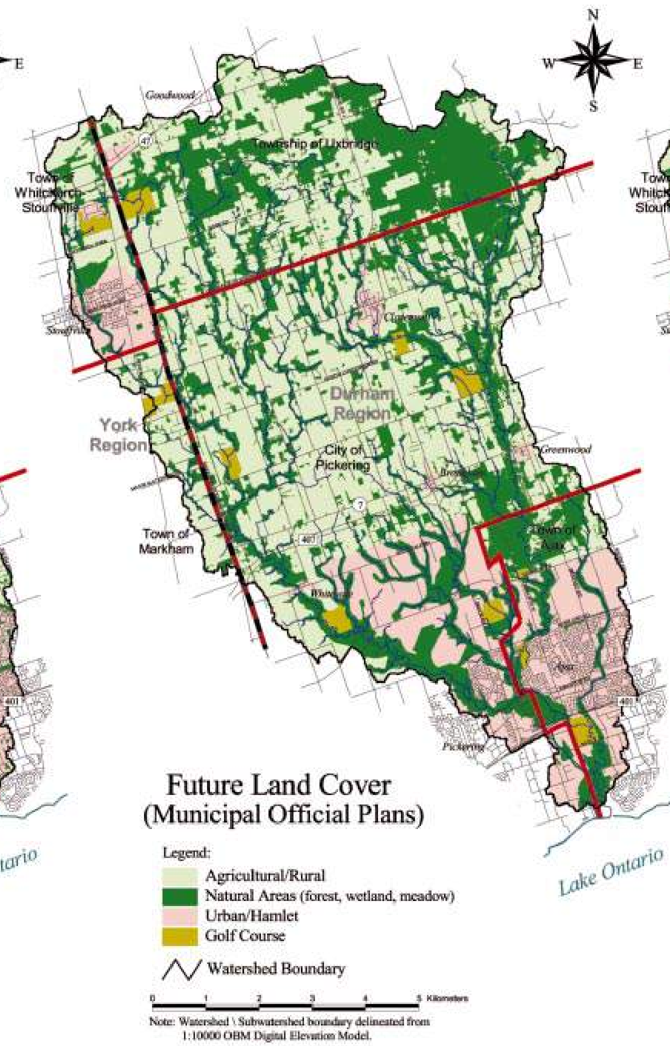
Three Land Use Scenarios in Duffins Creek and Three Land Use Scenarios in Carruthers Creek

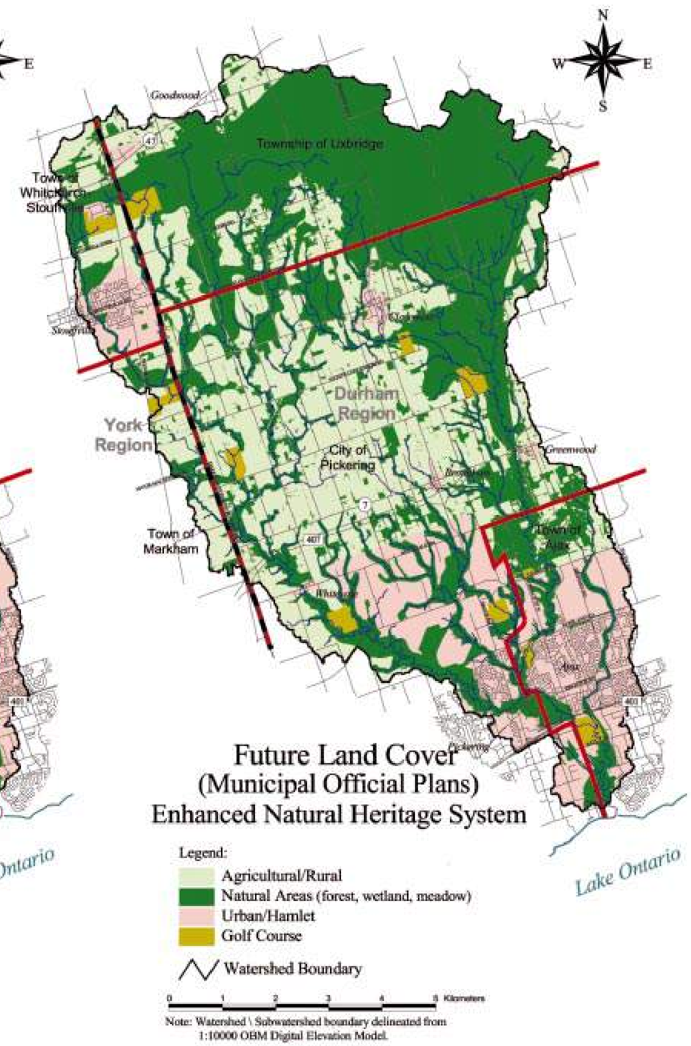
The following three figures per page for Duffins Creek and for Carruthers Creek illustrate the three land use scenarios in terms of the effects they would impose on watershed health. The three scenarios included: existing land use; future land use (as per the approved Official Plans); and future land use with enhanced natural cover. These scenarios reflected the primary drivers of change expected in the watersheds, including urban growth and opportunities for natural area protection.

The Task Forces have recommended that the most effective approach for managing the Duffins and Carruthers Creek watersheds involves achievement of an enhanced natural heritage system, together with the application of best management practices in all aspects of land use activities. Implementation of this management approach will involve a review and realization of opportunities for achieving an enhanced natural heritage system at subwatershed and site scales.


Lake Simcoe Region Conservatoion Authority
Goodwood
Scugog
Township of Uxbridge
Stouffville
Town of Whitchurch-Stouffville
Claremont
Mount Zion
Central Lake Ontario Conservation Authority
DURHAM REGION
Town of Whitby
Brougham
YORK REGION
Town of Markham
Whitevale
City of Pickering
Town of Ajax
Ajax
Pickering
Federal and Provincial Land Holdings
Railways
Local Municipal Boundary
Regional Municipal Boundary
Watershed Boundary
TRCA Property
Federal Airport Lands
Seaton Lands
Ministers Zoning Order
Oak Ridges Moraine
5 0 5 Kilometers
Note: Watershed boundaries delineated by the TRCA
1:10000 OBM Digital Elevation Model

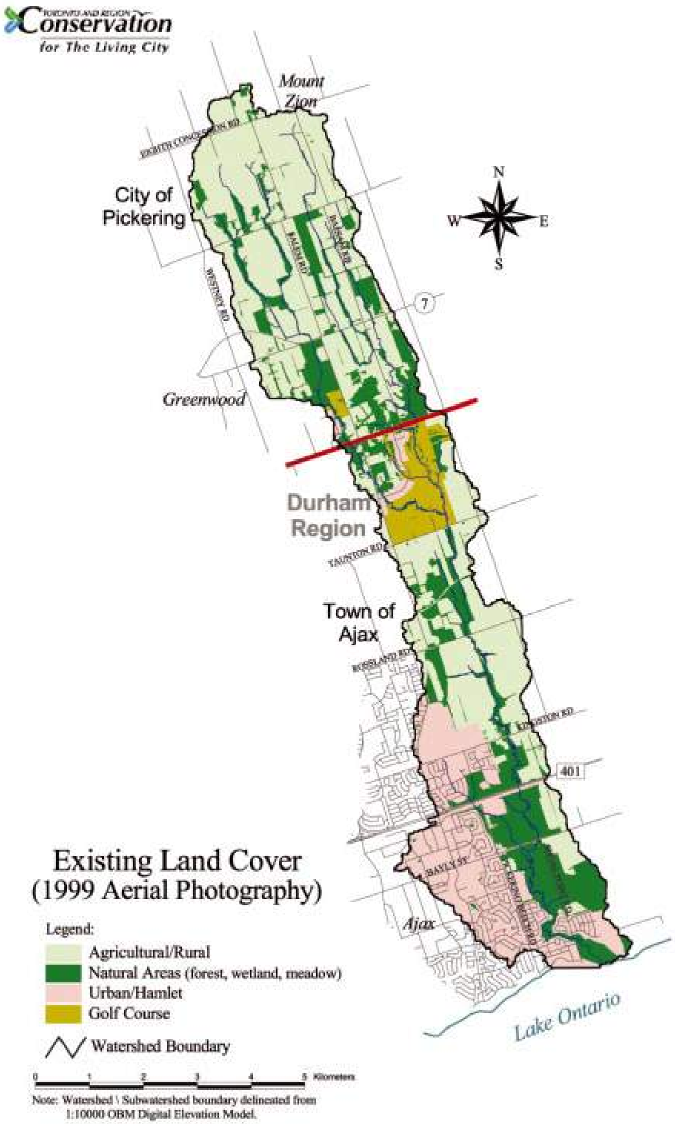


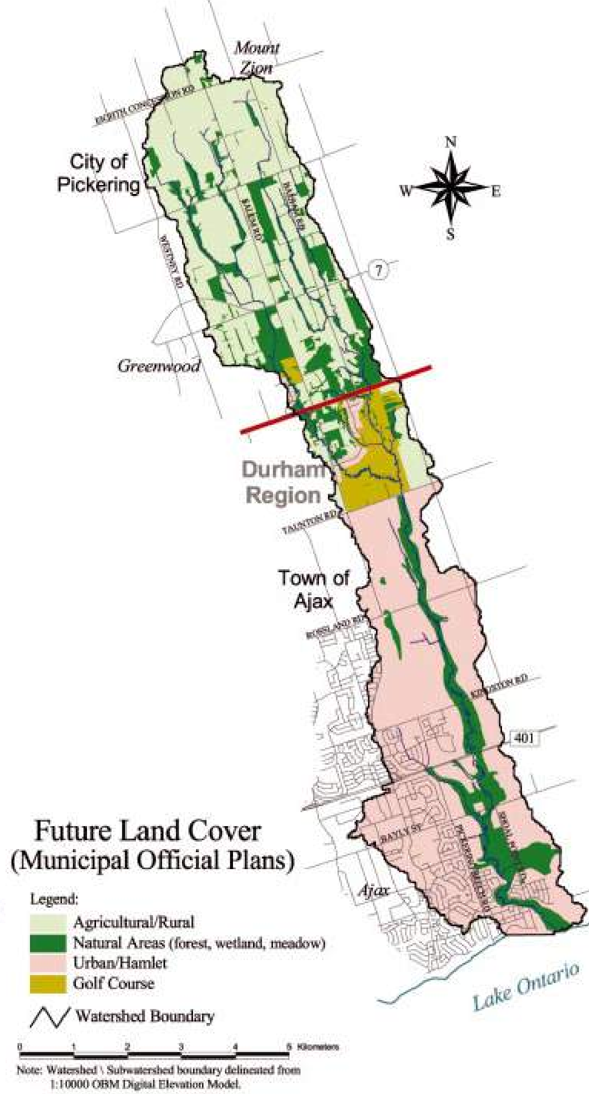


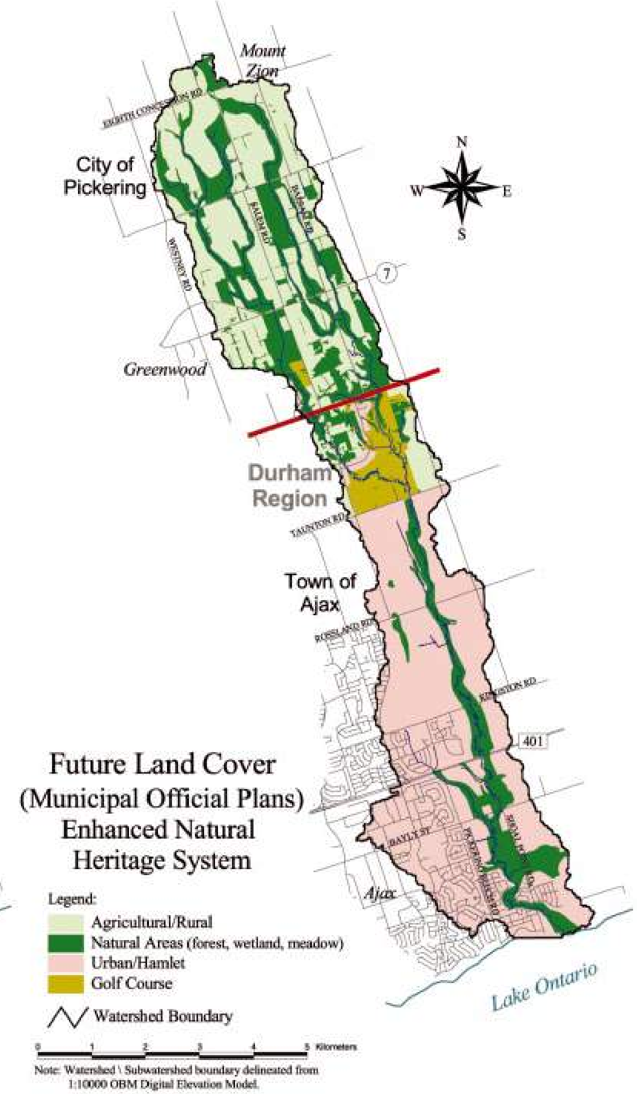


Note: The urban lands outlined in the two future land cover scenarios above were evaluated as part of the modeling exercise and do not represent the Pickering urban boundary as outlined in the Durham Region and City of Pickering's Official Plans. The actual urban boundary extends north to Highway 7.

The "Enhanced" Natural Heritage System, as depicted in the third scenario above, is a concept only. It is used to evaluate the benefits of an increase in natural cover. It does not define the exact locations for the increase or limit the increase in natural cover to only those areas identified in dark green.







Note: The urban lands outlined in the two future land cover scenarios above were evaluated as part of the modeling exercise and do not represent the Ajax and Pickering urban boundary as outlined in their Official Plans.

The “Enhanced” Natural Heritage System, as depicted in the third scenario above, is a concept only. It is used to evaluate the benefits of an increase in natural cover. It does not define the exact locations for the increase or limit the increase in natural cover to those areas identified in dark green.

CARRUTHERS CREEK TASK FORCE MEMBERS

Chair:	Dr. Neil Burnett, resident, Town of Ajax
Vice-Chair:	Regional Councillor Scott Crawford, Town of Ajax
Municipal Representatives:	Councillor Pat Brown (Alternate), Town of Ajax Alex Georgieff (Alternate), Regional Municipality of Durham Regional Councillor Rick Johnson (Alternate), City of Pickering Mayor Steve Parish, Town of Ajax, appointed by the Regional Municipality of Durham Councillor David Pickles, City of Pickering
Residents:	Jane Brooke, Town of Ajax David Clark, City of Pickering Steven Yourt, Town of Ajax
Stakeholders:	Neil Acton, Deer Creek Golf Course, representing Watershed Golf Courses Jackie Fraser, Aggregate Producers Association of Ontario (APAO) Alan Kimble, Urban Development Institute (UDI), Durham Chapter Gordon McKay, Citizens for Carruthers Cindy Mitton-Wilke, Ontario Ministry of Transportation
Supporting Staff Agencies and Municipalities:	Chris Darling, Regional Municipality of Durham, Planning Department Robert Flindall, Town of Ajax, Engineering Department Steve Gaunt, City of Pickering, Planning Department Kevin Heritage, Town of Ajax, Planning Department Tom Melymuk, Division Head, Corporate Projects and Policy, City of Pickering Tim Rance, Ministry of Natural Resources

Duffins and Carruthers Watersheds

DUFFINS CREEK TASK FORCE MEMBERS

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Vice-Chair: Councillor Mark Carroll, Town of Whitchurch-Stouffville

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Mayor Wayne Arthurs, City of Pickering, appointed by the Regional Municipality of Durham
Councillor Joe Dickson, Town of Ajax
Councillor Peter Dobrich (Alternate), Town of Whitchurch-Stouffville
Lilli Duoba (Alternate), Town of Markham
Alex Georgieff (Alternate), Regional Municipality of Durham
Barb Jeffrey (Alternate), Regional Municipality of York
Regional Councillor Rick Johnson (Alternate), City of Pickering
Councillor Randy Low (Alternate), Town of Ajax
Mayor Gerri Lynn O'Connor (Alternate), Township of Uxbridge
Regional Councillor Susan Para, Township of Uxbridge
Councillor David Pickles, City of Pickering
Councillor Erin Shapero, Town of Markham
Regional Councillor Tony Wong, Regional Municipality of York

Residents:

Dr. Doug Dodge, Town of Ajax
Deanna Fry, Town of Ajax, Environmental Advisory Committee
Margie Kenedy, Town of Whitchurch-Stouffville
Judy Sullivan, City of Pickering

Stakeholders:

Neil Acton, Deer Creek Golf Course, representing Watershed Golf Courses
Jackie Fraser, Aggregate Producers Association of Ontario (APAO)
Alan Kimble, Urban Development Institute (UDI), Durham Chapter
Patricia Short-Galle, Transport Canada

Supporting Staff Agencies and Municipalities:

Chris Darling, Regional Municipality of Durham, Planning Department
Robert Flindall, Town of Ajax, Engineering Department
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Kevin Heritage, Town of Ajax, Planning Department
Tom Melymuk, Division Head, Corporate Projects and Policy, City of Pickering
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Duffins and Carruthers Watersheds




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