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LAKE ST. CLAIR HYDROLOGIC TRANSFER FACTORS

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LAKE ST. CLAIR HYDROLOGIC TRANSFER FACTORS*

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Monthly hydrologic transfer factors were developed for Lake St. Clair for the period 1950-1974 to aid in the comparison and coordination of St. Clair and Detroit River monthly flows. The transfer factor is defined as the sum of the monthly precipitation and runoff minus the evaporation and change in storage. Each of the hydrologic constituents were determined independantly from available data.

1. INTRODUCTION

This study of the hydrologic transfer factors for Lake St. Clair was initiated to aid in the comparison and coordination of St. Clair and Detroit River monthly flows. As part of the comparison, the transfer factors will be used in the fine tuning of the GLERL St. Clair and Detroit River hydraulic transient models. The flow coordination is under the auspices of the River Flow Subcommittee of the International Coordinating Committee for Great Lakes Basic Hydraulic and Hydrologic Data.

The Lake St. Clair hydrologic system is shown in figure 1. The St. Clair River connects Lake St. Clair with Lake Huron while the Detroit River connects it with Lake Erie. Applying the hydrologic water balance equation to Lake St. Clair, we obtain

$$P + R + G + Q_{sc} = E + Q_D + AS, \qquad (1)$$

where
- P = overlake precipitation
- R = tributary runoff
- G = net ground water flux into the system
- Q_{sc} = inflow into Lake St. Clair from the St. Clair River
- E = lake evaporation
- Q_D = outflow from Lake St. Clair into the Detroit River
- AS = rate of change of storage in the lake.

* GLERL Contribution No. 82

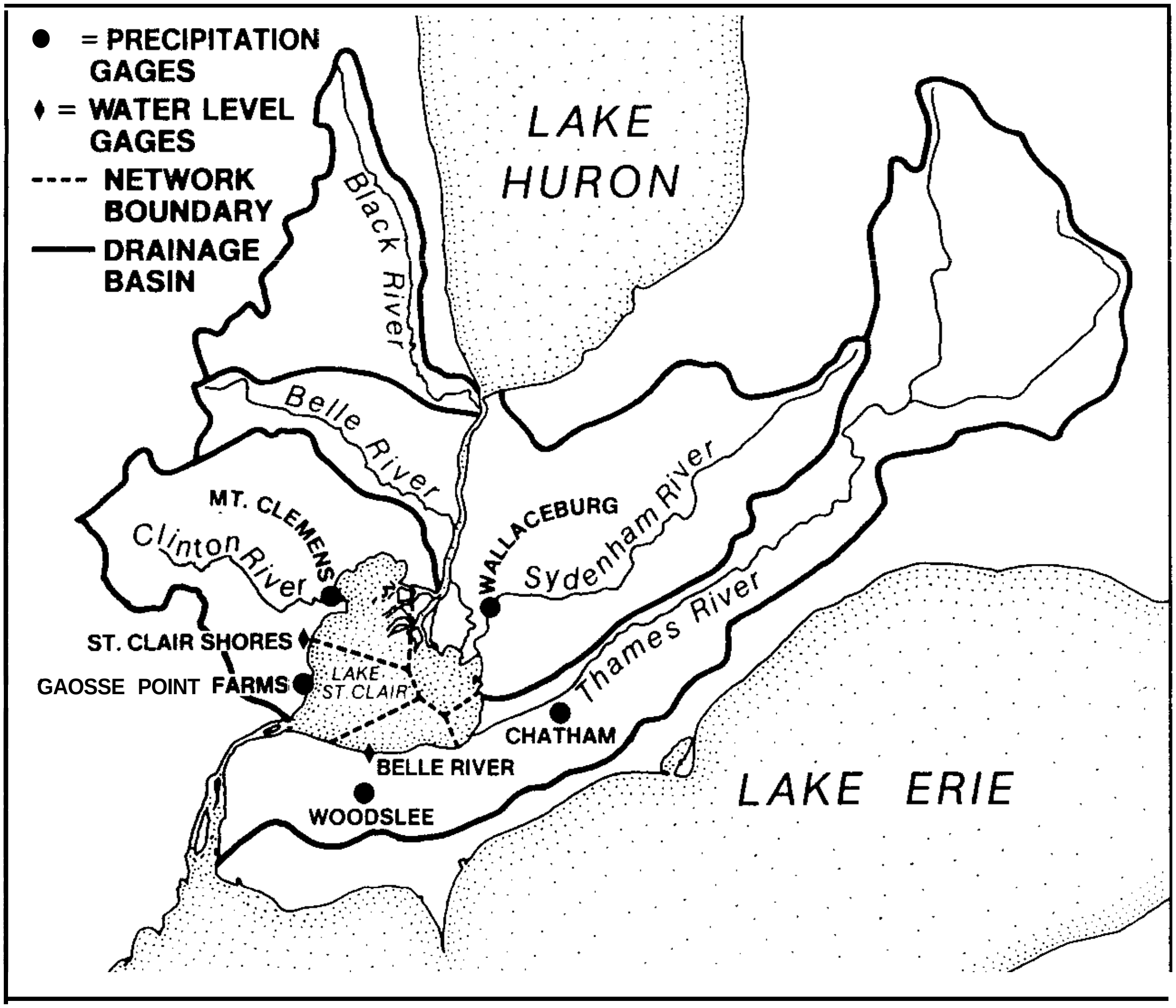

Figure 1. Lake St. Clair Hydrologic System

In all the following computations, the net flux of ground water into the lake is assumed to be negligible. The hydrologic transfer factor, T, is defined as

$$T = P + R - E - \Delta S . \qquad (2)$$

Substituting the transfer factor into equation (1), we obtain

$$Q_{SC} + T = Q_D . \qquad (3)$$

Equation (3) will be the primary equation used in the St. Clair and Detroit River flow comparisons and coordination.

2. OVERLAKE PRECIPITATION

The precipitation computations were expanded from Quinn (1971) by use of the Thiessen polygon procedure. The precipitation gages at Mt. Clemens and Grosse Pt. Farms in Mich. and at Chatham, Woodslee, and Wallaceburg in Ont. were used in this study. The gage locations, along with the five gage polygon network, are shown in figure 1. The Thiessen weighting factors for each of the gage networks used in the study are given in table 1. The selection of the appropriate gage network was dependent upon the number of stations in operation for any period. The monthly precipitation rates, expressed in hundreds of cubic feet per second (HCFS), are given in table 2.

Table 1. Thiessen Polygon Networks and Weighting Factors

Gage	3 Gage Network	3 Gage Network	4 Gage Network	4 Gage Network	4 Gage Network	5 Gage Network
Grosse Pt. Farms	0.679	0.542	0.358	0.542	0.339	0.339
Mt. Clemens			0.327		0.288	0.288
Chatham	0.136		0.130	0.046		0.046
Wallaceburg		0.264		0.236	0.179	0.151
Woodslee	0.185	0.194	0.185	0.176	0.194	0.176

Table 2. Lake St. Clair *Overwater* Precipitation in HCFS*

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1950	17	15	7	15	9	8	12	9	14	13	15	9
1951	10	11	11	10	10	12	12	8	7	14	12	15
1952	11	5	11	12	9	4	9	7	6	5	9	7
1953	9	2	10	11	9	12	9	6	7	3	4	7
1954	7	16	17	11	4	9	5	8	8	26	6	6
1955	6	11	10	9	5	8	9	12	8	14	12	5
1956	4	9	13	16	21	12	5	19	3	3	8	8
1957	7	8	5	18	12	12	20	8	16	12	9	13
1958	3	3	2	6	4	12	9	8	12	5	10	2
1959	11	8	8	15	12	3	9	19	12	15	11	13
1960	10	8	4	9	9	20	7	8	4	7	4	2
1961	1	10	9	20	9	11	9	16	16	5	11	5
1962	8	9	4	6	4	20	8	12	10	6	8	5
1963	4	2	9	12	8	12	6	7	6	2	5	5
1964	8	3	9	16	7	11	8	18	8	2	4	9
1965	13	11	10	9	7	8	11	13	10	13	6	14
1966	3	5	9	12	7	12	11	15	5	5	15	16
1967	9	5	3	11	5	28	13	12	9	15	10	20
1968	9	6	9	7	18	23	17	17	7	5	12	13
1969	11	1	6	15	17	15	26	8	4	7	12	7
1970	4	3	9	14	11	15	14	6	9	6	11	8
1971	2	13	7	4	5	8	6	12	8	4	5	14
1972	6	5	10	13	8	9	9	16	12	12	16	13
1973	5	5	17	7	10	20	12	7	7	8	16	12
1974	11	9	13	10	15	6	7	10	9	3	12	12

* HCFS – hundreds of cubic feet per second

3. LAKE EVAPORATION

The evaporation from Lake St. Clair was computed by Derecki (1976) with the mass transfer procedure. The evaporation rates were computed by the equation

$$E = 0.0097 (e_s - H e_a) R U_8, \qquad (4)$$

where E = lake evaporation, cm/day
e_s = saturation vapor pressure at the water surface, mb
H = monthly lake-land humidity ratio
e_a = vapor pressure of the air at 8 m, mb
R = monthly lake-land wind ratio
U_8 = wind speed over the lake at 8 m, m/s.

The meteorological data used in the computations are from stations located in close proximity to Lake St. Clair and were adjusted to the 8-m (26.3-ft) level. The wind speed and humidity data were taken from the Detroit City Airport in Mich. and from Windsor, Ont. The water surface temperatures were extrapolated from the Detroit municipal water intake temperatures. The average perimeter air temperatures are from the Detroit City Airport and Mt. Clemens, Mich., and from Windsor and Chatham, Ont.

The monthly evaporation rates computed from equation (5) were converted to HCFS and are given in table 3.

4. LAKE STORAGE

The rates of change of lake storage were computed by Kelley (1976) from the water level gages at Belle River, Ont., St. Clair Shores, Mich., and the Grosse Point Yacht Club in Mich. (fig. 1). The St. Clair Shores gage replaced the Grosse Point Yacht Club gage in 1970. Beginning-of-month levels were computed for each gage by averaging the daily mean water levels of the first day of the month and the last day of the previous month. The water levels at Belle River were corrected by a +0.10-foot datum correction. The beginning-of-month levels for the lake are the Grosse Point Yacht Club levels for the period 1950-1960 and a mean of the Grosse Point Yacht Club or St. Clair Shores and Belle River levels for the period 1961-1975, when the Belle River gage was in operation. The beginning-of-month lake levels are given in table 4.

*Table 3. Lake St. Clair Mass Transfer Evaporation in HCFS**

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1950	0	7	8	5	13	12	10	14	14	10	19	8	10
1951	5	5	2	0	12	10	8	13	21	11	15	8	9
1952	3	4	2	1	16	16	14	13	21	30	12	3	11
1953	3	5	-0	5	10	12	13	19	29	18	16	9	12
1954	8	1	6	-3	21	7	14	19	22	16	12	6	11
1955	8	4	4	-1	17	11	9	15	23	14	16	8	11
1956	5	5	3	4	11	7	8	11	21	10	14	1	8
1957	11	4	3	-2	17	13	9	18	17	20	15	3	11
1958	9	16	3	2	31	19	10	22	22	25	22	13	16
1959	14	11	4	4	15	21	17	14	26	18	17	1	14
1960	4	8	12	-5	14	13	13	11	19	18	13	14	11
1961	12	3	1	4	23	17	10	13	16	17	20	11	12
1962	15	11	5	7	18	15	13	14	24	15	12	13	14
1963	16	17	-1	9	23	15	17	25	24	22	16	13	16
1964	6	7	-1	0	24	18	15	17	20	17	14	4	12
1965	11	11	7	1	9	17	15	14	13	21	17	4	12
1966	16	6	3	5	23	15	18	16	22	21	10	9	14
1967	5	12	2	3	21	11	9	19	21	11	15	4	11
1968	9	14	-0	7	16	11	10	15	16	20	13	9	12
1969	10	9	11	2	16	12	10	15	25	23	12	9	13
1970	12	11	6	-0	13	15	8	22	23	12	18	10	12
1971	15	7	5	9	26	11	22	24	16	11	22	6	14
1972	13	12	8	6	14	16	7	13	22	21	13	4	12
1973	8	11	-6	5	15	9	12	17	32	18	16	11	12
1974	8	13	4	2	18	14	17	17	27	20	16	5	13
MEAN	9	9	4	3	17	13	12	16	21	18	15	7	12

* HCFS – hundreds of cubic feet per second

The monthly changes in storage were computed by multiplying the difference between two consecutive beginning-of-month levels by the area of Lake St. Clair, 430 square miles. The changes in storage were then converted into monthly rates by dividing by the number of seconds in each month. The rates of change of storage are given in table 5 expressed in hundreds of cubic feet per second-months (HCFS-months).

5. LAKE RUNOFF

The runoff from the land basin into Lake St. Clair was determined independently for the four river basins draining into the lake. These are the Thames and Sydenham basins in Ont. and the Clinton and Pine-Belle basins in Mich. (shown in fig. 1). The percentage of gaged area has changed from 40 to 59 percent during the 1950 to 1974 period, respectively, as shown in table 6. The data for the computations were obtained from the surface water records of the U.S. Geological Survey and the Water Survey of Canada.

The runoff into the lake from the unregulated basins was computed by the exponential relationship

$$R = R_g K^S, \qquad (5)$$

Table 4. Lake St. Clair Beginning-of-Month Water Levels in Feet (IGLD 1955)*

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1950	572.32	572.93	572.14	573.29	573.89	573.62	573.67	573.69	573.61	573.41	573.20	573.15
1951	573.12	572.85	573.70	574.15	574.63	574.69	574.82	574.86	574.76	574.46	574.41	574.34
1952	575.06	574.35	574.98	575.06	575.49	575.59	575.86	575.68	575.60	575.21	574.47	574.27
1953	574.28	574.32	574.17	574.56	574.86	575.06	575.21	575.18	575.06	574.60	574.34	573.91
1954	573.56	572.20	573.70	574.31	574.79	574.65	574.87	574.81	574.66	574.48	574.75	574.44
1955	574.69	574.09	574.62	574.74	574.95	574.90	574.87	574.71	574.41	573.93	573.60	573.15
1956	573.23	570.64	571.61	573.11	574.14	574.16	574.26	574.33	574.35	573.88	573.45	572.90
1957	572.90	571.93	572.92	572.99	573.61	573.64	573.72	573.88	573.56	573.32	572.98	572.56
1958	572.95	570.82	571.73	571.92	572.51	572.66	572.76	572.93	572.68	572.48	572.25	571.72
1959	571.49	571.04	571.31	572.60	572.91	573.13	573.03	572.88	572.87	572.62	572.38	572.28
1960	572.76	571.63	572.50	573.33	573.41	573.94	574.30	574.33	574.28	574.09	573.49	572.96
1961	573.02	572.37	573.25	573.37	574.15	573.92	573.97	574.00	573.76	573.46	573.00	572.88
1962	573.08	571.44	572.04	573.16	573.12	573.16	573.32	573.17	573.03	572.86	572.51	572.36
1963	572.74	571.55	571.50	572.66	572.72	572.58	572.58	572.46	572.28	571.98	571.76	571.56
1964	571.55	570.43	570.33	571.54	572.00	572.08	571.90	571.88	571.88	571.60	571.20	570.99
1965	571.11	570.20	570.70	571.91	572.24	572.40	572.50	572.32	572.35	572.23	572.10	571.83
1966	572.46	572.06	572.03	572.78	573.23	573.18	573.31	573.10	572.95	572.52	572.12	572.28
1967	572.78	572.84	572.50	573.05	573.34	573.63	574.01	573.80	573.66	573.30	573.19	573.30
1968	573.56	573.39	573.29	573.69	573.58	574.10	574.38	574.16	573.92	573.80	573.44	573.66
1969	573.65	574.10	573.82	573.91	574.49	574.84	575.02	575.30	574.96	574.56	574.16	573.74
1970	572.91	573.38	573.32	573.96	574.12	574.41	574.56	574.63	574.43	574.38	574.08	573.97
1971	574.18	573.11	574.07	574.39	574.53	574.80	574.90	574.79	574.92	574.58	574.28	574.08
1972	574.20	574.30	573.92	574.38	574.68	575.08	575.24	575.30	575.27	575.18	575.14	575.04
1973	575.26	575.48	575.22	576.01	575.88	576.04	576.39	576.14	575.90	575.62	575.09	575.09
1974	575.36	575.51	575.36	575.66	575.85	576.04	576.08	575.89	575.68	575.26	574.83	575.08

*IGLD – International Great Lakes Datum

where R = the runoff into the lake
R_g = the runoff at the furthermost downstream gaging station in the basin
K = A/A_g, where A is the total area of the drainage basin and A_g is the drainage area above the gaging station
S = the basin exponent.

The basin exponent, S, was determined from the relationship

$$s = \frac{\log \frac{R_1}{R_2}}{\log \frac{A_1}{A_2}} \qquad (6)$$

where R_1 and R_2 = the gaged runoffs from downstream and upstream gages, respectively, on the basin
A_1 and A_2 = the gaged areas corresponding to R_1 and R_2.

Table 7 gives the necessary drainage basin factors for the solution of equation (5).

*Table 5. Lake St. Clair Rate of Change of Storage in HCFS-Months**

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1950	26	-39	51	28	-12	2	1		-10	-9	-2	-3
1951	-12	42	20	22	3	6	2	-4	-14	-2	-3	32
1952	-32	30	4	20	4	12	-8	-4	-18	-33	-9	0
1953	2	-7	17	14	9	7	-1	-5	-21	-12	-20	-16
1954	-61	74	27	22	-6	10	-3	-7	-8	12	-14	11
1955	-27	26	5	10	-2	-1	-7	-13	-22	-15	-21	4
1956	-116	46	67	48	1	5	3	1	-22	-19	-25	0
1957	-43	49	3	29	1	4	7	-14	-11	-15	-19	17
1958	-95	45	9	27	7	5	8	-11	-9	-10	-25	-10
1959	-20	13	58	14	10	-5	-7	0	-12	-11	-5	21
1960	-51	42	5	4	24	17	1	-2	-9	-27	-25	3
1961	-29	44	50	-236	-10	2	1	-11	-14	-21	-6	9
1962	-73	30			2	7	-7	-6	-8	-16	-7	17
1963	-53	-2	52	3	-6	0	-5	-8	-14	-10	-9	0
1964	-50	-5	54	21	4	-8	-1	0	-13	-18	-10	5
1965	-41	25	54	15	7	5	-8	1	-6	-6	-12	28
1966	-18	-1	34	21	-2	6	-9	-7	-20	-18	7	22
1967	3	-17	25	13	13	18	-9	-6	-17	-5	5	12
1968	-8	-5	18	-5	23	13	-10	-11	-6		10	0
1969	20	-14	4	27	16	8	13	-15	-18	-16-18	-19	-37
1970	21	-3	29	7	13	7	3	-9	-2	-13	-5	7
1971	-48	48	14	6	12	5	-5	6	-16	-13	-9	5
1972	4	-18	21	4	18	7	3	-1	-4	-2	-5	10
1973	10	-13	35	-6	7	16	-11	-11	-13	-24	0	12
1974	7	-7	13	9	9	2	-9	-9	-19	-19	12	-12

* HCFS-Months - hundreds of cubic feet per second-months

Table 6. Lake St. Clair Drainage Areas in Square Miles

Basin	Station	Gaged Area 1950	Gaged Area 1974	Total Area
Clinton	Mount Clemens	733	733	776
Pine-Belle	Memphis	0	151	625
Thames	Ealing	519		2786
	N. Thames at London	657		
	Thamesville		1660	
Sydenham	Alvinston	283		1309
	Dresden		478	
	Bear Creek above Wilkesport		230	
(Total)		2192	3252	5496

The Clinton River Basin is comprised of 776 square miles, of which square miles or 94 percent is gaged. Due to the high percentage of gaged area, the basin exponent, S, is relatively unimportant and is assumed to be 1.0. The monthly runoff values into the lake (table 8) were computed by equation (5).

The Pine-Belle River Basin comprises ~~776~~ 424 square miles. ~~of which 733~~ To this was added 201 square miles of adjacent land draining into Lake St. Clair, giving an area of 625 square miles for computational purposes. The first streamflow gage in the basin was installed in October of 1962 on the Belle River at Memphis, with an upstream area of 151 square miles. The Belle River subbasin has 230 square miles; thus, 66 percent is gaged. The Pine River subbasin, with 194 square miles, is still ungaged at this time. As the total basin comprises three subbasins, only one of which is gaged. the total runoff into the lake is computed by linear areal extrapolation with the basin exponent, S, taken equal to 1.

Table 7. *Drainage Basin Factors for Unregulated Basins*

River Basin	Time Period	Gage	A	A_g	S	K
Clinton	1950-1974	Mt. Clemens	776	733	1.0	1.06
Pine-Belle	1950-1960	Black at Fargo	625	480	1.0	1.30
	1963-1974	Memphis	625	151	1.0	4.14
Sydenham	1950-1964	Alvinston	1309	283	0.874	4.63
	1965-1966	Alvinston and Bear Creek	1309	513	0.874	2.55
	1966-1974	Dresden and Bear Creek	1309	708	Variable	1.85

Table 8. *Clinton River Runoff in CFS**

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NO"	DEC
1950	1758	1387	2054	2182	578	523	281	148	290	383	505	1123
1951	1052	1769	1546	1175	567	349	212	144	189	320	618	608
1952	1811	1091	1684	1398	488	194	150	111	134	128	199	338
1953	364	313	789	717	599	308	246	148	112	103	110	161
1954	193	1938	1133	972	380	276	130	92	98	575	340	400
1955	725	628	1387	534	257	194	109	109	114	175	320	250
1956	136	341	1641	1356	2775	724	277	399	215	147	193	317
1957	347	647	721	1303	1123	469	912	201	266	360	629	1133
1958	375	346	575	434	174	199	225	115	151	126	162	115
1959	145	374	1514	1377	493	181	161	251	243	553	757	1313
1960	841	707	1005	1663	576	652	185	161	121	156	198	158
1961	122	271	441	758	573	340	193	246	285	182	326	280
1962	270	301	1589	541	357	263	143	184	214	177	228	161
1963	130	129	696	446	551	348	147	128	119	108	127	118
1964	177	170	279	586	578	205	204	212	158	140	137	209
1965	338	1207	1197	1260	357	257	166	168	156	226	182	612
1966	361	399	1017	747	705	324	169	184	131	148	371	882
1967	517	562	1483	1726	498	806	684	229	199	495	701	1710
1968	765	1697	1110	852	945	1348	679	412	320	277	448	687
1969	1069	694	639	1504	1246	665	916	316	167	255	388	340
1970	264	383	757	1178	686	507	341	235	306	313	436	484
1971	320	1304	1354	647	254	208	191	207	199	236	228	461
1972	540	339	1036	1141	556	325	333	477	399	567	1017	1254
1973	1365	692	2208	1067	685	1051	548	475	225	285	647	843
1974	1634	1285	2353	1635	1692	541	301	349	235	322	383	467

* CFS - cubic feet per second

In order to determine the runoff for the period 1950–1962, when no gages were available in the basin, a study was made by using gages on adjacent river basins. For the period 1963 to 1974, comparisons were made on a cfs/mi^2 basis between the following gages: Belle River at Memphis, Mich., Mill Creek at Avoca, Mich., Black River at Fargo, Mich., and the Clinton River at Mt. Clemens. The Black River at Fargo was found to most closely duplicate the Belle River runoff in cfs/mi^2 and was used in equation (5). The Pine-Belle River Basin runoff into Lake St. Clair is given in table 9.

The Sydenham Basin consists of 1309 square miles of land in the province of Ontario. For computational purposes the following three time periods were differentiated: 1950-1964, 1965-1966, and 1967-1974. For the first period the only available streamflow gage was on the Sydenham River at Alvinston, Ont., with a drainage area of 283 square miles. A second gage on Bear Creek above Wilkesport, Ont., with a drainage area of 230 square miles, became available for use in 1965. The final gage used in this study, the Sydenham near Dresden, Ont., with an area of 478 square miles, became available for use in the 1967 computations.

Table 9. *Belle-Pine River Runoff in CFS**

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1950	923	526	2214	1654	92	61	133	64	59	104	663	1341
1951	1020	1406	1393	1152	122	118	27	22	22	44	270	293
1952	1719	1497	2018	1576	406	61	92	35	26	21	39	81
1953	115	139	904	333	444	139	437	728	33	27	35	49
1954	48	2409	1510	564	1719	86	31	25	21	611	241	543
1955	841	854	1315	568	82	43	42	21	14	20	26	27
1956	22	22	1576	581	1966	126	53	57	25	18	23	48
1957	64	358	423	1151	589	99	109	26	23	29	48	266
1958	95	154	462	132	52	42	27	23	25	12	18	13
1959	14	21	1953	1328	374	238	61	146	59	143	440	1120
1960	499	342	1001	2005	464	259	43	29	23	20	29	25
1961	17	113	306	349	217	73	39	105	78	55	190	95
1962	42	62	2227	272	268	553	36	30	25	65	64	51
1963	37	33	484	145	224	33	25	21	25	21	33	25
1964	37	33	66	108	112	25	46	33	25	25	33	46
1965	99	1043	1039	1383	108	41	21	50	29	41	66	207
1966	240	273	836	414	319	95	25	25	29	50	79	389
1967	311	269	1565	1863	224	642	339	54	41	99	298	849
1968	211	1250	836	385	339	381	174	66	79	54	104	190
1969	373	373	377	944	840	236	211	124	33	54	87	75
1970	58	141	472	919	480	104	153	46	87	257	522	505
1971	170	1333	1399	447	195	66	29	33	37	50	58	166
1972	215	124	919	1155	257	70	157	104	83	261	592	956
1973	1304	439	2463	708	373	385	99	70	37	62	265	493
1974	1283	716	1710	1068	1118	161	70	66	37	-0	-0	-0

* CFS – cubic feet per second

The 1968 to 1974 period was used to determine the basin exponent, S, by equation (6). The results are summarized in table 10. The mean S value of 0.874 was selected for use during the 1950-1966 period.

For the period 1967-1974 the basin exponent, S, is defined by

$$s = \frac{\log \frac{R_1}{R_2}}{\log \frac{A_1}{A_2}} = 4.39 \log \frac{R_1}{R_2}$$

where R_1 = the recorded Sydenham River flow above Dresden
R_2 = the recorded flow at Alvinston
A_1 = the area above the Dresden gage, 478 square miles
A_2 = the area above the Alvinston gage, 283 square miles.

The Sydenham runoff is then computed by the equation

$$R = R_g \frac{A^S}{A_g} = R_g \, (1.85)^{4.39 \log \frac{R_1}{R_2}} \qquad (13)$$

where R_g = the combined recorded flows at Dresden and Bear Creek
A_g = the combined area, 708 square miles.

The monthly runoffs into Lake St. Clair from the Sydenham Basin are given in table 11.

Table 10. Sydenham Basin Exponent Computations

Gage 1	Gage 2	R_1 cfs	A_1 Miles^2	R_2 cfs	A_2 Miles'	S
Dresden plus Bear Creek	Alvinston	579	708	255	283	0.894
Dresden	Alvinston	399	478	255	283	0.854

*Table 11. Sydenham River Runoff in CFS**

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1950	3639	1863	3440	3204	431	171	159	184	157	208	956	2728
1951	2012	3578	2957	2248	457	357	228	90	93	104	610	530
1952	3848	1494	2343	2145	815	343	135	159	128	122	171	339
1953	579	423	2065	1044	1269	1208	363	1116	128	100	141	211
1954	415	3692	4001	2793	678	299	166	140	206	1593	1071	1764
1955	1962	2614	2957	1177	376	190	70	88	88	238	1124	937
1956	396	1463	4191	2004	3886	636	724	1269	613	323	375	1151
1957	1505	1901	1558	1669	949	290	363	135	299	602	1429	3258
1958	526	735	1334	560	258	404	248	95	182	132	255	155
1959	549	1425	3604	1802	1124	488	164	210	229	815	1482	2244
1960	2027	1825	1665	3654	1909	1836	173	150	107	136	198	129
1961	95	1494	1044	1798	796	234	184	652	284	153	472	396
1962	541	648	2892	632	266	205	95	104	95	253	1482	964
1963	256	187	2972	671	930	208	121	112	89	90	146	126
1964	476	469	1086	1337	777	151	110	392	224	135	140	716
1965	1146	2490	2674	2778	250	114	95	127	74	250	467	2043
1966	537	1809	1843	1462	535	760	78	82	81	79	537	3137
1967	1112	633	3363	3378	723	666	337	90	61	1148	2206	3081
1968	756	5489	3115	984	497	1302	552	154	93	76	328	1200
1969	2456	1353	1062	2586	1716	1037	290	59	35	48	513	1023
1970	191	654	1524	2386	497	363	162	53	53	61	696	1106
1971	341	1638	2944	1016	161	112	26	11	28	28	49	1084
1972	1064	339	4302	2686	465	149	290	239	42	233	1930	2454
1973	2732	1081	5393	1460	1020	535	92	54	27	32	447	1729
1974	3144	2085	3674	2123	2412	194	91	44	33	37	118	512

* CFS – cubic feet per second

The Thames is the only regulated river draining into Lake St. Clair. For this reason, the exponential technique cannot be applied. The Thames drains an area of 2386 square miles. To this was added 400 square miles of adjacent land draining into Lake St. Clair. For the period prior to 1956, two gages, the Thames at Ealing, Ont., 519 square miles, and the North Thames at London, Ont., 657 square miles, were available for computations. The monthly runoff was computed using straight areal extrapolation by the equation

$$R = R_g \frac{A}{A_g} = 2.37\ R_g, \qquad (14)$$

where R_g = the combined runoff at the London and Ealing gages
A = the total area, 2786 square miles
A_g = the total gaged area, 1176 square miles.

For the 1956-1975 period when the downstream gage at Thamesville, Ont., is available the runoff is computed by the relationship

$$R = R_g + C(R_g - R_1)\ \frac{(A - A)}{A_g - A_1} \qquad (15)$$

where R_g = the recorded runoff at Thamesville
C = a correction factor, 0.95, to be applied to the 1956-1971 period for compatability with the 1971-1974 period
R_1 = the recorded runoff at Byron, Ont., for the period 1956-1971 and the recorded runoff at Middlemiss, Ont., for the period 1972-1974
A = the total area, 2786 square miles
A_g = the drainage area above Thamesville, 1660 square miles
A_1 = the drainage area corresponding to R_1, 1200 square miles for Byron, 1450 square miles for Middlemiss.

Thus, the two equations for the 1956-1974 period are

1956-1971 $$R = 3.33\ R_g - 2.33\ R_1 \quad (16)$$
1972-1974 $$R = 6.36\ R_g - 5.36\ R_1 \quad (17)$$

The monthly runoffs from the Thames Basin as computed by equations (14), (16), and (17) are given in table 12.

The total runoff into Lake St. Clair from its drainage basin, given in table 13. is the sum of the four individual basin runoffs.

6. TRANSFER FACTORS

The Lake St. Clair transfer factors were computed by equation (2) and are shown in table 14. A sensitivity analysis was conducted on equation (2) by incrementing each of the independent parameters by 10 percent and noting the effect on the transfer factor. The results for the months of February, June, and September and the annual mean are given in table 15.

On an annual basis and during most of the year, the transfer factor is seen to be most sensitive to the runoff into the lake. The evaporation, however, becomes the most important parameter during the high evaporation months of August through October. The average monthly values for each of the parameters constituting the transfer factors are shown in table 16.

7. RECOMMENDATION

It is recommended that the Lake St. Clair transfer factors given in this report be applied in the analysis and coordination of the St. Clair and Detroit River monthly flows and in the hydrologic balancing of the St. Clair and Detroit River and Lake St. Clair hydrologic system.

Table 12. *Thames River* Runoff in CFS*

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1950	9239	3056	10471	9121	936	473	672	782	496	628	2866	6136
1951	6681	6657	5709	7462	1329	718	782	394	384	594	2722	2362
1952	7297	4004	7368	6183	2288	572	457	406	346	316	427	1275
1953	2033	2078	7107	2729	3241	3715	550	365	562	292	295	656
1954	843	10447	9215	8149	1668	573	302	263	367	6041	1504	3558
1955	4013	1831	10195	4198	997	363	248	156	275	498	1954	2266
1956	735	1362	11660	5408	12802	1068	1150	704	2948	697	585	3079
1957	3272	2829	6423	5813	2410	466	2356	273	967	1224	3445	7609
1958	2196	1189	4628	2515	668	785	504	215	623	419	1131	1151
1959	1553	3574	10824	6211	2938	983	347	274	396	1487	2719	4411
1960	3501	2889	608	15282	4947	3661	627	383	306	126	478	403
1961	242	1463	3615	5540	2865	1260	549	825	529	247	955	1801
1962	1059	934	8822	3848	954	307	156	385	191	388	1788	1718
1963	683	373	6372	5116	2485	643	202	111	141	156	257	226
1964	915	1616	4511	4134	2063	319	274	1112	664	194	195	1606
1965	2975	8319	8914	7098	1638	301	71	119	200	643	1187	5244
1966	2213	4461	5434	3368	2059	1278	207	258	227	387	1214	6944
1967	2723	2583	3873	8229	2752	1756	1771	987	467	2100	4129	5738
1968	2845	8646	6264	3151	1586	2634	1190	812	878	1264	1137	5377
1969	4222	11324	3327	6544	4544	2055	812	477	382	484	1515	2486
1970	948	1912	3975	5721	1619	696	650	258	152	313	1107	4141
1971	2103	3974	8259	4892	964	450	329	447	431	413	578	1485
1972	2205	1739	6955	7213	2177	933	1366	1256	433	831	3825	3233
1973	5731	1660	13065	4225	2488	1340	684	570	423	328	1346	5040
1974	9189	6674	8286	5300	5004	1161	764	456	598	640	1154	2470

* CFS – cubic feet per second

Table 13. Lake St. Clair Runoff in HCFS*

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1950	156	68	182	162	20	12	12	12	10	13	50	113
1951	108	134	116	120	25	15	12	6	7	11	42	38
1952	147	81	134	113	40	12	8	7	6	6	8	20
1953	31	30	109	48	56	54	16	24	8	5	6	11
1954	15	175	159	125	44	12	6	5	7	88	32	63
1955	75	59	159	65	17	8	5	4	5	9	34	35
1956	13	32	191	93	214	26	22	24	38	12	12	46
1957	52	57	91	99	51	13	37	6	16	22	56	123
1958	32	24	70	36	12	14	10	4	10	7	16	14
1959	23	54	179	107	49	19	7	9	9	30	54	88
1960	69	58	43	226	79	64	10	7	6	4	9	7
1961	5	33	54	84	45	19	10	18	12	6	19	26
1962	19	19	155	53	18	13	4	7	5	9	36	29
1963	11	7	105	87	42	12	5	4	.	4	6	5
1964	16	23	59	62	35	7	6	17	11	5	5	26
1965	46	131	138	125	24	7	4	5	5	12	19	81
1966	34	69	91	60	36	25	5	5	5	7	22	114
1967	47	40	103	152	42	39	31	14	8	38	73	114
1968	46	171	113	54	34	57	26	14	14	17	20	75
1969	81	137	54	116	83	40	22	10	6	8	25	39
1970	15	31	67	102	33	17	13	6	6	9	28	62
1971	29	82	140	70	16	8	6	7	7	7	9	32
1972	40	25	132	122	35	15	21	21	10	19	74	79
1973	111	39	231	75	46	33	14	12	7	7	27	81
1974	152	108	160	101	102	21	12	9	9	10	17	34

* HCFS – hundreds of cubic feet per second

Table 14. St. Clair Transfer Factors in HCFS*

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NO"	DEC
1950	147	115	130	144	28	6	13	11	20	25	48	117
1951	125	98	105	108	20	11	14	5	7	16	42	13
1952	187	52	139	104	29	-12	11	5	9	14	14	24
1953	35	34	102	40	46	47	13	16	7	2	14	25
1954	75	116	143	117	33	,	0	1	1	86	40	52
1955	100	40	160	65	7	6	12	14	12	24	51	28
1956	128	-10	134	57	223	26	16	31	42	24	31	53
1957	91	12	90	90	45	8	41	10	26	29	69	116
1958	121	-34	60	13	-22	2	1	1	9	-3	29	13
1959	40	38	125	104	36	6	6	14	7	38	53	79
1960	126	16	-2	236	50	54	3	6	0	20	25	-8
1961	23	-4	57	64	41	11	8	32	26	15	16	11
1962	85	-13	104	54	2	11	6	11	-1	16	39	4
1963	52	-6	63	87	33	9	-1	-6	0	-6	4	-3
1964	68	24	15	57	14	8	0	18	12	8	5	26
1965	89	106	87	118	15	-7	8	3	8	10	20	63
1966	39	69	63	46	22	16	7	11	8	9	20	99
1967	48	50	79	147	13	38	44	13	13	47	63	116
1968	54	168	104	59	13	56	43	27	11	18	9	79
1969	62	1.3	45	102	68	35	25	18	3	10	44	74
1970	-14	26	41	109	18	10	16	-1	-6	16	26	53
1971	64	40	128	59	-17	0	-5	-11	15	13	1	35
1972	29	36	113	125	11	1	20	25	,	12	82	78
1973	98	46	219	83	34	28	25	13	-5	21	27	70
1974	148	111	156	100	90	11	11	11	10	12	1	53

* HCFS - hundreds of cubic feet per second

Table 15. Effect of IO-Percent Parameter Changes on the computed Transfer Factor

Parameter	-Percent Change in Transfer Factor—			
	February	June	September	Annual
Precipitation	2	7	10	2
Runoff	14	13	10	12
Evaporation	2	7	20	2
Change in storage	4	7	10	0

*Table 16. Average Monthly Transfer Factor Parameters in HCFS**

Month	J	F	M	A	M	J	J	A	S	O	N	D
Precipitation	8	7	9	12	9	12	11	11	9	8	10	10
Tributary Runoff	55	67	121	98	48	22	13	10	9	15	28	54
Lake Evaporation	9	9	4	3	17	13	12	16	21	18	15	7
Change in Storage	-27	15	28	15	6	6	-2	-6	-13	-14	-9	5

* HCFS - hundreds of cubic feet per second

8. REFERENCES

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