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EVAPORATION FROM LAKE ST. CLAIR

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EVAPORATION FROM LAKE ST. CLAIR*

Jan A. Derecki

Available land-based data adjusted to overwater conditions were used to determine monthly evaporation from Lake St. Clair for individual years of a 26-year period, 1950-75, by the mass transfer method. Because of extensive ice cover on the lake, the overwater mass transfer results were adjusted for the ice cover during winter. The ice-cover adjustment reduced the average annual evaporation by 100 mm, with a resultant average annual evaporation of 750 mm. The mass transfer method is the only technique that permits operational evaporation estimates from this lake with presently available data; it is also most amenable for future improvements.

1. INTRODUCTION

Evaporation from Lake St. Clair removes nearly 1 m of water from the lake surface annually. Despite this large loss of water, there have been no reliable estimates of evaporation from this lake owing to difficulties in applying the traditional water budget computations to Lake St. Clair and to concentration of more recent evaporation research on the Great Lakes proper, excluding Lake St. Clair.

The water budget computations for Lake St. Clair are meaningless because of extremely large inflow-outflow volumes in relation to the size of the lake. Because the values of inflow and outflow are approximately two orders of magnitude larger than other water budget factors, evaporation is equivalent to roughly 1 percent of the inflow or outflow. Since 1 percent accuracy in the inflow and outflow exceeds practical limits, water budget determination of Lake St. Clair evaporation is not feasible.

In this study, evaporation is determined by the mass transfer method, with basic data collected on land and adjusted to overwater conditions. The land to lake adjustments for wind and humidity (air and dew point temperatures) are based on air stability and overwater fetch criteria. applicable to Lake St. Clair. Resulting overwater estimates of lake evaporation are potentially too high during winter because of extensive ice cover on Lake St. Clair. The ice-cover reduction of evaporation is included by considering both open-water and ice-covered areas of the lake during winter. Monthly evaporation rates from the lake are computed for individual years of a 26-year period, 1950-75. These results are compared with other evaporation estimates.

Another potentially feasible approach for computing long-term Lake St. Clair evaporation is the energy budget method. However, data

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requirements for the energy budget method are even more critical and preclude computation by individual years. Comparison of preliminary estimates for Lake St. Clair evaporation (Derecki, 1974) as computed by the mass transfer, energy budget, and water budget methods showed that only the mass transfer results are realistic.

2. MASS TRANSFER EVAPORATION

Lake evaporation as determined by the mass transfer method is a function of wind speed and the vapor pressure difference between the saturated air at the lake surface and the air above. All measurements for the above input parameters should represent overwater conditions. For Lake St. Clair, as well as the Great Lakes proper, this requirement cannot be satisfied for any appreciable period of time, since climatological data are normally recorded at a network of land stations, where climatic conditions may differ considerably from those over the lake. Climatic variations are due to differences in the rates of heat absorption and dissipation between land and water areas and the lack of orographic obstructions to wind movement over extensive water areas. During the 26-year period of study, 1950-75, available overwater data on Lake St. Clair were limited to a few periodic measurements obtained during synoptic surveys on adjacent Great Lakes. These shipboard observations were normally restricted to the dredged navigation channel and are not representative of the whole lake. The available overwater measurements also lack a primary requirement, namely, the continuity of data. Because of insufficient data on Lake St. Clair, short-fetch land to lake adjustments derived from the Great Lakes observations were employed. The water surface temperature adjustments were derived from water temperature surveys conducted by the Great Lakes Environmental Research Laboratory (GLERL), NOAA, during 1974.

The mass transfer equation used to compute evaporation from Lake St. Clair was developed on Lake Hefner (U.S. Geological Survey, 1954) and tested successfully in different climatic conditions on Lake Mead (U.S. Geological Survey, 1958). It was adapted for use on the Great Lakes by Richards (1964), who modified the basic equation by incorporating lake/land wind and humidity ratios. These ratios represent an empirical relationship for each parameter and were derived from simultaneous observations over land and over water. The overwater observations were obtained during synoptic surveys conducted primarily on the lower Great Lakes (Lakes Ontario and Erie) and a few on Lake Huron. The lake/land wind and humidity ratios enable use of long-term perimeter data in the mass transfer determination of evaporation. The modified Lake Hefner equation, expressed in metric units, becomes

$$E_w = 0.097(e_w - H_c e_{a1}) R_c u_8 , \qquad (1)$$

where

E_w = lake evaporation (overwater), m/day
e_w = saturation vapor pressure at water surface temperature, mb
H_c = constant monthly lake/land humidity ratio
e_{a1} = perimeter vapor pressure of the air (8 m), mb
R_c = constant monthly lake/land wind ratio
u_8 = perimeter wind speed at 8 m, m/s.

Employment of monthly ratios represents crude land to lake adjustments, but equation (1) was considered to give acceptable results for computing evaporation from the Great Lakes (Richards and Irbe, 1969; Derecki, 1976). However, the ratios for wind (Lemire, 1961; Richards, 1964) and humidity (Richards and Fortin, 1962) are based on Great Lakes data and may not be applicable to Lake St. Clair. Because of their large size, the Great Lakes have a substantial capacity to modify the atmosphere above them, while Lake St. Clair may not. The surface area of Lake St. Clair (1270 km^2) covers only a small fraction of any one of the Great Lakes, each of which is 15 to 65 times larger.

In this study constant monthly wind and humidity ratios are replaced by variable land to lake adjustments based on air stability and overwater fetch criteria applicable to Lake St. Clair. These adjustments were obtained from the results presented by Phillips and Irbe (1978), which were determined from the International Field Year on the Great Lakes (IFYGL) observations conducted on Lake Ontario during 1972. Their lake/land wind ratios and humidity adjustments, expressed as land - lake air and dew point temperature differences, are grouped into five ranges of atmospheric stability and lengths of overwater fetch. Different atmospheric stability conditions (very stable, stable, neutral, unstable, and very unstable) are determined by the air - water temperature difference ($T_{a1} - T_w$) from readily available land-based air temperatures. For application to Lake St. Clair, the land to lake adjustments for the five air stability ranges and a single representative overwater fetch of 11-23 km (7-14 nmi) were selected. This length of overwater fetch corresponds to the average radius of the lake. To avoid artificial grouping of the land to lake adjustments, the adjustment values at the mid-point of each air stability range were fitted with compound curves and their equations determined and used in the study to give adjustments based on actual air stability values for each month. Equations for the compound curves for the lake/land wind ratios and the land - lake air and dew point temperature differences (humidity adjustments) are listed in Table 1. This format of humidity adjustments is retained in the present study because of high interest in land to lake temperature modifications, although it might be more convenient to use lake/land humidity ratios for evaporation computations.

The Lake Hefner equation, modified for the variable wind and humidity adjustments based on air stability criteria, becomes

$$E_w = 0.097(e_w - e_{aw})R_w u_8 , \qquad (2)$$

where

E_w = lake evaporation (overwater), mm/day
e_w = saturation vapor pressure at water surface temperature, mb
e_{aw} = overwater vapor pressure of the air (8 m), mb
R_w = variable lake/land wind ratio based on overwater air stability
u_8 = perimeter wind speed at 8 m, m/s.

Parameters listed in equation (2) for the water surface and meteorological data contain adjustments applicable to Lake St. Clair that are based on overwater observations. Consequently, equation (2) should produce valid estimates of evaporation from the lake for open-water conditions. The wind and humidity adjustments were derived from upwind overwater observations on Lake Ontario, but are restricted to small overwater fetch in the nearshore areas of the lake, and should apply as well to Lake St. Clair. The humidity adjustment does not appear separately in the equation, but is contained in the air vapor pressure term derived from adjusted dew point temperature, namely,

$$T_{dw} = T_{dl} - \Delta T_d , \qquad (3)$$

where

T_{dw} = overwater dew point temperature, °C
T_{dl} = perimeter dew point temperature, °C
ΔT_d = land - lake dew point temperature difference, °C.

The water surface temperature (T_w) is determined in a similar manner by applying a water intake-water surface temperature correction (ΔT_w) based on Lake St. Clair observations to the water intake temperature data (T_m). A detailed description of these temperatures is given in subsequent sections dealing with input data.

During winter, extensive ice cover on the lake reduces evaporation computed by the standard mass transfer method, based on open-water conditions. The ice-cover reduction of evaporation may be significant (Derecki, 1976), but has not been included in previous Great Lakes mass transfer evaporation estimates because of inconclusive results, generally low winter evaporation, or lack of sufficient ice-cover data. It was incorporated in this study by determining average ice cover during individual winter months and considering the effect of ice cover on various input parameters. The ice surface temperature (T_i) was assumed to be equal to the perimeter air temperature (T_{al}), with a limiting maximum value of 0°C. These surface temperatures were used to determine air stability over ice and to compute wind and humidity adjustments by equations listed in Table 1 for the ice-covered portion of the lake. With the new adjustments, the over-ice values for the parameters were evaluated and combined with the standard overwater data to produce overlake data reflecting actual overwater and ice-covered conditions of the lake surface. The follwing equation was used to combine the over-ice and overwater data for various parameters:

$$P = (P_i(IC/100) + P_w(1 - IC/100) , \qquad (4)$$

where

P = overlake parameter data
P_i = over-ice parameter data
P_w = overwater parameter data
IC = ice-covered area, percent.

The final mass transfer equation used to compute lake evaporation in this study was modified as follows:

$$E = 0.097(e_o - e_a)Ru_8 , \qquad (5)$$

where

E = lake evaporation (over-ice and water), mm/day
e_o = saturation vapor pressure at lake surface temperature, mb
e_a = overlake vapor pressure of the air (8 m), mb
R = variable lake/land wind ratio based on overlake air stability
u_8 = perimeter wind speed at 8 m, m/s.

The effect of land to lake wind adjustments, based on air stability criteria, for both overwater and actual lake surface conditions is summarized in Table 2. The comparison shows that the land to lake increase in wind speed over Lake St. Clair is substantial, varying from approximately 20 percent during late spring and early summer to about 50 percent

Table 1. Lake St. Clair Land to Lake Adjustment Equations

Overwater Fetch: 11-23 km

Air Stability: $S = (T_{al} - T_w)$, °C

Stability	Adjustment Equation
	Wind Speed Ratios: $R_w = u/u_8$
$s > 8.3$	$R_w = 1.07 - 0.0036\ S$
$-8.3 < S < 8.3$	$R_w = 42.17(S + 30.5)^{-1.012}$
$S < -8.3$	$R_w = 1.31 - 0.0627\ S$
	Air Temperature Difference: $\Delta T_a = T_{al} - T_{aw}$
$S > 8.3$	$\Delta T_a = 0.5639\ S - 1.68$
$-8.3 < S < 8.3$	$\Delta T_a = 7.063X10^{-4}(S + 34)^{2.493} - 5$
$S < -8.3$	$AT_a = 0.1976\ S - 1.05$
	Dew Point Temperature Difference: $\Delta T_d = T_{dl} - T_{dw}$
$S \geq 0$	$\Delta T_d = 1.080X10^{-7}\ (S + 25)^{4.762} - 1.5$
$-16.6 \leq S < 0$	$\Delta T_d = 2.904(S + 17.675)^{0.110} - 5$
$s < -16.6$	$\Delta T_d = 0.2147\ S - 1.49$

Table 2. Average Lake/Land Wind Ratios for Lake St. Clair, 1950-75

Month	Overwater R_w	Overlake R
Jan.	1.55	1.38
Feb.	1.50	1.35
Mar.	1.31	1.28
Apr.	1.20	1.19
May	1.24	1.24
June	1.21	1.21
July	1.25	1.25
Aug.	1.35	1.35
Sept.	1.44	1.44
Oct.	1.44	1.44
Nov.	1.49	1.49
Dec.	1.49	1.45
Annual	1.37	1.34

in late fall, with an annual average of 34 percent. It also shows that ice cover on the lake reduces this increase by about 15 percent during mid-winter because of increased air stability.

2.1 Mass Transfer Coefficient

The mass transfer coefficient (0.097) represents the Lake Hefner calibrated constant and its use on Lake St. Clair may be questionable. Based on the classical approach of correlation between the mass transfer product and evaporation estimates computed by other methods, the coefficient was found to be applicable to Lake Erie (Derecki, 1976). The calibrated constant for the 8-m level with the water budget evaporation estimates was 0.100, in good agreement with the Lake Hefner value of 0.097. However, in subsequent extensive evaporation studies conducted on Lake Ontario during IFYGL, Quinn and den Hartog (1978) obtained considerably lower coefficient values from correlations with the water budget, energy budget, and aerodynamic evaporation estimates. Their best 3-m level coefficient (M) from the regression (aerodynamic estimates) is 0.107, which is approximately 14 percent lower than the corresponding Lake Hefner values of 0.124.

Derivation of the above Lake Ontario mass transfer coefficient (M) is reproduced in Figure 1. As pointed out by the authors, the trend of data points is clearly curvilinear, indicating the effects of neglecting wind speed and air stability. Thus, use of the 0.107 constant, representing straight line regression, will produce underestimates during high

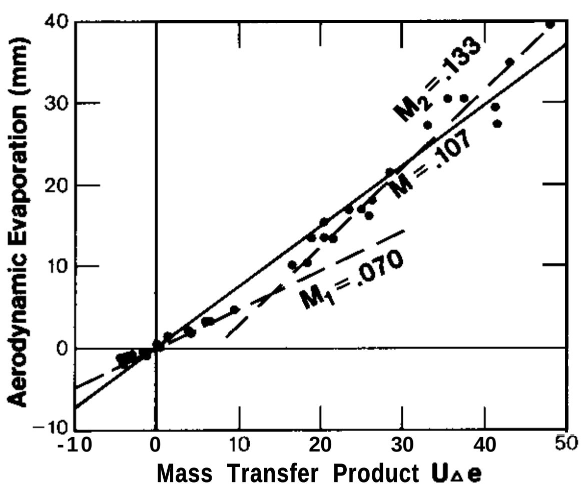

Figure 1. Mass transfer coefficient (M) derived from Lake Ontario IFYGL results.

evaporation periods and overestimates during low evaporation periods. Since low evaporation (including condensation) is clustered around zero, its overestimation will have little effect on the net total, with a resulting reduction of net evaporation values. This bias can be reduced by approximating the curve with two straight lines (indicated by dashed lines in the figure) for the low and high evaporation periods. Weighting the resulting constants of 0.070 and 0.133 for the low and high evaporation, respectively, within the indicated range gives a weighted coefficient of about 0.120, which is much closer to the Lake Hefner value (about 3 percent difference).

2.2 Meteorological Data

Meteorological data used in the mass transfer computations are based on records from a number of stations (Figure 2). Records from these stations were standardized at 8 m to be compatible with the equation (8-m coefficient) and to eliminate bias induced by the different heights of various sensors (Table A.l). The wind speed and relative humidity represent average values from Detroit (City Airport), Mich., and Windsor, Ont. (Tables A.2 and A.3). Although values from these stations do not provide balanced coverage for the lake, there are no other stations around Lake St. Clair with published wind and humidity

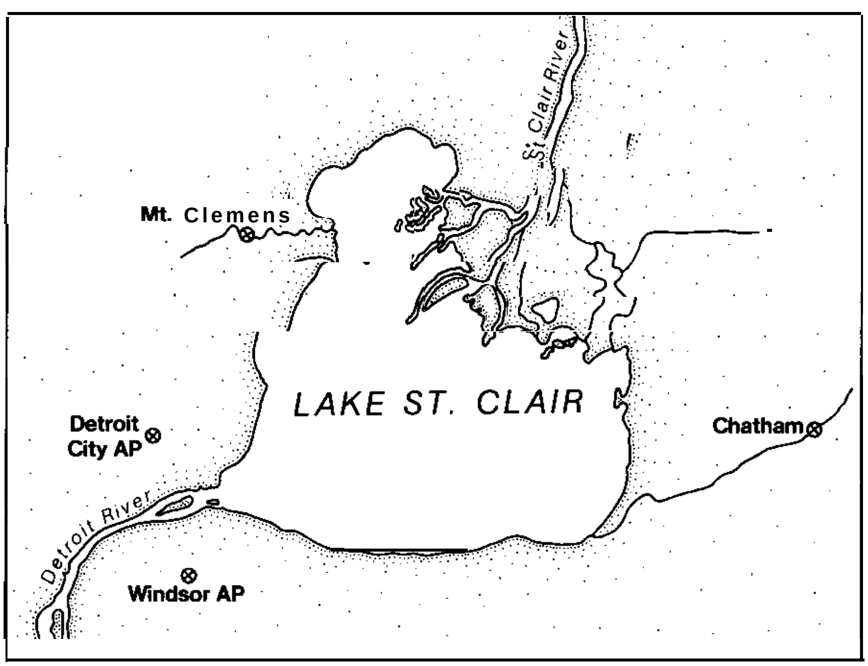

Figure 2. Lake St. Clair and location of data stations.

data. The Detroit station also contains substantial urban effect, as it is located within a large metropolitan area. Adjustment of the wind speed to the standard height of 8 m was made with the 1/7 power law, expressed by the equation

$$u_2 = u_1\left(\frac{Z_2}{Z_1}\right)^{1/7} \tag{6}$$

where

u_2 = wind speed at height level two
u_1 = wind speed at height level one
Z_2 = height level two
Z_1 = height level one.

Comparisons of the average monthly and annual wind speeds at the lake perimeter for the recorded and 8-m adjusted values, the overwater winds, and winds adjusted to actual lake surface conditions are shown in Table 3. Adjustment of the wind speed to 8 m reduced average recorded values by 8 percent. The overwater adjustment increased average perimeter data by about 37 percent annually. Actual wind speed over the lake is somewhat lower (about 3 percent per year) because ice-cover reduces the overwater winds during winter. During mid-winter this reduction amounted to about 10 percent.

The average perimeter air temperature for Lake St. Clair is based on records from four stations located around the lake, namely, Detroit (City Airport) and Mt. Clemens, Mich., and Windsor and Chatham, Ont. (Table A.4). Average values from these stations should provide reasonably balanced coverage for the lake. Comparisons of the average monthly and annual air temperatures for the perimeter, overwater, and overlake data are shown in Table 4. The overwater adjustment reduced average perimeter air temperatures during spring and early summer and increased them during the rest of the year, with an average annual increase of about 5 percent. Nearly half of this annual air temperature increase (2 percent) was reduced by ice cover during winter. Because of extensive ice cover, the overlake air temperatures during mid-winter were closer to the lake perimeter data than to the overwater air temperatures.

The corresponding average monthly and annual dew point temperatures are listed in Table 5. Perimeter dew point temperatures, derived from air temperatures and humidity data, are about 20 percent per year lower than the overwater values, which are approximately 1°C higher throughout the year. Annually, dew point temperatures over the lake surface are about 5 percent higher than the overwater values because of winter reduction of the overlake air temperatures due to ice cover.

Table 3. Average wind speed for Lake St. Clair, m/s, 1950-75

	Perimeter		Overwater	Overlake
	Recorded	8m	8m	8m
Month	u_m	u_8	$R_w u_8$	Ru_8
Jan.	5.30	4.85	7.52	6.69
Feb.	5.33	4.88	7.32	6.59
Mar.	5.46	5.01	6.56	6.41
Apr.	5.27	4.83	5.80	5.75
May	4.61	4.23	5.25	5.25
June	4.09	3.75	4.54	4.54
July	3.64	3.34	4.18	4.18
Aug.	3.57	3.26	4.40	4.40
Sept.	3.89	3.56	5.13	5.13
Oct.	4.29	3.93	5.66	5.66
NOV.	5.08	4.66	6.94	6.94
Dec.	5.15	4.73	7.05	6.86
Annual	4.64	4.25	5.86	5.70

Table 4. Average Air Temperatures for Lake St. Clair, °C, 1950-75

Month	Perimeter T_{al}	Overwater T_{aw}	Overlake T_a
Jan.	-4.0	-2.4	-3.3
Feb.	-3.3	-1.9	-2.9
Mar.	1.1	1.3	1.1
Apr.	8.1	7.2	7.1
May	14.2	13.8	13.8
June	20.0	19.3	19.3
July	22.3	22.0	22.0
Aug.	21.4	22.0	22.0
Sept.	17.5	18.6	18.6
Oct.	11.8	12.9	12.9
Nov.	4.7	6.1	6.1
Dec.	-1.5	-0.1	-0.4
Annual	9.4	9.9	9.7

Table 5. Average Dew Point Temperatures for *Lake St. Clair, "C, 1950-75*

Month	Humidity h(%)	Lake Perimeter Dew Pt. Temp. T_{dl}	Overwater T_{dw}	Overlake T_d
Jan.	76	-7.6	-6.5	-5.8
Feb.	75	-7.2	-6.1	-5.2
Mar.	72	-3.3	-2.3	-1.9
Apr.	66	2.2	2.8	2.8
May	64	7.6	8.4	8.4
June	67	13.9	14.5	14.5
July	67	16.1	16.9	16.9
Aug.	71	16.1	17.1	17.1
Sept.	72	12.6	13.7	13.7
Oct.	72	6.9	8.0	8.0
Nov.	75	0.7	1.8	1.8
Dec.	78	-4.8	-3.7	-3.5
Annual	71	4.4	5.4	5.6

2.3 Water Surface Temperature

Water temperature data for Lake St. Clair were obtained from the municipal water intake at Detroit. Water intakes are the only source of long-term water temperature records on the Great Lakes, but they are located in submerged cribs and so do not represent lake surface temperatures. The water intake temperatures were adjusted to represent lake surface conditions from water surface data on the basis of shipboard observations. GLERL conducted extensive water temperature surveys on Lake St. Clair during the 1974 open-water season. These surface temperature records were used to derive average lake temperatures for monthly periods of the open-water season. Water surface temperatures during winter were estimated with the aid of ice-cover observations and air temperatures. The seasonal distribution of the 1974 monthly water surface and corresponding water intake temperatures is shown in Figure 3. From the two sets of temperatures, average monthly temperature corrections were determined (Table 6) and applied through the 1950-75 period to adjust water intake data for open-water conditions. For winter data, additional surface temperature corrections were applied to the ice-covered portions of the lake. Surface temperature of the ice was estimated from the perimeter air temperatures, with a maximum value of 0°C. Equation (4) was used to combine the water surface and ice surface temperatures to produce surface temperatures reflecting actual lake surface conditions (Table A.5).

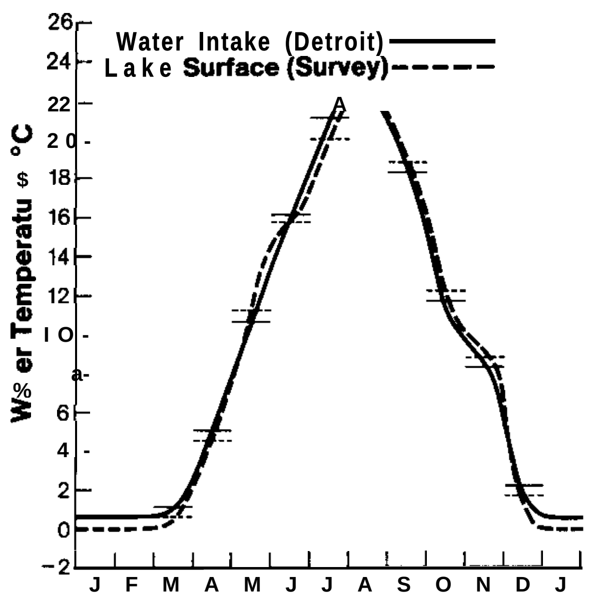

Figure 3. Lake St. Clair seasonal water surface temperature distribution, 1974.

Table 6. Lake St. Clair Water Surface Temperature Adjustments, °C, 1974

Month	Water Intake T_m	Lake Surface T_w	Temperature Adjustment $\Delta T_w = T_m - T_w$
Jan.	0.6	0.0"	0.6
Feb.	0.6	0.0*	0.6
Mar.	1.1	0.6**	0.5
Apr.	5.0	4.5**	0.5
May	10.6	11.2"	-0.6
June	16.1	15.7	0.4
July	21.1	20.0	1.1
Aug.	22.2	22.1	0.1
Sept.	18.3	18.8	-0.5
Oct.	11.7	12.2	-0.5
Nov.	8.3	8.8*	-0.5
Dec.	2.2	1.7**	0.5
Annual	9.8	9.6	0.2

*Values extrapolated from partial records or ice cover.

**Estimated values.

Comparisons of the average monthly and annual water temperatures for the water intake, water surface, ice surface, and actual lake surface sets of data are shown in Table 7. The average annual water intake and water surface temperatures are about the same, but their seasonal distribution differs. The average monthly ice surface temperatures during mid-winter are much lower than water temperatures and reduce lake surface temperature by about 3°C. The resulting composite average annual lake surface temperature is about 7 percent lower than the water surface temperature.

The saturation vapor pressure, based on lake surface temperatures, and the vapor pressure of the air, based on dew point temperatures, were combined to determine the vapor pressure difference over the lake. Adjustment to the standard height of 8 m increased the vapor pressure difference by 20 percent. The vapor pressure height adjustment was made with the logarithmic formula derived from Lake Hefner data (Derecki, 1975)

$$\Delta e_2 = \Delta e_1 \frac{\log Z_2 + 4.174}{\log Z_1 + 4.174}, \qquad (7)$$

where

Δe_2 = vapor pressure difference at height level two
Δe_1 = vapor pressure difference at height level one
Z_2 = height level two, m
Z_1 = height level one, m.

2.4 Ice Cover

The ice cover on Lake St. Clair was obtained from ice surveys conducted regularly since the winter of 1961 by both the Lake Survey Center (presently GLERL), NOAA, and the Ice Forecast Center in Canada. Estimates of the average monthly ice cover on the lake were determined from the individual surveys for the period of record covering the 1961-75 seasons. Extensive ice cover normally occurs during January, February, and March, with average concentrations of approximately 75, 90, and 45 percent, respectively. The ice cover is normally moderate in December, with an average concentration of about 20 percent, and seldom extends into April. Ice-cover variations during individual seasons may be considerable for all months. A few times the lake was completely ice covered during January or February.

The ice cover for the period preceding the 1961 winter season (1950-60) was determined by monthly ice-cover equations derived from the available ice-cover data. A simple relationship between monthly ice cover and the sum of perimeter air temperatures for the month plus one-half of the preceding month was found to give reasonable estimates of ice cover on Lake St. Clair. This relationship for the month of March, with maximum ice-cover extent, is illustrated in Figure 4. The monthly

Table 7. Average Surface Temperatures for Lake St. Clair, °C, 1950-75

Month	Water Intake T_m	Water Surface T_w	Ice Surface T_i	Lake Surface T_o
Jan.	0.7	0.1	-4.0	-3.0
Feb.	0.6	0.0	-3.4	-3.0
Mar.	1.1	0.6	-0.3	0.1
Apr.	5.2	4.7	0.0	4.6
May	11.4	12.0		12.0
June	17.5	17.1		17.1
July	21.5	20.4		20.4
Aug.	22.0	21.9		21.9
Sept.	19.4	19.9	–	19.9
Oct.	13.7	14.2	–	14.2
Nov.	7.5	8.0	–	8.0
Dec.	2.2	1.7	-1.8	1.0
Annual	10.2	10.1		9.4

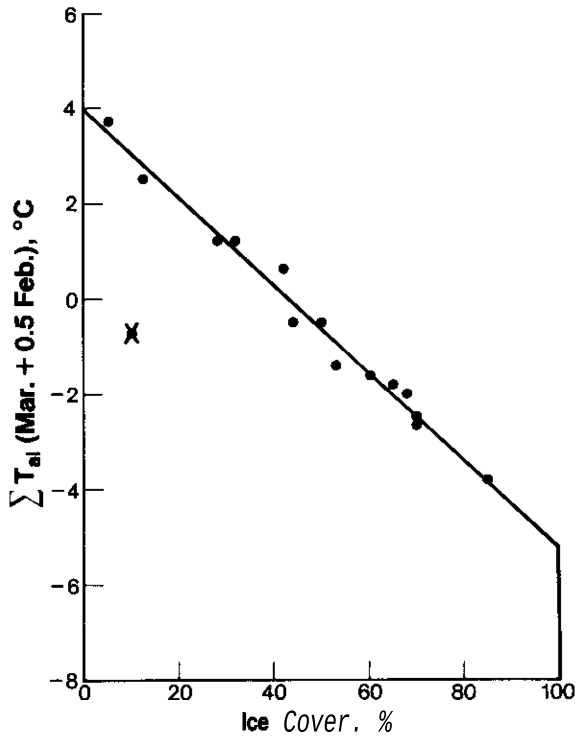

Figure 4. Ice-cover and air temperature relationship for March, 1961-75.

equations derived by the least square method are summarized in Table 8. Multiple correlation equations for the three variables were also developed to check the least square equations. The multiple correlation equations closely reproduced listed equations and did not offer any significant improvement.

The correlations between ice cover and air temperatures are strongest for the fully developed winter months of February and March. This coincides with the quality of ice-cover data. Frequently, especially in the early years, ice surveys did not begin until the middle of January, presenting considerable difficulty in the development of ice-cover data for the early winter months. A few points that diverged from the monthly trends were eliminated in the derivation of equations. The ice-cover estimates for the period of record (1961-75), along with corresponding computed values and monthly averages, are given in Table 9. The table also shows average monthly values for the period of study (1950-75).

Table 8. Lake St. Clair Monthly Ice-Cover Equations

Month	Temperature, °C	Ice Cover Equation, %	Correlation Coefficient	Standard Error, %
Dec.	$\Sigma T_{al} \geq 2.75$	IC = 0		
	$\Sigma Tal < 2.75$	$IC = 22.27 - 8.11(T_{12} + 0.5T_{11})$	0.93	2.5
Jan.	$\Sigma T_{al} > -10.81$	$IC = 42.17 - 5.35(T_{1} + 0.5T_{12})$	0.93	6.2
	$ET_{al} \leq 10.81$	IC = 100		
Feb.	$\Sigma T_{al} > -8.73$	$IC = 63.00 - 4.24(T_{2} + 0.5T_{1})$	0.97	1.7
	$\Sigma T_{al} \leq$ -a.73	IC = 100		
Mar.	$\Sigma T_{al} \geq 3.96$	IC = 0		
-5.23	$< \Sigma T_{al} < 3.96$	$IC = 43.11 - 10.88(T_{3} + 0.5T_{2})$	0.99	3.0
	$\Sigma T_{al} \leq -5.23$	IC = 100		
Apr.	$\Sigma T_{al} \geq 7.00$	IC = 0		
	$\Sigma T_{al} < 7.00$	$IC = 56.74 - 8.10(T_{4} + 0.5T_{3})$	0.87	3.6

Note: Use equations to compute ice cover during 1950-60 winter seasons.

Table 9. Estimates of Lake St. Clair Average Monthly Ice Cover, %, 1961-75 Seasons

Winter	Dec.		Jan.		Feb.		Mar.		Apr.	
Season	Obs.	Comp.	Obs.	Comp.	Obs.	Comp.	Obs.	Comp.	Obs.	Comp.
1961	35	33	80	84	79	81	12	16	0	0
1962	15	17	90	77	98	97	60	60	0	0
1963	40	41	100	100	100	100	68	64	0	0
1964	40	39	93	68	80	80	28	31	0	0
1965	30	12	60	71	88	89	85	85	20	15
1966	0	0	75	73	92	89	32	30	0	0
1967	20	19	56	56	90	90	65	62	0	0
1968	15	12	80	73	94	95	42	37	0	0
1969	25	21	95	72	a4	83	44	48	0	0
1970	25	29	90	96	98	100	70	72	0	0
1971	10	15	85	80	88	87	53	58	0	3
1972	0	0	58	59	93	90	70	70	5	5
1973	15	13	53	52	80	83	5	2	0	0
1974	40	12	76	61	90	90	10	50	0	0
1975	5	6	45	50	74	74	50	48	10	14
Mean 1961-75	21	18	76	71	89	89	46	49	2	2
1950-75	--	17	--	67	--	85	--	49	--	2

2.5 Evaporation

Mass transfer evaporation as computed by the Lake Hefner equation and modified for lake surface conditions is given in Table 10. Adjustment of the wind speed and vapor pressure difference to the standard height of 8 m produced a net computed increase in evaporation of 10 percent. The average annual evaporation from Lake St. Clair for the 1950-75 period is 748 mm, with annual extremes of 533 mm in 1956 and 967 mm in 1958. The seasonal distribution of the mass transfer evaporation estimates, indicating average, maximum, and minimum monthly values, is shown in Figure 5. The average monthly evaporation varies from 17 mm in February to 134 mm in September. The individual monthly extremes range from 8 mm condensation to 193 mm evaporation. The low evaporation trough for Lake St. Clair extends throughout winter and early spring, in contrast to that for the Great Lakes, which normally occurs in spring. Extension of the low evaporation through winter is caused by extensive ice cover, which reduces winter evaporation on Lake St. Clair. Even without the ice, the low and high evaporation on Lake St. Clair would tend to occur sooner because of the limited heat storage capacity in this shallow lake.

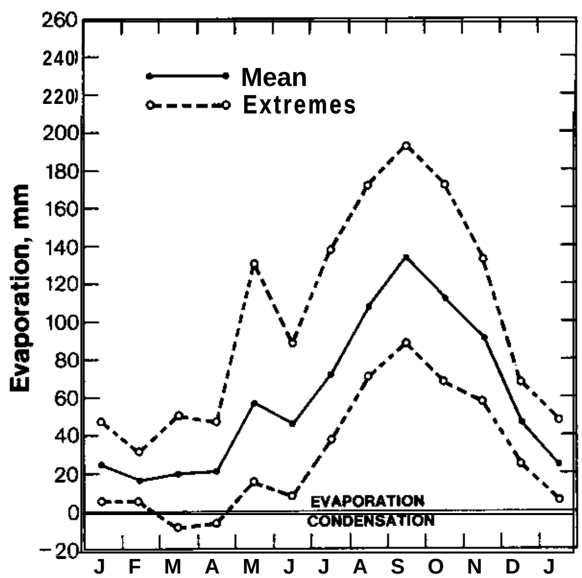

Figure 5. Lake St. Clair mass transfer evaporation, 1950-75.

Table 10. Lake St. Clair Mass Transfer Evaporation, mm

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1950	17.3	14.0	26.5	17.9	36.5	40.0	59.6	93.9	88.8	67.7	111.9	33.1	607.1
1951	17.6	9.6	15.4	7.8	32.6	34.6	44.3	83.7	133.1	77.6	90.2	39.2	585.8
1952	15.1	15.5	14.2	12.7	55.4	57.5	77.4	86.9	133.6	172.0	71.0	37.9	749.2
1953	19.7	30.9	9.5	29.9	16.1	33.7	68.7	121.8	176.9	108.1	94.0	65.6	774.8
1954	26.7	16.5	33.6	-1.6	79.0	8.0	86.1	123.7	133.5	106.1	71.9	42.0	725.5
1955	26.8	10.2	24.2	5.3	57.0	43.1	48.0	95.1	135.3	95.5	97.9	39.4	677.8
1956	15.6	11.1	18.0	21.1	26.8	17.2	40.7	73.4	130.0	69.5	84.3	24.7	532.5
1957	23.6	11.3	21.9	-0.8	53.5	35.5	48.6	121.8	104.9	121.7	91.6	39.5	673.1
1958	36.8	22.9	18.4	18.1	131.1	75.7	49.8	142.3	145.5	149.9	133.4	43.5	967.4
1959	11.8	15.8	27.9	26.2	37.9	89.4	104.6	91.1	161.5	129.0	98.9	26.7	820.8
1960	21.3	19.9	13.9	-6.3	28.9	39.3	76.0	70.8	116.8	112.3	77.4	65.4	635.6
1961	20.4	12.0	17.5	21.3	85.7	62.0	57.3	83.9	103.5	114.9	117.5	63.9	759.8
1962	28.1	6.4	24.7	37.0	47.6	52.2	77.4	88.5	152.7	103.4	69.9	51.1	739.0
1963	6.0	8.2	2.6	45.7	89.6	61.8	105.1	171.8	149.8	126.9	97.7	51.6	916.9
1964	24.9	18.6	6.8	9.7	85.1	73.2	90.3	113.2	130.3	101.7	81.5	32.7	768.1
1965	25.2	17.7	17.9	6.4	17.2	64.7	92.8	95.6	91.1	131.8	95.7	41.8	697.9
1966	37.0	11.2	19.2	27.4	94.7	54.8	96.9	107.6	141.5	126.7	63.5	51.7	832.2
1967	25.7	12.4	10.7	20.9	82.8	31.7	53.4	128.4	135.3	78.1	90.0	35.2	704.7
1968	17.3	20.5	8.1	36.9	49.9	26.9	57.3	101.7	101.4	125.2	81.0	54.3	680.5
1969	24.6	26.7	50.7	15.1	55.4	42.0	45.5	99.8	156.0	145.0	72.7	42.8	776.5
1970	7.7	14.9	25.2	8.9	29.9	54.5	38.3	146.3	140.7	84.0	107.6	62.2	720.1
1971	25.3	14.1	26.4	43.0	103.7	28.8	137.5	162.7	105.9	81.7	127.4	51.9	908.5
1972	48.0	26.1	38.4	30.8	40.9	63.5	41.4	85.3	132.7	132.4	76.9	37.2	753.5
1973	4.26	22.8	-7.7	33.1	50.2	15.9	66.5	108.7	192.8	120.4	96.4	68.0	809.8
1974	32.3	20.1	24.7	19.7	59.5	49.2	97.9	111.1	166.2	121.7	95.6	41.5	839.4
1975	43.4	32.0	39.5	46.6	37.0	31.9	100.3	94.8	130.8	115.1	58.2	69.6	799.0
Mean	24.7	17.0	20.3	20.5	57.1	45.7	71.6	107.8	134.2	112.2	90.5	46.6	748.3

Ice-cover reduction of Lake St. Clair evaporation is significant throughout winter. Comparisons of the overlake, overwater, and lake perimeter mass transfer evaporation estimates are shown in Figure 6. The average ice-cover reduction is approximately 40 mm in January and February and 10 mm in March and December, with an annual total of about 100 mm. Ice-cover reduction in April may be important during individual years, but has no significant effect on the average long-term values. The reduction in evaporation due to ice cover is equivalent to the increase in evaporation derived from overwater adjustment of lake perimeter data. Presented lake perimeter evaporation estimates (without wind and humidity adjustments) contain no ice-cover adjustments and should be compared with the overwater values during winter. Without wind and humidity adjustments, the lake perimeter evaporation estimates greatly underestimate evaporation (about 30 mm per month) during the entire high evaporation season and produce an annual total that is about 100 mm too low.

3. OTHER EVAPORATION ESTIMATES

Other feasible approaches for qualitive determination of long-term Lake St. Clair evaporation consist of indirect methods, based on comparison with other lakes or pan evaporation data. Results for these estimates are summarized briefly to provide relative evaluation of the mass transfer results.

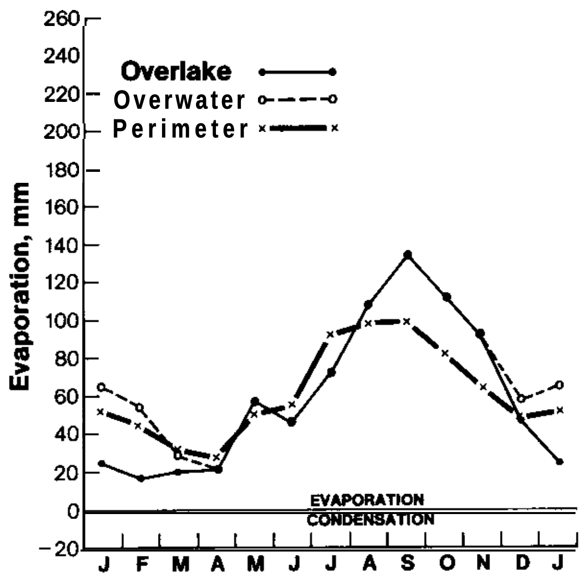

Figure 6. Comparison of mass transfer evaporation estimates for Lake St. Clair, 1950-75.

The indirect evaluation of Lake St. Clair evaporation, based on comparison with adjacent lakes and pan evaporation data, is shown in Figure 7. Because of climatic and physical similarities, Lake Erie was chosen as the most appropriate. Lake Erie evaporation was determined by the water budget method (Derecki, 1976) and should reflect actual surface conditions during winter. The ice cover on Lake Erie is also extensive and the available mass transfer estimates do not include ice cover reduction of evaporation. Both magnitude and seasonal distribution of evaporation on the two lakes appear reasonable. Lake Erie values are higher during most of the year, reflecting greater overwater fetch and greater heat storage effects during summer and winter, respectively.

The pan evaporation data are for southeast lower Michigan, with some estimates based on extrapolation of partial records during winter months. As expected, annual pan evaporation is much higher than lake evaporation. Reduction of pan evaporation by a pan coefficient, such as the traditional 0.70 value employed, produces annual evaporation of

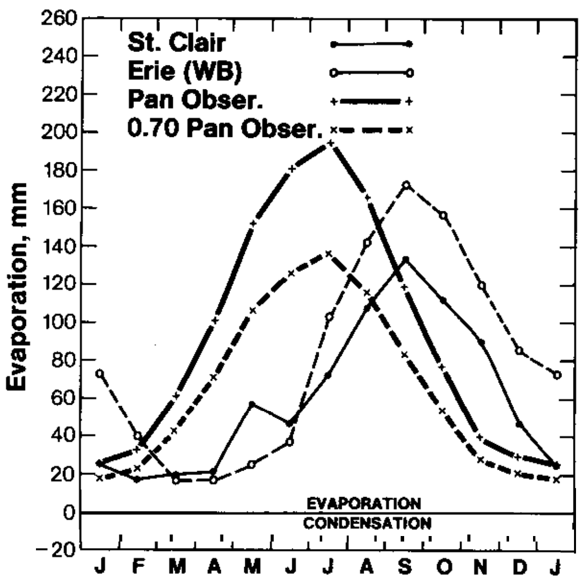

Figure 7. Comparison of Lake St. Clair evaporation with Lake Erie and pan observation, 1950-75.

reasonable magnitude, which could be used as a rough indication of lake evaporation. However, seasonal distribution of pan evaporation is completely different because of heat storage effects.

SUMMARY AND CONCLUSIONS

Evaporation from Lake St. Clair was determined by the mass transfer method with basic data modified to overwater conditions. The ice-cover reduction of evaporation was incorporated during winter by considering both the open-water and ice-covered surfaces of the lake. These modifications permit use of the available lake perimeter data and enable determination of long-term evaporation. Results for a 26-year period of study (1950-75) indicate that evaporation removes approximately 750 mm of water from the lake surface annually, with annual extremes of 533 and 967 mm. Average monthly evaporation values vary from 17 mm in February to 134 mm in September, and the monthly extremes range from about 8 mm condensation to 193 mm evaporation. The ice cover during winter reduced average annual evaporation by about 100 mm, with monthly reductions of approximately 40 mm during January and February and 10 mm during March and December. Because of extensive ice cover on Lake St. Clair, the low evaporation trough of approximately 20 mm extends throughout winter and early spring.

The mass transfer results cannot be verified by other direct methods, such as water budget or energy budget computations. Comparisons of preliminary estimates for Lake St. Clair evaporation as computed by the mass transfer, energy budget, and water budget methods have shown that only the mass transfer results are realistic. The mass transfer approach is the only method that permits operational evaporation estimates from the lake with presently available data. This method is also the most amenable approach for future improvements.

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Appendix A. BASIC METEOROLOGICAL DATA

Table A.1. Measurement Heights of Meteorological Instruments, 1950-75

Station	Variable	Period	Height ft	Height m
Detroit (CA), Mich.	Wind Speed	Jan. 1950-May 1970	81	24.7
		June 1970-Dec. 1975	42	12.8
	Humidity	Jan. 1950-Dec. 1975	5	1.5
	Air temp.	Jan. 1950-Dec. 1975	5	1.5
Windsor (AP), Ont.	Wind speed	Jan. 1950-May 1962	36	11.0
		June 1962-Dec. 1975	33	10.1
	Humidity	Jan. 1950-Dec. 1975	NOTE	
	Air temp.	Jan. 1950-Dec. 1975	"	
Mt. Clemens, Mich.	Air temp.	Jan. 1950-Dec. 1975	"	
Chatham, Ont.	Air temp.	Jan. 1950-Dec. 1975	"	

NOTE: Standard height exposure (4-5 ft); because exact heights throughout this period could not be determined, 1.5 m was used.

Table A. 2. Average Perimeter Wind Speed for Lake St. Clair at 8m, m/s

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1950	4.25	4.75	5.36	5.13	3.62	3.63	2.81	2.95	3.18	3.14	5.05	4.21	4.01
1951	4.51	4.50	5.22	4.33	3.47	2.70	3.01	2.63	3.27	3.19	4.56	4.50	3.83
1952	4.29	4.03	4.34	4.32	3.47	3.87	3.60	2.81	3.23	4.46	4.23	4.44	3.93
1953	4.59	5.25	4.91	3.14	3.78	3.81	3.24	3.18	3.71	3.32	4.2~4	5.44	4.22
1954	4.88	4.95	5.40	4.82	4.39	3.74	3.30	3.58	4.21	3.97	3.93	4.3~8	4.30
1955	4.47	3.91	5.18	4.15	3.34	2.48	2.55	2.91	3.07	3.90	4.96	4.43	3.78
1956	4.39	4.13	4.60	4.39	3.93	2.75	2.77	2.92	3.19	3.26	4.08	3.97	3.70
1957	3.82	3.46	3.93	3.68	4.06	3.98	2.96	2.92	3.08	3.72	5.94	5.79	3.95
1958	5.26	5.94	4.84	5.06	5.16	4.44	4.00	3.98	4.31	4.88	6.04	4.86	4.90
1959	5.43	5.81	5.96	5.92	4.39	4.10	3.67	3.67	4.22	4.42	5.35	4.72	4.80
1960	5.18	5.83	5.67	5.70	5.02	4.33	3.65	3.13	3.06	3.24	4.79	5.37	4.57
1961	4.51	4.77	6.10	5.39	5.20	4.65	3.59	3.30	3.48	4.53	4.82	5.73	4.67
1962	6.04	5.43	5.32	5.68	4.87	3.72	3.11	3.10	3.67	3.99	3.58	4.97	4.45
2963	4.79	5.03	5.31	4.33	4.52	3.05	3.49	3.95	3.88	3.77	5.03	4.26	4.33
1964	5.11	4.15	5.34	4.81	4.56	3.58	3.22	3.52	3.45	3.44	3.91	4.39	4.12
1965	5.28	5.45	4.58	4.53	3.93	3.86	3.29	3.39	3.79	4.45	4.79	4.76	4.34
1966	5.02	3.92	4.78	4.57	4.41	3.45	3.28	3.03	3.14	4.31	3.98	4.43	4.03
1967	5.09	5.29	4.33	4.64	4.37	3.26	2.76	3.18	3.15	4.04	4.68	4.39	4.10
1968	4.55	5.61	5.01	4.92	4.23	3.74	3.49	3.42	3.44	4.10	4.54	5.52	4.38
1969	4.81	4.23	4.85	4.32	3.46	3.62	2.79	2.72	3.25	3.95	4.11	3.79	3.83
1970	3.45	4.73	4.35	4.93	4.34	3.93	3.48	3.23	3.72	3.91	5.10	5.12	4.19
1971	5.78	6.29	5.14	4.74	4.65	3.80	4.14	3.95	3.69	3.54	4.86	4.45	4.59
1972	5.30	4.62	4.86	4.65	4.18	4.18	3.54	3.28	3.84	4.15	4.26	4.45	4.28
1973	5.35	4.80	4.67	4.88	4.39	3.96	3.62	3.15	3.58	3.79	4.90	5.07	4.35
1974	4.75	4.99	5.36	5.24	a.45	4.45	3.75	3.39	3.90	4.10	4.45	4.27	4.42
1975	5.30	5.05	4.84	4.82	3.69	4.39	3.67	3.59	4.16	4.65	5.07	5.23	4.54
MEAN	4.05	4.80	5.01	4.83	4.23	3.75	3.34	3.26	3.56	3.93	4.66	4.73	4.25

Table A.3. Average Perimeter Humidity for Lake St. Clair, %

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1950	80	80	74	71	67	66	66	69	77	78	77	79	74
1951	80	82	74	71	67	71	68	71	71	74	74	80	74
1952	82	77	77	66	64	60	62	70	68	58	72	83	70
1953	82	70	76	68	72	67	66	65	66	68	71	75	70
1954	78	76	72	72	60	70	63	69	70	77	79	81	72
1955	76	80	72	66	61	64	66	70	66	74	78	76	71
1956	82	80	78	69	71	70	70	74	73	71	76	82	75
1957	72	77	66	72	70	71	68	69	75	72	75	78	72
1958	73	70	70	60	50	66	73	69	74	68	72	76	68
1959	78	76	72	66	70	63	66	76	72	78	75	81	73
1960	82	78	76	71	73	70	67	75	73	72	76	74	74
1961	73	80	72	74	62	65	69	76	78	74	72	77	73
1962	76	80	72	61	64	69	69	73	73	76	77	80	72
1963	75	73	77	62	62	62	63	68	72	64	75	79	69
1964	76	74	76	72	63	68	68	72	72	67	76	82	72
1965	79	75	76	70	65	66	68	76	79	75	70	74	73
1966	69	77	70	70	61	62	66	74	72	66	80	80	71
1967	77	78	78	71	61	68	73	72	73	77	76	83	74
1968	82	71	73	63	73	73	69	71	76	73	76	78	73
1969	76	66	59	67	65	72	72	68	71	70	76	73	70
1970	73	71	73	65	67	65	71	65	71	76	78	78	71
1971	76	80	76	60	53	68	62	65	76	76	70	73	70
1972	66	65	66	60	59	63	64	73	75	70	77	77	68
1973	68	71	74	62	64	68	66	70	65	74	74	74	69
1974	72	71	69	62	66	64	59	69	68	62	75	78	68
1975	69	68	65	57	61	70	62	72	75	70	77	78	69
MEAN	76	75	72	66	64	67	67	71	72	72	75	78	71

Table A.4. Average Perimeter Air Temperature for Lake St. Clair, °C

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1950	-.u			4.9	14.2	19.6	21.3	20.8	17.0	13.2	2.4	-4.0	8.7
1951	-2.80	-2.9 -3.5	-1.3 1.9	7.4	15.0	19.3	22.1	20.4	16.6	12.5	1.2	-2.3	9.0
1952	-1.9	-1.8	1.0	9.3	13.7	22.2	24.4	21.4	17.8	8.6	5.7	.8	10.1
1953	-1.3	-.5	3.0	6.7	14.8	21.2	22.7	22.8	17.9	13.3	6.5	.5	10.6
1954	-3.7	.4	.4	9.5	12.5	21.5	21.8	21.1	18.3	12.3	4.9	-1.4	9.8
1955	-3.4	-2.5	1.7	12.0	16.3	19.8	25.9	24.0	18.5	12.5	3.0	-2.8	10.4
1956	-3.3	-2.E	-.1	6.9	13.0	20.4	21.7	21.5	15.5	13.7	4.6	1.3	9.4
1957	-6.6	-1.8	2.2	8.8	13.3	20.2	22.5	20.7	17.0	10.3	4.9	1.0	9.4
1958	-3.0	-5.4	2.1	9.2	14.1	17.3	22.1	20.9	17.2	12.1	5.6	-6.0	8.8
1959	-6.4	-3.9	.8	8.5	15.9	20.5	22.8	23.9	19.1	10.9	2.3	.9	9.6
1960	-2.2	-2.7	-3.8	9.6	14.1	19.1	21.2	21.7	18.9	1.1.4	5.9	-4.3	9.1
1961	-5.7	-1.4	3.2	5.7	12.5	19.2	22.3	21.8	20.0	13.0	4.9	-1.7	9.5
1962	-5.7	-5.2	1.0	8.7	17.7	20.1	21.3	21.2	16.1	11.8	4.0	-4.3	8.9
1963	-8.9	-8.1	2.1	8.5	13.0	20.4	22.5	19.9	lb.0	15.4	6.7	-5.4	8.5
1964	-2.1	-2.9	2.6	8.3	16.2	19.6	23.2	19.4	lb.9	9.4	6.1	-1.8	9.6
1965	-4.5	-4.0	-1.8	6.1	15.9	18.8	20.3	20.0	18.0	9.7	4.9	1.4	8.7
1966	-6.4	-3.0	2.7	6.8	11.2	20.7	23.4	20.7	16.5	10.4	4.7	-2.0	8.8
1967	-1.7	-5.5	1.0	8.6	11.2	22.0	20.8	19.6	15.9	11.0	2.1	-.1	6.8
1968	-5.6	-4.7	2.9	9.8	12.3	19.5	21.6	22.1	19.0	12.1	4.7	-2.3	9.3
1969	-4.4	-2.5	.8	8.8	13.5	17.3	22.2	22.4	17.8	10.5	4.0	-2.8	9.0
1970	-8.7	-4.4	-.5	8.9	15.8	20.4	22.8	22.5	18.6	12.8	5.0	-1.6	9.3
1971	-6.2	-2.5	-.1	6.6	13.5	21.2	21.4	20.8	19.1	15.3	4.6	1.8	9.6
1972	-4.0	-4.5	-.2	6.5	15.6	17.8	22.5	20.9	17.7	9.2	3.7	-.7	8.7
1973	-1.5	-4.0	5.7	9.0	13.0	21.5	22.6	22.3	17.9	13.3	5.2	-1.4	10.3
1974	-2.8	-4.9	1.8	9.2	12.6	19.4	22.8	22.0	16.0	10.2	5.3	-.6	9.3
1975	-1.2	-1.9	.5	5.0	17.8	20.8	23.2	22.4	15.2	12.4	8.7	-1.2	10.1
MEAN	-4.0	-3.3	1.1	8.1	14.2	2010	22.3	21.4	17.5	11.8	4.7	-1.5	9.4

Table A.5. Adjusted Lake St. *Clair* Water Surface Temperature, °C

YEAR	JAN	FEB	MAF	API	HAY	JUN		AUG	SEP	OCT	NOV	DEC	ANNUAL
1950	.5	0.0	.1	3.4	11.7	lb.3	19.5	21.0	18.8	14.9	7.2	.b	9.5
1951	0.0	0.0	.b	3.9	12.3	17.4	19.5	21.0	19.4	14.4	5.5	1.7	9.6
1952	0.0	0.0	.6	5.1	12.3	17.9	21.1	21.6	19.9	12.2	7.7	2.8	10.1
1953	.5	0.0	1.2	4.5	11.7	17.4	20.6	22.7	20.5	15.5	9.4	2.8	10.6
1954	0.0	0.0	.b	5.1	11.2	16.8	20.0	21.6	19.4	14.9	8.3	1.7	10.0
1955	.5	0.0	1.2	6.7	13.9	17.4	22.8	23.8	20.5	14.4	7.2	.b	10.7
1956	0.0	0.0	.1	4.5	10.6	16.8	19.5	21.6	18.8	14.4	8.3	2.3	9.7
1957	0.0	0.0	.6	4.5	12.3	17.4	20.0	22.1	19.4	13.8	7.2	1.7	9.9
1958	0.0	0.0	[illegible]	3.9	12.3	15.7	20.0	21.6	19.4	14.4	8.8	.1	9.7
1959	0.0	0.0	.1	5.1	13.4	18.5	21.7	23.8	21.1	14.4	6.1	1.7	10.5
1960	0.0	0.0	.1	4.5	11.7	16.3	19.5	21.6	21.1	14.9	8.3	1.2	9.9
1961	0.0	0.0	1.2	3.9	11.2	lb.3	20.0	22.1	21.6,	14.9	a.0	1.7	10.1
1962	0.0	0.0	.b	5.1	13.9	17.9	20.6	21.6	19.4	14.4	7.7	1.7	10.2
1963	0.0	0.0	.1	6.2	12.3	17.9	21.1	21.6	18.8	16.6	9.4	1.7	10.5
1964	0.0	0.0	.6	5.1	14.5	18.5	22.2	20.5	19.4	12.2	9.4	.6	10.2
1965	.5	0.0	.1	2.8	11.2	lb.8	2o.c	21.0	19.4	13.3	7.7	2.3	9.6
1966	.5	0.0	1.2	5.1	11.2	17.4	22.2	22.1	19.9	12.7	7.7	2.3	10.2
1967	0.0	0.0	.b	6.2	10.6	18.5	20.0	21.6	19.4	12.7	6.6	2.3	9.9
1968	0.0	0.0	.b	6.7	11.7	16.8	19.5	22.1	20.5	14.9	7.7	1.2	10.1
1969	0.0	0.0	1.2	5.1	12.3	15.7	20.6	22.7	21.1	14.4	7.2	1.2	10.1
1970	0.0	0.0	.6	3.9	12.3	17.4	20.0	23.2	20.5	14.4	8.8	2.3	10.3
1971	0.0	0.0	.6	4.5	11.7	17.4	20.6	21.6	20.5	16.6	8.8	3.4	10.5
1972	0.0	0.0	.1	3.4	11.2	15.2	18.3	21.0	19.9	12.7	7.2	1.2	9.2
1973	0.0	0.0	1.2	5.6	10.6	lb.8	20.0	22.1	21.1	16.1	8.3	2.3	10.4
1974	0.0	0.0	.6	4.5	11.2	.5.7	20.0	22.1	18.8	12.2	8.8	1.7	9.6
1975	.5	0.0	.6	3.4	13.4	L7.4	21.1	22.1	17.7	13.8	9.4	2.3	10.1
MEAN	.1	0.0	.b	4.7	12.0	17.1	20.4	21.9	19.9	14.2	8.0	1.7	10.1

Appendix B. DESCRIPTION OF SYMBOLS

E = lake evaporation, mm/day

E_w = lake evaporation (overwater), mm/day

e_a = overlake vapor pressure of the air, mb

e_{al} perimeter vapor pressure of the air, mb

e_{aw} = overwater vapor pressure of the air, mb

e_o = saturation vapor pressure at lake surface temperature, mb

e_w saturation vapor pressure at water surface temperature, mb

H_c = constant monthly lake/land humidity ratio

h = perimeter relative humidity, percent

IC = ice cover, percent

M = mass transfer coefficient derived from Lake Ontario IFYGL results

M_1 = coefficient M for low evaporation range

M_2 = coefficient M for high evaporation range

P = overlake parameter data

P_i = over-ice parameter data

P" = overwater parameter data

R = variable lake/land wind ratio based on overlake air stability

R_c = constant monthly lake/land wind ratio

R_w = variable lake/land wind ratio based on overwater air stability

S = atmospheric stability index of the air, °C

T_a = overlake air temperature, °C

T_{al} = perimeter air temperature, °C

T_{aw} = overwater air temperature, °C

T_d = overlake dew point temperature, °C

T_{d1} = perimeter dew point temperature, °C

T_{dw} = overwater dew point temperature, °C

T_i = ice surface temperature, °C

T_m = water intake temperature, °C

T_o = lake surface temperature, °C

T_w = water surface temperature, °C

T_1 = January perimeter air temperature, °C

T_2 = February perimeter air temperature, °C

T_3 = March perimeter air temperature, °C

T_4 = April perimeter air temperature, °C

T_{11} = November perimeter air temperature, °C

T_{12} = December perimeter air temperature, °C

u = overwater wind speed, m/s

u_m = recorded perimeter wind speed, m/s

u_1 = wind speed at height level one, m/s

u_2 = wind speed at height level two, m/s

u_8 = perimeter wind speed at 8 m, m/s

Z_1 = height level one, m

Z_2 = height level two, m

Δe_1 = vapor pressure difference at height level one, mb

Δe_2 = vapor pressure difference at height level two, mb

ΔT_a = land - lake air temperature difference, °C

ΔT_d = land - lake dew point temperature difference, °C

ΔT_w = water intake - lake surface temperature difference, °C.

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