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IV Hydrology

F. Mero

A. The watershed

The Jordan Valley is the inland drainage with the lowest base level in the world (400 m below sea level at the Dead Sea). Lake Hula and Lake Kinneret represent intermediary base levels. Lake Kinneret drains a catchment area of 2,730 km^2 from an altitude of 2,800 m (Mount Hermon) down to a base level of 209 m below MSL.

The Kinneret watershed can be subdivided into four sectors (Fig. 31): (i) The catchment area of the tributaries of the Jordan: Hermon, Dan, Snir and Ayun rivers. This sector represents an area of 820 km^2. (ii) The Hula Basin, collecting the waters of Sector (i) and the Golan Heights. These waters are collected in the canals of the presently regulated Jordan River. This sector is approximately 648 km^2. (iii) Small catchments along the banks of the Jordan River in the portion of the river between the Pardes Huri station and the lake. This sector includes a narrow strip of 122 km^2. (iv) Catchment areas draining their waters directly into the lake through wadis, ground water or shore and sublacustrine springs. This sector is located in the immediate vicinity of the lake and covers an area of 968 km^2.

Each of the hydrological sectors includes one or more superficial catchment units drained by a central river or wadi. The underground flow system is much more complex. The stratigraphical discontinuities due to the considerable faulting and block type tectonics explain why the underground aquifers are divided into numerous and discontinuous units. The natural outlets of these aquifers are the springs located on the fringes of the Rift Valley, along the faults and on the lake bottom.

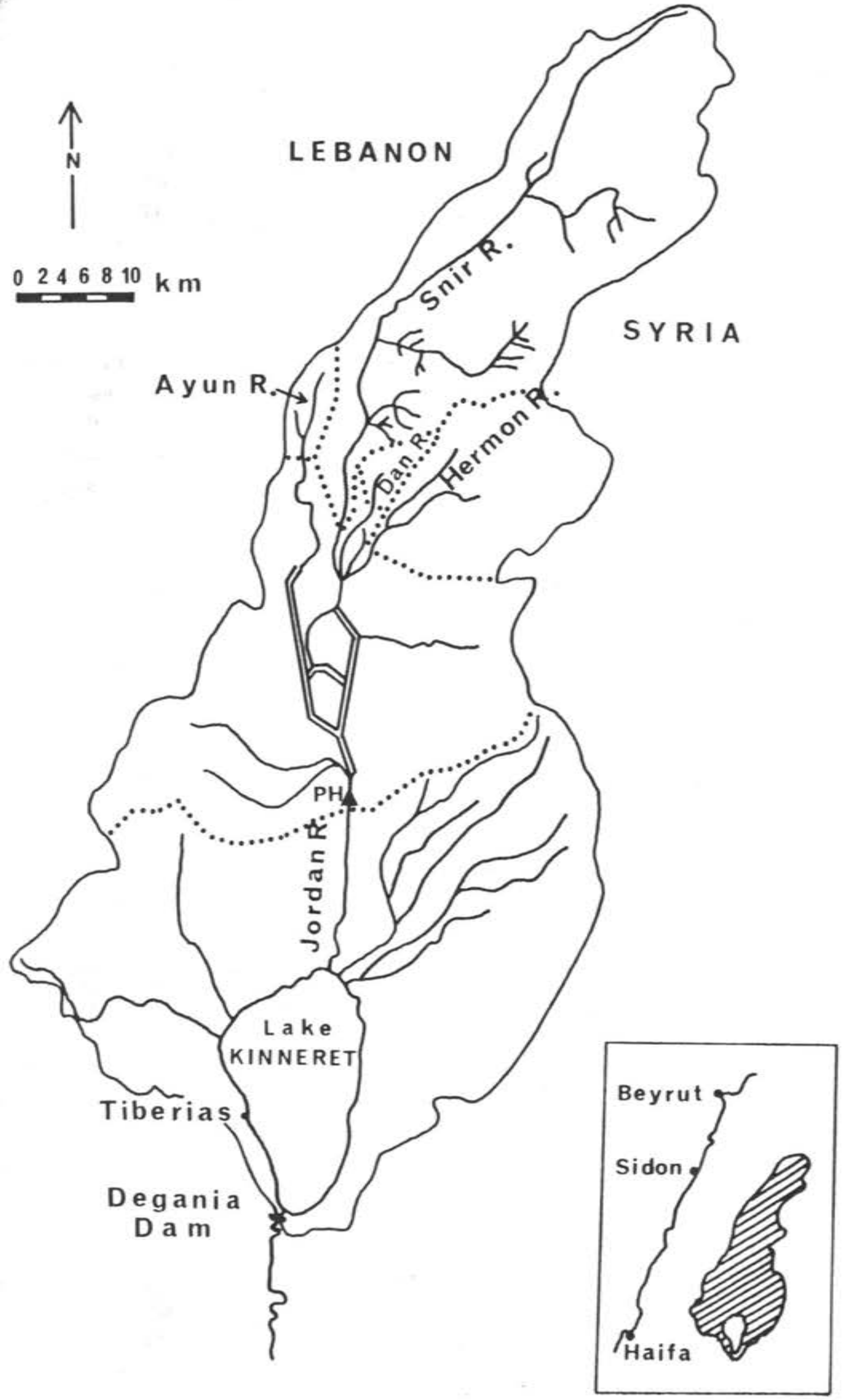

Fig. 31. The main hydrological units of the Kinneret watershed. PH = Pardes Huri, station of the hydrological service.

B. The superficial waters

1. The Jordan River

The Jordan River is the most important inlet to the lake. It results from the junction of three rivers: the Snir (Hatsbani River), the Dan River and the Hermon River (Banias River). Formerly, the Jordan River used to flow into the swamp area of Lake Hula. In 1957, the artificial drainage of the Hula plain was completed and the river regulated. It now flows into two canals (western and eastern canals) which drain the plain on both sides and join into a single canal which ends at the gauging station of Pardes Huri.

The average yield values (Pardes Huri station, period 1959–1960/1970–1971) range from 7.9 m^3/sec in August to 29.6 m^3/sec in February (Table 11). The maximum known discharge was 214 m^3/sec on 23 January 1969, and the minimum was 0.80 m^3/sec on 10 July 1973.

Table 11. Yields of the Jordan River at Pardes Huri station. Monthly averages for the 1959–1960/1970–1971 period.*

	Yields m^3/sec		Yields m^3/sec
October	9.5	April	24.6
November	11.6	May	17.6
December	15.9	June	11.6
January	23.5	July	8.1
February	29.6	August	7.9
March	29.0	September	9.0

* Data from the Hydrological Service.

The base flow of the Jordan River is not higher than a few cubic meters per second and its regime is of the flood type. Its yields are consequently very variable from year to year, as shown in Fig. 32 for the yield of the Jordan River during the period 1965–1974.

2. Other rivers and wadis

The western watershed is drained mainly by Wadis Amud and Tsalmon which are completely dry in summer. The central part of the Golan Heights, which forms the eastern watershed of the lake, is drained essentially by the Meshushim River. Its average yield is generally below 1 m^3/sec, although the maximum known yield reached 115 m^3/sec on 4 April 1971. The other wadis are of secondary importance.

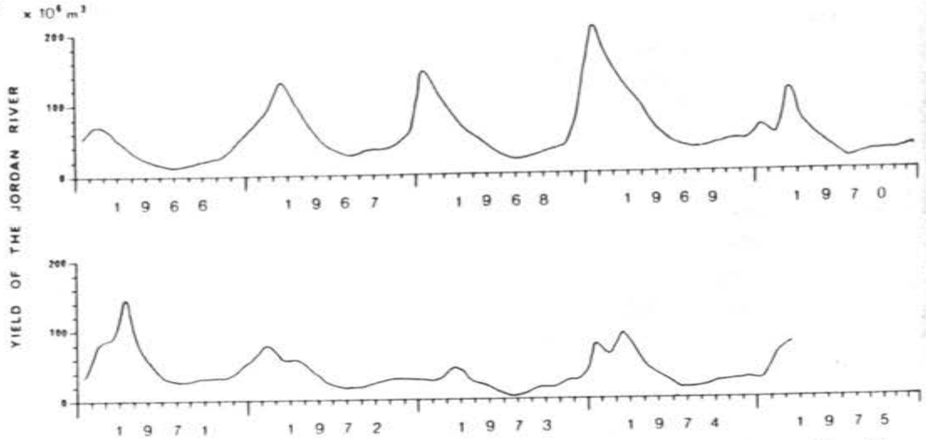

Fig. 32. Monthly yields of the River Jordan. (Data from the Hydrological Yearbook of Israel.)

3. The springs

The very recent tectonic disturbances have caused the discontinuity of water-bearing layers which find an outlet in numerous freshwater springs. In Table 12, a list of the main springs of the lake vicinity can be found, together with their main characteristics. Their location is shown in Fig. 33.

Table 12. List of freshwater springs in the lake vicinity. Serial numbers indicate location of spring in Fig. 33. Data from the Hydrological Yearbook of Israel.

No.	Name	Elevation m	*Average discharge l/sec	†Cl mg/l
3	Meron	+695	23	24
4	Bar-Yohay	+655	–	–
5	Taron	+530	4	22
6	Yaqim	+520	24	23
7	Zetim	+705	3	26
8	Amud	−100	–	–
9	Parod	+480	12	26
10	Ravid	−100	121	30
11	Nun	−192	70	54
12	Arbel	−140	17	45
13	Sanabir	+310	38	26
14	Sheikh-Husein	+260	4	57
15	Dardare	−130	3	30
16	Qutsbiya-el-Jedida	+445	44	29
17	Hushnie	+790	3	23
18	Fahem	+710	142	22
19	Tanuriya	+630	30	22
20	Umm-a-Dannir	+600	9	22
21	Umm-a-Dapun	+590	16	22
22	Mantsura	+560	20	18
23	Mujahiya	+100	26	37
24	Rapid 1	+700	–	–
25	Rapid 2	+730	9	28
26	Butmiya	+695	11	25
27	Beja	+660	26	30
28	Betset Juhader	+570	52	–
29	Sahina	−120	300	72
30	Magela	−160	128	532
31	Balzam	−150	182	330
33	Po'em	+515	–	–
34	Ramiel	+630	–	–
36	Re'ah	−100	–	–

* Interannual average.
† Values of October 1972.

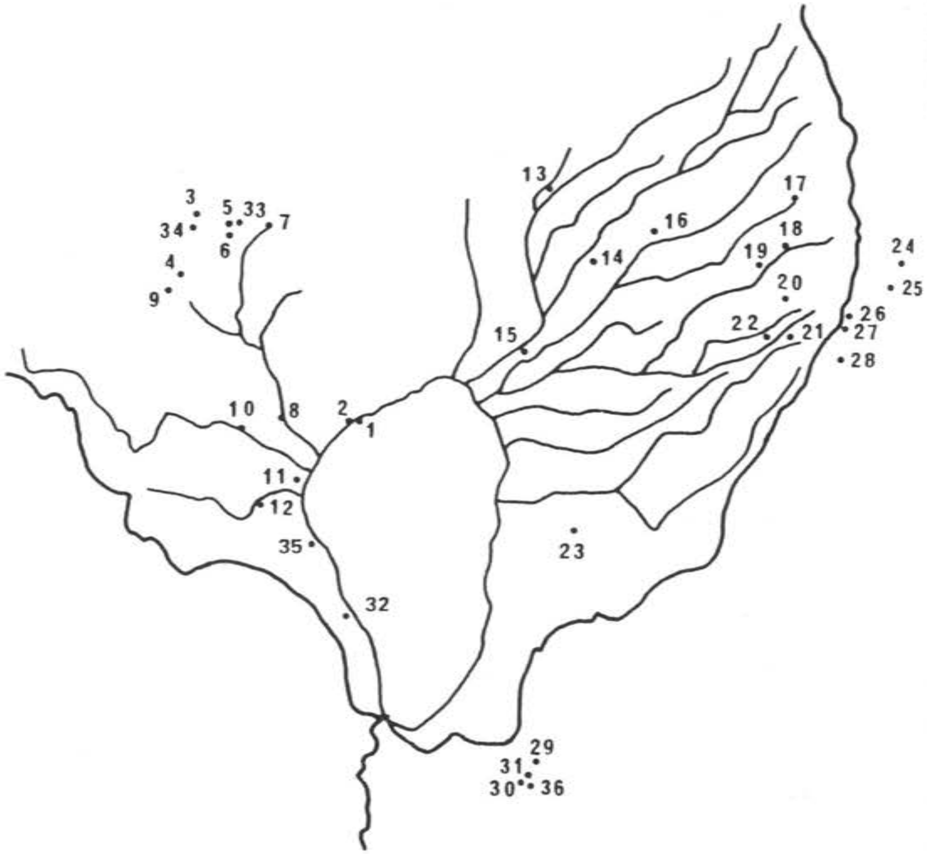

Fig. 33. Location of freshwater springs. The numbers correspond to the list of Table 12. (data from the Hydrological Yearbook of Israel).

C. The thermo-mineral springs

Although the main source of water of the lake, the Jordan River, presents the 'normal' ionic sequence of most of the inland freshwater bodies ($Ca > Mg > Na > K$ and $HCO_3 > SO_4 > Cl$), a completely different chemical pattern characterizes the lake water ($Na > Mg > Ca > K$ and $Cl > HCO_3 > SO_4$) as shown in Fig. 34.

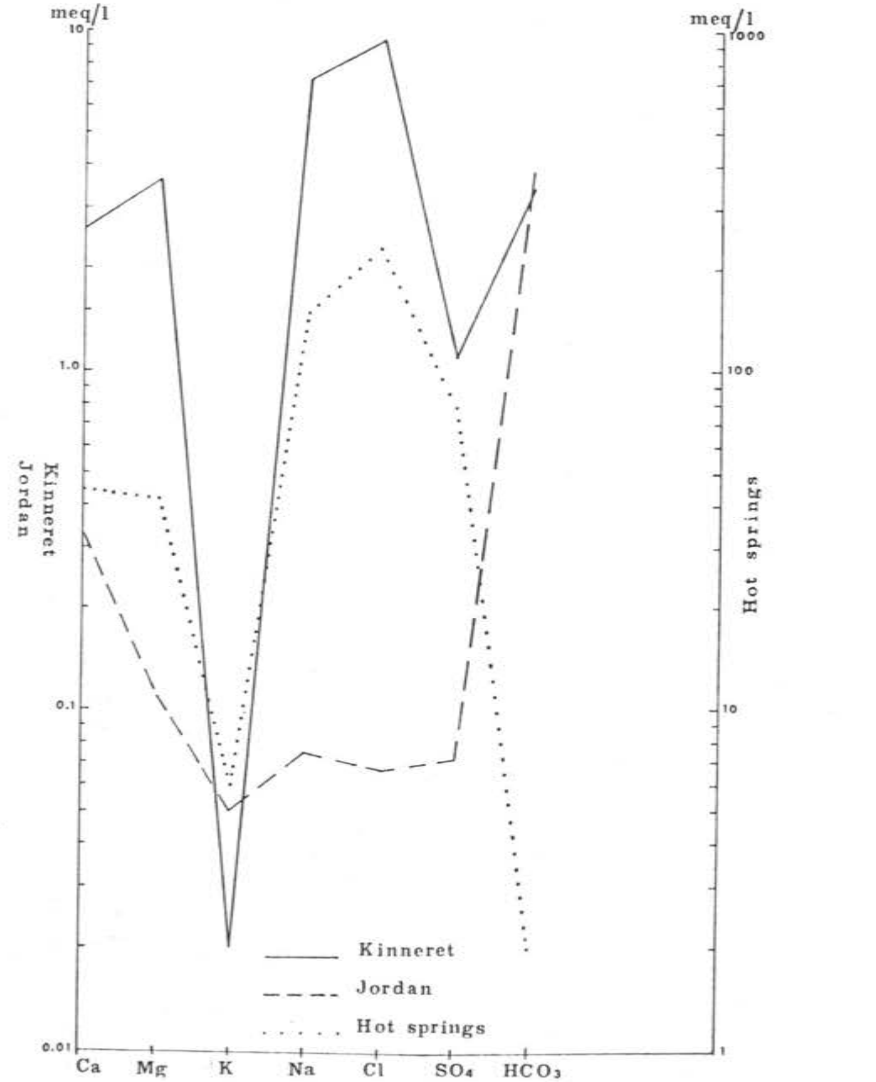

Fig. 34. Comparative chemical composition of the Kinneret, River Jordan and Hot Springs waters. (From C. Serruya & U. Pollingher, 1971, Mitt. Internat. Verein. Limnol., 19.)

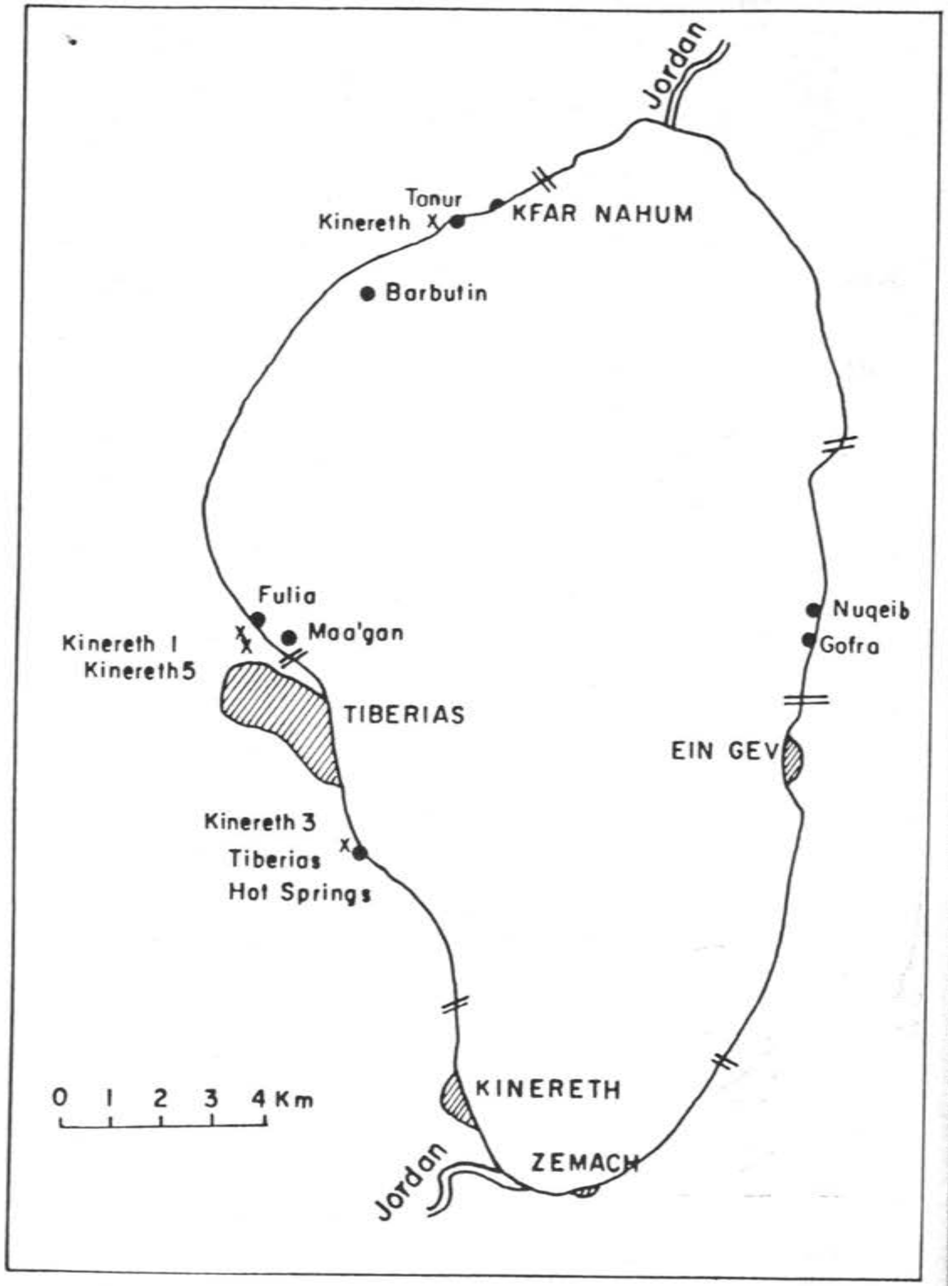

Fig. 35. Location of the thermo-mineral springs in the Kinneret vicinity.

Moreover, the chloride concentration of the Jordan water does not exceed 20 ppm, whereas in the lake, it amounts to 250 ppm. These considerable differences between the chemistry of the lake water and the water of its main inlet are due to the presence of thermo-mineral springs on the shores and on the bottom of the

Table 13. Main features of the thermo-mineral springs

Spring name and location	Discharges m³/sec Max.	Min.	Ave.	Chloride concentration ppm Max.	Min.	Ave.	Mean Cl⁻ discharge 10³ tons/yr	Temp. °C Max.	Min.
Western coast:									
Ein Sheva Group (201.87–253.11)	0.210	0.080	0.135	1,400	400	1,050	4,500	29	21
Ein Nur Group (201.79–253.16)	0.893	0.486	0.700	2,500	1,300	1,970	43,500	30	22
Ein Fuliya Group (199.63–246.00)	~0.500	~0.05	~0.350	1,300	~600	~1,100	~12,150	32	27
Hamei Tveria Group (201.83–241.40)	0.035	0.022	0.029	16,500	18,200	17,900	16,400	61	56
Total known springs on western coast	1.156	0.638	1.214	–	–	–	~76,550	–	–
Sublacustrine springs:									
Barbutim Group (201.40–251.70)	?	?	?	4,000	1,100	~2,500		31	26
Ma'agan Group				2,400	1,100	1,800		36	33
Saline seepages along eastern and western shores of lake	?	?	?	22,000	1,000	?		?	?
Estimated total	?	?	~1.60			~2,000	~71,000	–	–

lake. The location of these springs is shown in Fig. 35, and the characteristics of the main springs are listed in Table 13.

The exact location of three groups of sublacustrine mineral springs was determined during the bathymetric measurements carried out in the 1960's by TAHAL (Water Planning for Israel).

The Barbutim group in the NW sector of the lake consists of a series of 'craters' within a general NE–SW directed depression. The largest crater is located at the southern part of the depression and has the strongest discharge. The Ma'agan group, situated 800 m offshore of the Tiberias fisheries port, consists of six circular funnels. The largest one is approximately 40 m wide and 20 m deep (Fig. 36). The Fuliya group consists of various sublacustrine springs emerging at about 150 m from the shore or close to the shore. Although their discharge is modest in comparison with other sources of water, the chloride balance indicates that the springs bring to the lake an annual amount of 150,000 tons (±20%) of chloride. As can be seen from Table 13, only half of the saline influx originates from springs on or close to shore. The other half is contributed by sublacustrine springs and seepages. The danger that this salt represents to the quality of the lake water explains the detailed investigations which have been conducted in order to clarify the origin of the salty water and the hydraulic mechanisms which bring it back to the surface. The results of these studies are reported in Chapter V.

D. The water balance of Lake Kinneret

In the Kinneret watershed, the amount of precipitation ranges from 400 mm/yr in the lake area to 1,200 mm/yr in the Hermon mountains, and reaches a total average volume of 2,160 MCM/yr. The deviation from this average value is considerable: 160 to 30% of this amount is received by the watershed in very wet and very dry years respectively.

Approximately 75% of the total superficial runoff is of underground origin, and corresponds to the rather uniform baseflow of rivers and springs. The remaining 25% comes from storm runoff and surface flow occurring during and after the rainy period.

The considerable interannual variations of the discharge are caused by the nearly direct response of the surface flow to the rainfall amounts and their time distribution.

The generalized water balance presented in Table 14 has been established according to the average precipitation and discharge data of the period 1959–1974. The water inflow of the drainage area of the Jordan River accounts for 66% of the total lake inflow. It is interesting to note that the average net Jordan inflow (558 MCM) is practically equal to the average lake outflow (546 MCM). This means that the 295 MCM of water lost annually by evaporation must be compensated for by an equivalent additional inflow coming from the immediate vicinity of the lake (the 282 MCM of the Kinneret Basin). If we subtract the amount of annual precipitation on the lake (70 MCM), we obtain an amount of water corresponding to the surface flow of the wadis and to the freshwater and saline springs (212 MCM). Since the saline flux is estimated to be 90×10^6 m^3/yr, it follows that the freshwater supply of the basin close to the lake amounts to 122 MCM.

An attempt has been made to determine the contribution of each geological formation of the Kinneret Basin, which was divided into four areas: (i) An area covered with basalts in the northern and western sectors of the basin. It covers 125 km^2 and includes minor aquifer units. (ii) An area of 85 km^2 where the dominant Eocene limestone forms confined aquifers of medium size. (iii) The Turonian–Cenomanian karstic formations extending over 180 km^2. The water of this aquifer seems to mix with the saline water and consequently plays a role in the final chemical composition of the mineral springs. (iv) An area of 205 km^2 along the eastern shore of the lake. It is covered with basalts and includes a minor aquifer giving rise to numerous springs.

The known hydrological features of each formation allowed the estimation of the superficial and underground annual influx through each formation for the period 1959–1960/1973–1974 (Table 15).

The average total influx (217 MCM) is in excellent agreement with the contribution of the Kinneret Basin (212 MCM) calculated in the overall water balance of Table 14. We note also that the Golan Heights contributes as much as 60% of

Table 14. Generalized water balance of Lake Kinneret

Name of watershed or river basin	Drainage area $10^6 km^2$	Aver. prec. mm/yr	Yearly discharges (MCM) winter	summer	total
(1) *Upper Jordan:*					
Hermon River	141.0	?	82.0	35.0	117.0
Dan River (mainly ground water)	24.0*	?	150.0	114.0	264.0
Snir River	623.0	?	98.0	32.0	130.0
Ayun River	32.0	?	9.0	0.3	9.3
Total:	820.0	~1,200	339.0	181.3	520.3
(2) *Hula Basin:*					
Eastern border catchments	237.0	881	~40.0	20.0	60.0
Western border catchments	254.0	720	35.0	14.0	49.0
Hula Valley	157.0	551	~16.0	8.0	24.0
Total:	648.0	703	91.0	42.0	133.0
Total Jordan at Pardes Huri gauging station	1468.0	980	430.0	223.3	653.3
(3) *Jordan–Korazim Valley*†	122.0	460	~10.0	~5.0	~15.0
Total Jordan into Lake Kinneret (undiverted)	1,590.0	955	440.0	228.3	668.3
Estimated upstream use†	–	–	~15.0	~95.0	~110.0
Total net Jordan inflow	1,590.0	955	425.0	133.3	558.0
(4) *Kinneret Basin:*					
Eastern catchments (S. Golan)†	583.0	615	91.0	12.0	103.0
Western basins and springs†	385.0	620	71.0	38.0	109.0
Lake surface (direct rain)†	169.0	415	70.0	–	70.0
Total Kinneret Basin contribution†	1,137.0	587	232.0	50.0	282.0
Total net lake inflow‡	2,727.0	793	662.0	188.0	840.0
(5) Evaporation losses from lake (calculated by energy balance)	169.0	1,740.0	−101.0	−193.0	−294.0
Total of average lake outflow					~546.0

* The indicated catchment area for the Dan springs refers to the surface catchment only. The extent of the ground water catchment area is unknown. Its extent is about 500 km^2, estimated from water balance considerations.

† Discharges are estimated averages, obtained by hydrometeorological and conventional water balances.

‡ Based on daily water balances, lake levels, outflow measurements, etc.

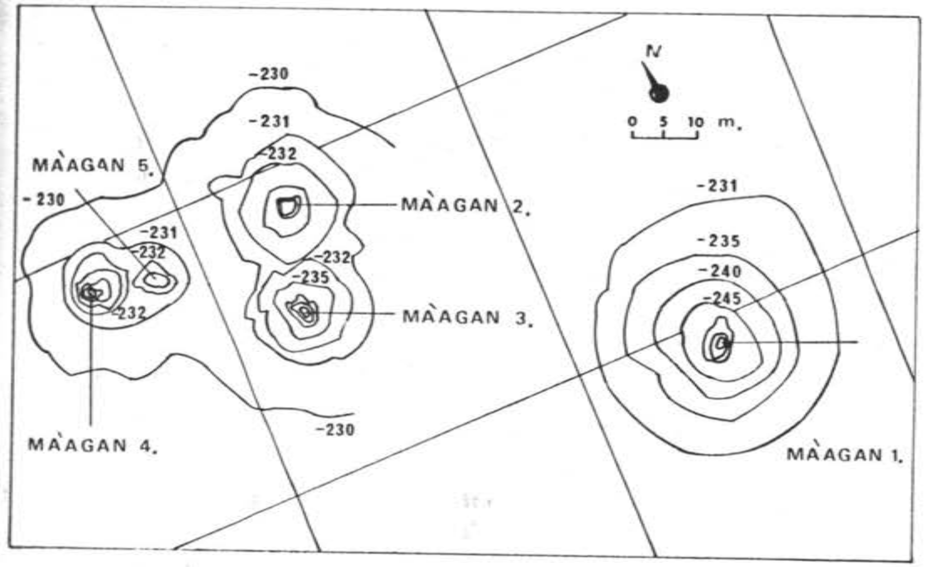

Fig. 36. Topography of the funnels of the Ma'agan sublacustrine springs.

the total influx. Although one can hardly speak of basaltic aquifers, large amounts of water pass through the basalts and find their way through underlying formations.

Table 15. Contribution of the different geological formations to the lake inflow. Results in MCM. GW = ground water flow. SUR = superficial flow.

		West & North basalts	Eocene	Cenoman	Golan	Total
	GW	1.4	25.7	53.3	22.5	102.9
1959/60	SUR	1.8	1.9	3.9	10.5	18.1
	TOTAL	3.2	27.6	57.2	33.0	121.0
	GW	2.2	17.8	49.4	36.1	105.5
1960/61	SUR	2.8	1.4	3.0	27.5	34.7
	TOTAL	5.0	19.2	52.4	63.6	140.2
	GW	17.9	25.1	57.1	85.4	185.5
1961/62	SUR	10.2	4.4	7.9	55.1	77.6
	TOTAL	28.1	29.5	65.0	140.5	263.1
	GW	5.6	18.9	52.2	70.5	147.2
1962/63	SUR	3.7	2.3	4.1	40.5	50.6
	TOTAL	9.3	21.2	56.3	111.0	197.0
	GW	8.7	17.8	49.9	78.2	154.6
1963/64	SUR	6.3	3.1	4.4	46.8	60.6
	TOTAL	15.0	20.9	54.3	125.0	215.2
	GW	20.3	25.7	56.9	96.4	199.3
1964/65	SUR	10.3	4.7	8.1	49.9	72.5
	TOTAL	30.6	30.4	64.0	145.8	271.8
	GW	3.0	13.3	45.6	39.9	101.8
1965/66	SUR	3.1	1.3	1.9	19.9	26.2
	TOTAL	6.1	14.6	47.5	59.8	128.0
	GW	14.0	21.4	50.8	96.7	182.9
1966/67	SUR	7.8	3.9	5.6	59.4	76.7
	TOTAL	21.8	25.3	56.4	156.1	259.6
	GW	7.2	20.0	51.8	75.1	154.1
1967/68	SUR	4.4	3.5	5.5	41.9	55.3
	TOTAL	11.6	23.5	57.3	117.0	209.4
	GW	34.7	40.5	69.5	165.1	309.9
1968/69	SUR	23.5	13.6	21.1	131.7	189.9
	TOTAL	58.2	54.1	90.6	296.8	499.7
	GW	4.6	20.6	55.7	71.3	152.2
1969/70	SUR	3.5	2.4	3.7	35.2	44.8
	TOTAL	8.1	22.0	59.4	106.5	197.0
	GW	7.7	18.6	51.2	85.8	163.3
1970/71	SUR	7.2	2.9	3.8	63.3	76.4
	TOTAL	14.1	21.5	55.0	149.1	239.7
	GW	1.7	15.0	46.0	67.8	130.5
1971/72	SUR	1.9	1.6	1.6	32.2	37.3
	TOTAL	3.6	16.6	47.6	100.0	167.8
	GW	0.0	7.3	35.5	38.8	81.6
1972/73	SUR	0.6	0.5	0.5	21.8	23.4
	TOTAL	0.6	7.8	36.0	60.6	105.0
	GW	6.0	16.7	45.3	91.1	159.1
1973/74	SUR	3.7	3.5	5.5	62.7	75.4
	TOTAL	9.7	20.2	50.8	153.8	234.5
Average	GW	9.1	20.3	51.3	74.7	155.4
Average	SUR	5.9	3.4	5.4	46.5	61.2
Average	TOTAL	15.0	23.7	56.7	121.2	216.6

V Mineral waters of the Kinneret basin and possible origin

E. Mazor

D. The water balance of Lake Kinneret

In the Kinneret watershed, the amount of precipitation ranges from 400 mm/yr in the lake area to 1,200 mm/yr in the Hermon mountains, and reaches a total average volume of 2,160 MCM/yr. The deviation from this average value is considerable: 160 to 30% of this amount is received by the watershed in very wet and very dry years respectively.

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Total net lake inflow‡	2,727.0	793	662.0	188.0	840.0
(5) Evaporation losses from lake (calculated by energy balance)	169.0	1,740.0	–101.0	–193.0	–294.0
Total of average lake outflow					~546.0

* The indicated catchment area for the Dan springs refers to the surface catchment only. The extent of the ground water catchment area is unknown. Its extent is about 500 km², estimated from water balance considerations.

† Discharges are estimated averages, obtained by hydrometeorological and conventional water balances.

‡ Based on daily water balances, lake levels, outflow measurements, etc.

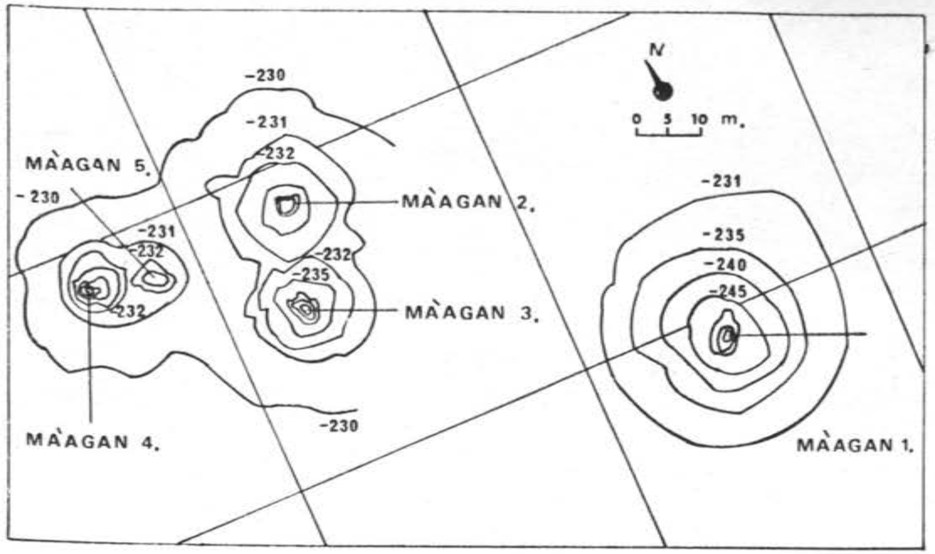

Fig. 36. Topography of the funnels of the Ma'agan sublacustrine springs.

the total influx. Although one can hardly speak of basaltic aquifers, large amounts of water pass through the basalts and find their way through underlying formations.

Table 15. Contribution of the different geological formations to the lake inflow. Results in MCM. GW = ground water flow. SUR = superficial flow.

		West & North basalts	Eocene	Cenoman	Golan	Total
	GW	1.4	25.7	53.3	22.5	102.9
1959/60	SUR	1.8	1.9	3.9	10.5	18.1
	TOTAL	3.2	27.6	57.2	33.0	121.0
	GW	2.2	17.8	49.4	36.1	105.5
1960/61	SUR	2.8	1.4	3.0	27.5	34.7
	TOTAL	5.0	19.2	52.4	63.6	140.2
	GW	17.9	25.1	57.1	85.4	185.5
1961/62	SUR	10.2	4.4	7.9	55.1	77.6
	TOTAL	28.1	29.5	65.0	140.5	263.1
	GW	5.6	18.9	52.2	70.5	147.2
1962/63	SUR	3.7	2.3	4.1	40.5	50.6
	TOTAL	9.3	21.2	56.3	111.0	197.0
	GW	8.7	17.8	49.9	78.2	154.6
1963/64	SUR	6.3	3.1	4.4	46.8	60.6
	TOTAL	15.0	20.9	54.3	125.0	215.2
	GW	20.3	25.7	56.9	96.4	199.3
1964/65	SUR	10.3	4.7	8.1	49.9	72.5
	TOTAL	30.6	30.4	64.0	145.8	271.8
	GW	3.0	13.3	45.6	39.9	101.8
1965/66	SUR	3.1	1.3	1.9	19.9	26.2
	TOTAL	6.1	14.6	47.5	59.8	128.0
	GW	14.0	21.4	50.8	96.7	182.9
1966/67	SUR	7.8	3.9	5.6	59.4	76.7
	TOTAL	21.8	25.3	56.4	156.1	259.6
	GW	7.2	20.0	51.8	75.1	154.1
1967/68	SUR	4.4	3.5	5.5	41.9	55.3
	TOTAL	11.6	23.5	57.3	117.0	209.4
	GW	34.7	40.5	69.5	165.1	309.9
1968/69	SUR	23.5	13.6	21.1	131.7	189.9
	TOTAL	58.2	54.1	90.6	296.8	499.7
	GW	4.6	20.6	55.7	71.3	152.2
1969/70	SUR	3.5	2.4	3.7	35.2	44.8
	TOTAL	8.1	22.0	59.4	106.5	197.0
	GW	7.7	18.6	51.2	85.8	163.3
1970/71	SUR	7.2	2.9	3.8	63.3	76.4
	TOTAL	14.1	21.5	55.0	149.1	239.7
	GW	1.7	15.0	46.0	67.8	130.5
1971/72	SUR	1.9	1.6	1.6	32.2	37.3
	TOTAL	3.6	16.6	47.6	100.0	167.8
	GW	0.0	7.3	35.5	38.8	81.6
1972/73	SUR	0.6	0.5	0.5	21.8	23.4
	TOTAL	0.6	7.8	36.0	60.6	105.0
	GW	6.0	16.7	45.3	91.1	159.1
1973/74	SUR	3.7	3.5	5.5	62.7	75.4
	TOTAL	9.7	20.2	50.8	153.8	234.5
Average	GW	9.1	20.3	51.3	74.7	155.4
Average	SUR	5.9	3.4	5.4	46.5	61.2
Average	TOTAL	15.0	23.7	56.7	121.2	216.6

V Mineral waters of the I

E. Mazor

See Esp. p. 178 Section 9.

D. Energy balance and evaporation

G. Stanhill & J. Neumann

The radiation balance at the lake's surface and the thermal regime of its waters are the two major elements determining the lake's energy balance and evaporation loss. The different flux components of the energy balance are considered in this chapter using the following balance equations:

$$Q_* = K\downarrow + L\downarrow - L\uparrow - R = LE + S + A + V + M$$

where: Q_* is the net radiation balance at the water surface
$K\downarrow$ is the global, short-wave radiation from sun and sky
$L\downarrow$ is the atmospheric, long-wave radiation from the sky
$L\uparrow$ is the long-wave radiation emitted by the water surface
R is the short-wave radiation reflected by the water surface
LE is the latent heat of evaporation
S is the change in heat storage in the water
A is the sensible heat exchange with the air
V is the net advective heat exchange via the water fluxes
M is the change in metabolic heat storage

All fluxes are expressed per unit water surface area, positive values representing ...es to the water surface.

1. Global radiation

In the absence of direct measurements, 25 years of observations of the cloud cover at Degania A were used with the following empirical equation:

$$K\downarrow = K\downarrow\downarrow\,(0.7985 - 0.0311\ C - 0.001\ C^2)$$

where: $K\downarrow$ is mean global radiation in cal cm^2 day^{-1}
$K\downarrow\downarrow$ is mean solar radiation at the top of the atmosphere in the same units
C is mean cloud cover from observations at 08, 14 and 20 hours local time, in tenths of sky covered

The equation was derived from 94 pairs of monthly data obtained prior to 1960 from three stations in unpolluted areas of Israel (Stanhill, 1962). As no difference was found between the relationships at the three stations, despite an altitude difference of more than 700 m, it may be assumed that the relationship will also yield monthly estimates for Lake Kinneret with a mean standard error of 4.4%, as observed at the other three stations.

The annual total insolation calculated, 199.3 Kcal cm^{-2} yr^{-1}, agrees to within ... of the nearest measured value at Amir, 52 km to the north of the lake in the Upper Jordan Rift (Stanhill, 1970). The calculated mean monthly values at Lake

Kinneret, listed in Table 21, are somewhat higher in the winter and slightly lower in the summer than those measured at Amir.

2. Reflected short-wave radiation, R

The short-wave radiation reflected from the lake has not been systematically measured. In Table 21, the values presented are calculated with the mean monthly albedo values listed by Kondratyev (1972), appropriate to the latitude and mean cloud cover of the lake. Two days of measurement in the center of the lake during the early summer of 1966 gave a mean albedo of 6.0%, in good agreement with the tabulated values for that time of the year.

3. Long-wave emission, L↑

Emission was calculated as $L\uparrow = \varepsilon\sigma T^4$, where T is the water temperature on the absolute scale. The values used are mean monthly values, each based on an average of six dates of measurement, each of which is based on 15 points of measurement selected to sample the lake surface (Stanhill, 1969). σ is the Stefan–Bolzmann constant and ε is the emissivity of the water surface; the value used for ε was 0.97 (U.S. Geological Survey, 1954).

4. Net radiation balance, Q_*

Data from four years of continuous measurement of the radiation balance over the water surface are available from a special station established at Ginnosar as part of the Lake Kinneret Evaporation Project, initiated by Water Planning for Israel Ltd. under the supervision of the late Dr. J. Frenkiel, and now under the supervision of F. Miro. A description of the instrumentation, exposure and calibration procedures can be found in the first report (Miro & Kahanovitz, 1969). The mean monthly values presented in Table 21 are taken from data presented in three progress reports (Miro & Kahanovitz, 1972, 1973, 1974). Fluxes for the individual periods are shown in Fig. 68.

The areal variation in the radiation balance is probably small. Measurements during August 1964 near the shore at Ginnosar and Ein Gev show a 5% difference in the mean daily total (Fig. 69), almost certainly due to the difference in water surface temperature occurring in the summer months (Stanhill, 1969).

5. Long-wave sky radiation, L↓

Values of this flux, calculated as the difference from the radiation balance equation, are listed in Table 21. It may be noted that the values calculated exceed those for the short-wave global radiation received at the water surface.

6. Heat storage change in the water, S

Four series of lake water temperature measurements are available from which this flux may be calculated. The first, presented by Ashbel (1945), is for a 14-month

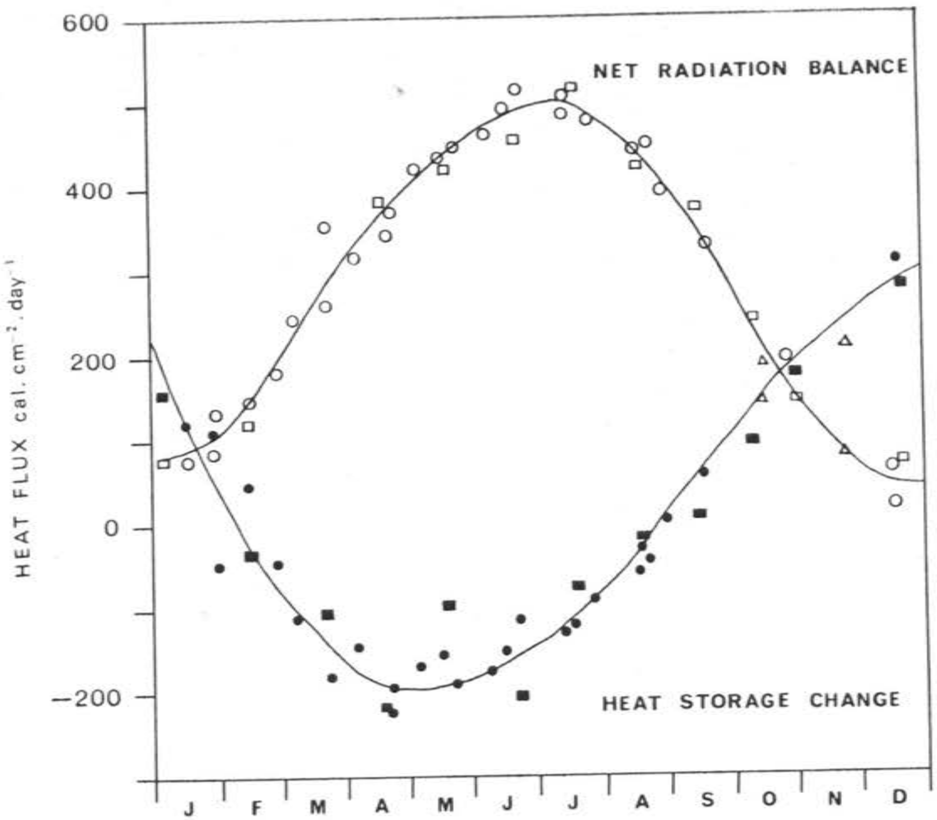

Fig. 68. Measured values of net radiation balance over Lake Kinneret at Ginnosar and heat storage changes in the Lake for corresponding periods. Original data in Miro & Kahanovitz, 1972 and 1973 and Kahanovitz & Karni, 1974.

period between 1943 and 1945 and is published as mean monthly values for 5 depths based on two fixed points of measurement near the shore at Ein Gev and Hamei Tiberias and an unspecified number of points on the lake. The annual heat storage change, i.e. the sum of changes through the calendar year neglecting signs, totalled 67,000 Kcal cm^{-2} yr^{-1}.

Oren (1962) reports the results of a series of measurements taken during 27 months between 1948 and 1951. Twenty sets of measurements were made at four depths along two transects, one from Tiberias to Ein Gev and a second from Ginnosar to El-Kursi. The annual flux totalled 47,433 Kcal cm^{-2} yr^{-1}.

A third series of measurements presented by Stanhill (1969) consists of 72 sets of data collected at ten depths at 15 stations chosen to sample representatively the lake's volume. The fluxes for the two years of measurement, from 1965 to 1967, were 40,000 and 47,240 Kcal cm^{-2} yr^{-1}. The standard deviation of temperature differences were used to calculate the error of the estimates of heat storage change. For the great majority of the periods examined, the coefficient of variation was less than 3%.

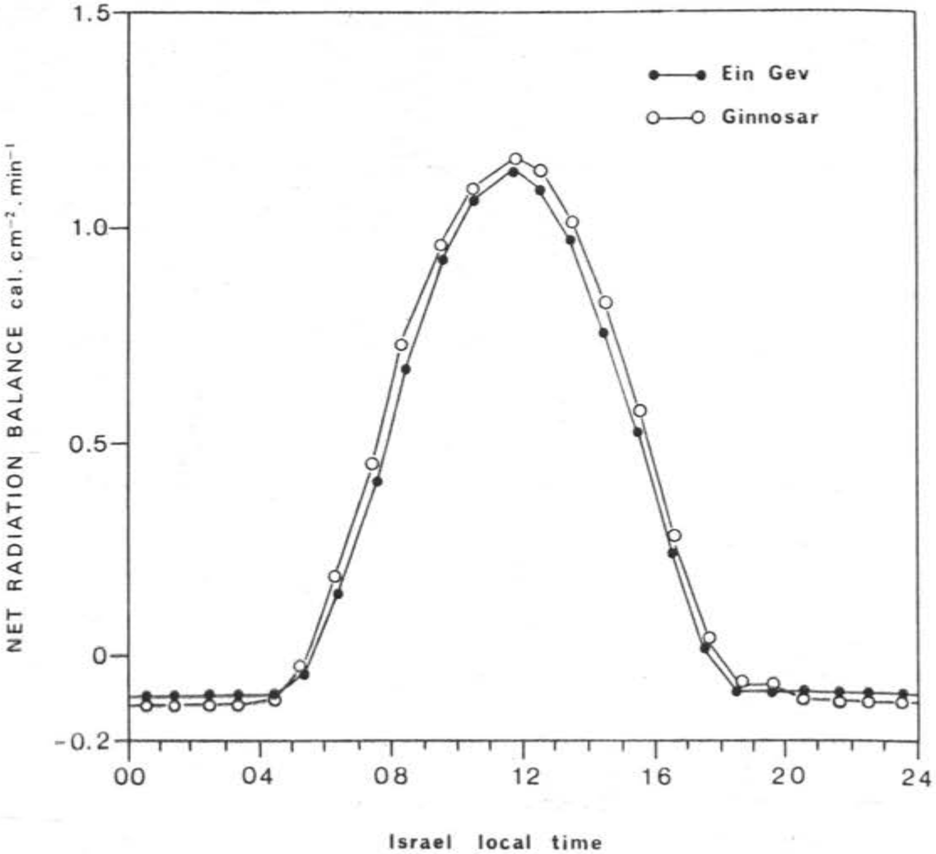

Fig. 69. Measured values of net radiation balance over Lake Kinneret at Ginnosar and Ein Gev, mean monthly values for August 1964.

The heat storage changes shown in Fig. 68 and presented as mean monthly values in Table 21 are based on the 40 sets of measurements taken over the same time periods as the net radiation measurements. During the four-year period, the number of sampling stations varied, starting at 15 and increasing to 45 during the last two years of the period. There were ten depths of measurement. The original data are presented in the same reports referred to for the net radiation data. The annual heat storage fluxes averaged 50,321 Kcal cm^{-2} yr^{-1}.

The degree of annual variation in heat storage can also be seen in Fig. 57, reproduced from Serruya (1975), which shows the isotherms measured in the center of the lake.

7. Advective heat exchange, V

Heat is advected into the lake in the water entering the lake through surface flow, rainfall and subterranean springs, and out of the lake in evaporating water vapor and in the water pumped into the National Water Carrier. Neither the

Table 21. Radiant and heat flux densities at Lake Kinneret. Mean monthly values cal cm^{-2} day^{-1}, negative values represent fluxes from the lake surface.

Flux component		J	F	M	A	M	J	J	A	S	O	N	D	Annual total Kcal cm^{-2} yr^{-1}
Global radiation	$K\downarrow$	320	406	511	622	692	769	757	705	610	482	367	307	199.34
Albedo %		9.6	7.8	6.9	6.0	5.9	5.7	5.7	5.8	6.7	7.0	8.7	10.1	6.8
Reflected short wave	R	−31	−32	−35	−38	−41	−44	−43	−41	−41	−34	−32	−31	−13.49
Emitted long wave	$L\uparrow$	−806	−801	−812	−843	−880	−921	−937	−950	−942	−915	−885	−840	−319.04
Sky radiation	$L\downarrow$	596	572	624	613	660	677	717	715	711	675	658	616	240.22
Net radiation balance	Q_*	79	145	288	354	431	481	494	429	341	208	108	52	107.03
														+251.6
Heat storage change	S	125	−13	−120	−190	−180	−161	−105	−55	48	140	215	292	−251.6
Net heat flux	Q_*-S-V-M	200	128	164	160	248	317	386	371	386	345	319	340	105.71
Evaporation, mm day^{-1}		2.9	2.9	2.7	3.9	4.4	5.0	6.8	6.8	6.7	5.3	4.0	4.8	1.716
Latent heat	LE	−171	−171	−159	−230	−260	−295	−401	−401	−336	−313	−236	−283	−101.13
Sensible heat exchange	A	−29	43	−5	70	12	−22	15	30	−50	−32	−83	−57	−4.58

temperature nor the volume of the various terms are precisely known; an estimate can, however, be made based on the estimates of the lake's water balance (Negev & Keller, 1964), measurements of water temperature in the Jordan and the assumption that the water pumped from the lake is at surface temperature. The annual totals of heat advected into the lake are 4.72 Kcal cm^{-2} lake surface in Jordan inflow, 3.05 Kcal cm^{-2} via the subterranean hot springs and 0.41 Kcal cm^{-2} in rainfall. The heat advected from the lake in evaporation was calculated to be 4.20 Kcal cm^{-2} and in the pumped water, 5.00 Kcal cm^{-2}. Thus the net advective heat exchange is 1.00 Kcal cm^{-2} yr^{-1} from the lake.

8. Metabolic heat, M

The solar radiation fixed metabolically by algal photosynthesis (primary production) forms a very small fraction of the incident global radiation, less than 0.2%, but is of great significance for the quality of the lake's water and also provides the food base for the 1,672 tons of fish harvested from the lake each year. Average values of primary production (Lake Kinneret Report, 1974), with the heat of combustion of algae (5.5 Kcal g^{-1}), gave a total annual net metabolic heat fixation of 0.32 Kcal cm^{-2} lake surface, with a maximum flux of 1.4 cal cm^{-2} day^{-1} in April.

9. Latent heat of evaporation, LE

Approximately the same volume of water leaves the lake in water vapour as is pumped from the lake into the National Water Carrier. No doubt because of its significance in the national water balance, the size of this flux has been the subject of numerous investigations using a variety of methods. The results have been summarized in Table 22 in the form of the various estimates of annual evaporation. The average of the six estimates is 175 cm yr^{-1}, equivalent to a latent heat flux of 103.25 Kcal cm^{-2} yr^{-1}. The 7% variation between the estimates includes the various errors of measurement and estimation involved in each method plus the year-to-year variation introduced by considering different periods. Data given in the references numbered 2, 4, 5 and 6 in Table 22 suggest that this year-to-year variation can be considerable, as do the values of year-to-year variation in the size of the heat storage term previously presented.

Estimates of monthly evaporation obtained by the different investigations show much more variation than do the annual totals. The first energy balance estimate, based on Ashbel's early heat storage measurements (Neumann, 1953), showed an autumn maximum and late spring minimum, whereas all other estimates indicate midsummer maxima and early winter minima. Estimates by the combined water balance and mass-transfer method (Stanhill, 1969) differed in that the midsummer maximum (353 mm in July) was almost 50% more than the amount estimated in the other three investigations (nos. 2, 3 and 6 in Table 22). These three estimates, all based on the more recent series of heat storage measurements, show a fair agreement on monthly values.

All three energy balance estimates contain a systematic error by ignoring the unmeasurable but marked diurnal variation in the heat storage term. The most re-

Table 22. Estimates of annual Evaporation from Lake Kinneret

Method of estimation	Annual evaporation, cm	Reference
1. Energy Balance Lakeside climatological data Ashbel's thermal survey data	163	Neumann 1953
2. Energy Balance Lakeside climatological data Oren's thermal survey data	178	Neumann 1961
3. Combined Energy Balance and Mass Transfer Lakeside climatological data Oren's thermal survey data	171	Stanhill 1963
4. Combined Water Balance and Mass Transfer Lakeside climatological data Lake water balance data	184	Stanhill 1969
5. Evaporation Pan Class A evaporation pan and reduction constant, mean of five lakeside stations for three years	167	Bezer 1970
6. Energy Balance Micrometerorological measurements at Ginnosar with concurrent thermal surveys, 4 year mean	187	Miro & Kahanovitz, 1969–1973 Kahanovitz & Karni, 1974

cent estimate (no. 6, Table 22) is the most precise in that micrometeorological measurements made at Ginnosar over the water surface were used to derive hourly values of Bowen's ratio needed to partition the available energy between latent and sensible heat fluxes. In contrast, the earlier estimates used mean monthly climatological values from lakeside stations and thermal survey data for the same purpose.

Unfortunately, the greater precision of the Ginnosar measurements introduces the problem of areal variation in evaporation over the lake, the Ginnosar data representing predominantly windward shore conditions. The marked increase in vapour pressure at the eastern shore, in particular during midday in the summer months, has already been referred to in a previous chapter. Further evidence for the areal differences in atmospheric evaporation potential can be found in the values of Class A evaporation measured at the different lakeside stations (Bezer, 1970). The annual value measured at Migdal, 3 km south of Ginnosar, was 18% more than that measured at Kafer Aaqeb, almost on the same latitude on the downwind, eastern bank, and 13% more than that measured at Ha'on, on the southern section of the eastern shore.

Clearly, accurate estimates of the seasonal variation in evaporation from the lake require detailed information on a diurnal basis of the areal variation in the factors controlling this flux. In the absence of such information, and because, for the previously stated reasons, evaporation at Ginnosar is believed to be higher than over the lake as a whole, the lower, earlier estimates of evaporation based on

Table 23. A Comparison of the Annual Radiation and Energy balance in three Mid-latitude Lakes

		Mean annual values in cal cm^{-2} day^{-1} Negative values represent fluxes from surface		
Lake		Kinneret	Mead*	Hefner*
Coordinates		33°N, 35°E	36°N, 114°W	35°N, 97°W
Altitude		−210 m	400 m	375 m
Flux components				
Global radiation	$K_\downarrow$	546	506	420
Reflected short wave	R	−37	−37	−26
Emitted long wave	$L_\uparrow$	−874	−842	−781
Sky radiation	$L_\downarrow$	658	672	619
Net radiation balance	Q_*	293	299	232
Advective	V	−3	52	4
Latent heat	LE	−277	−344	−222
Sensible heat	A	−13	−5	8
Evaporation mm day^{-1}		4.7	5.8	3.8

* Data from Harbeck *et al.* (1958).

lakeside climatological data (Stanhill, 1963) have been used for the monthly values given in Table 21.

10. Sensible heat exchange with the air, A

There is a small sensible heat flux from the lake to the air totalling 4.58 Kcal cm^{-2} yr^{-1}. The monthly values of this flux given in Table 21 should be regarded as an approximate indication only, being calculated by difference and incorporating all the uncertainties in the heat balance. The values suggest that the lake warms the passing air from late summer to early winter, with a marked cooling effect confined to late spring. This pattern is consistent with the previously-noted variation in air temperature around the lakeside, but it is believed that other factors, including the topographical influences discussed elsewhere, and the much greater sensible heat exchange from the land surfaces during the summer months, are probably of greater significance.

11. Conclusions

The size of the major terms in the annual heat balance of Lake Kinneret are by now well established. A comparison of these data with that of other lakes shows that the annual flux of radiant heat and the changes in its heat storage are, per unit area, among the highest recorded (Table 23). The seasonal variation of the radiation balance components and of the changes in heat storage are also satisfactorily established, but the accuracy of the latent and sensible heat fluxes is less accurately known. To obtain this information, a detailed study of the areal and diurnal variation in these heat fluxes is required, information which is also needed to model the circulation of heat, water and momentum in the lake and its surroundings.

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D. The water balance of Lake Kinneret

In the Kinneret watershed, the amount of precipitation ranges from 400 mm/yr in the lake area to 1,200 mm/yr in the Hermon mountains, and reaches a total average volume of 2,160 MCM/yr. The deviation from this average value is considerable: 160 to 30% of this amount is received by the watershed in very wet and very dry years respectively.

Approximately 75% of the total superficial runoff is of underground origin, and corresponds to the rather uniform baseflow of rivers and springs. The remaining 25% comes from storm runoff and surface flow occurring during and after the rainy period.

The considerable interannual variations of the discharge are caused by the nearly direct response of the surface flow to the rainfall amounts and their time distribution.

The generalized water balance presented in Table 14 has been established according to the average precipitation and discharge data of the period 1959–1974. The water inflow of the drainage area of the Jordan River accounts for 66% of the total lake inflow. It is interesting to note that the average net Jordan inflow (558 MCM) is practically equal to the average lake outflow (546 MCM). This means that the 295 MCM of water lost annually by evaporation must be compensated for by an equivalent additional inflow coming from the immediate vicinity of the lake (the 282 MCM of the Kinneret Basin). If we subtract the amount of annual precipitation on the lake (70 MCM), we obtain an amount of water corresponding to the surface flow of the wadis and to the freshwater and saline springs (212 MCM). Since the saline flux is estimated to be 90×10^6 m^3/yr, it follows that the freshwater supply of the basin close to the lake amounts to 122 MCM.

An attempt has been made to determine the contribution of each geological formation of the Kinneret Basin, which was divided into four areas: (i) An area covered with basalts in the northern and western sectors of the basin. It covers 125 km^2 and includes minor aquifer units. (ii) An area of 85 km^2 where the dominant Eocene limestone forms confined aquifers of medium size. (iii) The Turonian–Cenomanian karstic formations extending over 180 km^2. The water of this aquifer seems to mix with the saline water and consequently plays a role in the final chemical composition of the mineral springs. (iv) An area of 205 km^2 along the eastern shore of the lake. It is covered with basalts and includes a minor aquifer giving rise to numerous springs.

The known hydrological features of each formation allowed the estimation of the superficial and underground annual influx through each formation for the period 1959–1960/1973–1974 (Table 15).

The average total influx (217 MCM) is in excellent agreement with the contribution of the Kinneret Basin (212 MCM) calculated in the overall water balance of Table 14. We note also that the Golan Heights contributes as much as 60% of

Table 14. Generalized water balance of Lake Kinneret

Name of watershed or river basin	Drainage area $10^6 km^2$	Aver. prec. mm/yr	Yearly discharges (MCM) winter	summer	total
(1) *Upper Jordan:*					
Hermon River	141.0	?	82.0	35.0	117.0
Dan River (mainly ground water)	24.0*	?	150.0	114.0	264.0
Snir River	623.0	?	98.0	32.0	130.0
Ayun River	32.0	?	9.0	0.3	9.3
Total:	820.0	~1,200	339.0	181.3	520.3
(2) *Hula Basin:*					
Eastern border catchments	237.0	881	~40.0	20.0	60.0
Western border catchments	254.0	720	35.0	14.0	49.0
Hula Valley	157.0	551	~16.0	8.0	24.0
Total:	648.0	703	91.0	42.0	133.0
Total Jordan at Pardes Huri gauging station	1468.0	980	430.0	223.3	653.3
(3) *Jordan–Korazim Valley*†	122.0	460	~10.0	~5.0	~15.0
Total Jordan into Lake Kinneret (undiverted)	1,590.0	955	440.0	228.3	668.3
Estimated upstream use†	–	–	~15.0	~95.0	~110.0
Total net Jordan inflow	1,590.0	955	425.0	133.3	558.0
(4) *Kinneret Basin:*					
Eastern catchments (S. Golan)†	583.0	615	91.0	12.0	103.0
Western basins and springs†	385.0	620	71.0	38.0	109.0
Lake surface (direct rain)†	169.0	415	70.0	–	70.0
Total Kinneret Basin contribution†	1,137.0	587	232.0	50.0	282.0
Total net lake inflow‡	2,727.0	793	662.0	188.0	840.0
(5) Evaporation losses from lake (calculated by energy balance)	169.0	1,740.0	−101.0	−193.0	−294.0
Total of average lake outflow					~546.0

* The indicated catchment area for the Dan springs refers to the surface catchment only. The extent of the ground water catchment area is unknown. Its extent is about 500 km², estimated from water balance considerations.

† Discharges are estimated averages, obtained by hydrometeorological and conventional water balances.

‡ Based on daily water balances, lake levels, outflow measurements, etc.

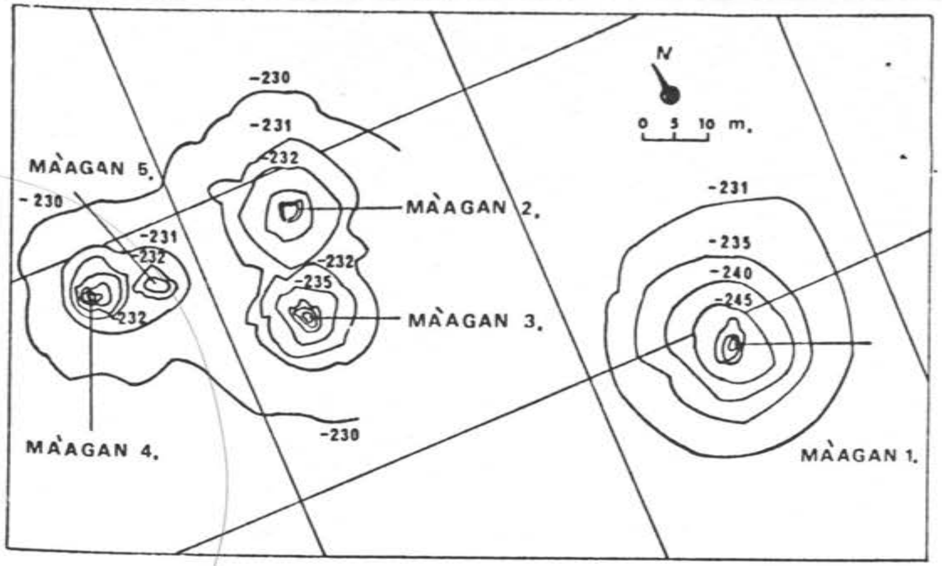

Fig. 36. Topography of the funnels of the Ma'agan sublacustrine springs.

the total influx. Although one can hardly speak of basaltic aquifers, large amounts of water pass through the basalts and find their way through underlying formations.

Table 15. Contribution of the different geological formations to the lake inflow. Results in MCM. GW = ground water flow. SUR = superficial flow.

		West & North basalts	Eocene	Cenoman	Golan	Total
	GW	1.4	25.7	53.3	22.5	102.9
1959/60	SUR	1.8	1.9	3.9	10.5	18.1
	TOTAL	3.2	27.6	57.2	33.0	121.0
	GW	2.2	17.8	49.4	36.1	105.5
1960/61	SUR	2.8	1.4	3.0	27.5	34.7
	TOTAL	5.0	19.2	52.4	63.6	140.2
	GW	17.9	25.1	57.1	85.4	185.5
1961/62	SUR	10.2	4.4	7.9	55.1	77.6
	TOTAL	28.1	29.5	65.0	140.5	263.1
	GW	5.6	18.9	52.2	70.5	147.2
1962/63	SUR	3.7	2.3	4.1	40.5	50.6
	TOTAL	9.3	21.2	56.3	111.0	197.0
	GW	8.7	17.8	49.9	78.2	154.6
1963/64	SUR	6.3	3.1	4.4	46.8	60.6
	TOTAL	15.0	20.9	54.3	125.0	215.2
	GW	20.3	25.7	56.9	96.4	199.3
1964/65	SUR	10.3	4.7	8.1	49.9	72.5
	TOTAL	30.6	30.4	64.0	145.8	271.8
	GW	3.0	13.3	45.6	39.9	101.8
1965/66	SUR	3.1	1.3	1.9	19.9	26.2
	TOTAL	6.1	14.6	47.5	59.8	128.0
	GW	14.0	21.4	50.8	96.7	182.9
1966/67	SUR	7.8	3.9	5.6	59.4	76.7
	TOTAL	21.8	25.3	56.4	156.1	259.6
	GW	7.2	20.0	51.8	75.1	154.1
1967/68	SUR	4.4	3.5	5.5	41.9	55.3
	TOTAL	11.6	23.5	57.3	117.0	209.4
	GW	34.7	40.5	69.5	165.1	309.9
1968/69	SUR	23.5	13.6	21.1	131.7	189.9
	TOTAL	58.2	54.1	90.6	296.8	499.7
	GW	4.6	20.6	55.7	71.3	152.2
1969/70	SUR	3.5	2.4	3.7	35.2	44.8
	TOTAL	8.1	22.0	59.4	106.5	197.0
	GW	7.7	18.6	51.2	85.8	163.3
1970/71	SUR	7.2	2.9	3.8	63.3	76.4
	TOTAL	14.1	21.5	55.0	149.1	239.7
	GW	1.7	15.0	46.0	67.8	130.5
1971/72	SUR	1.9	1.6	1.6	32.2	37.3
	TOTAL	3.6	16.6	47.6	100.0	167.8
	GW	0.0	7.3	35.5	38.8	81.6
1972/73	SUR	0.6	0.5	0.5	21.8	23.4
	TOTAL	0.6	7.8	36.0	60.6	105.0
	GW	6.0	16.7	45.3	91.1	159.1
1973/74	SUR	3.7	3.5	5.5	62.7	75.4
	TOTAL	9.7	20.2	50.8	153.8	234.5
Average	GW	9.1	20.3	51.3	74.7	155.4
Average	SUR	5.9	3.4	5.4	46.5	61.2
Average	TOTAL	15.0	23.7	56.7	121.2	216.6

V Mineral waters of the

E. Mazor

See Esp. p. 178
Section 9.

D. Energy balance and evaporation

G. Stanhill & J. Neumann

The radiation balance at the lake's surface and the thermal regime of its waters are the two major elements determining the lake's energy balance and evaporation loss. The different flux components of the energy balance are considered in this chapter using the following balance equations:

$$Q_* = K\downarrow + L\downarrow - L\uparrow - R = LE + S + A + V + M$$

Where: Q_* is the net radiation balance at the water surface
$K\downarrow$ is the global, short-wave radiation from sun and sky
$L\downarrow$ is the atmospheric, long-wave radiation from the sky
$L\uparrow$ is the long-wave radiation emitted by the water surface
R is the short-wave radiation reflected by the water surface
LE is the latent heat of evaporation
S is the change in heat storage in the water
A is the sensible heat exchange with the air
V is the net advective heat exchange via the water fluxes
M is the change in metabolic heat storage

All fluxes are expressed per unit water surface area, positive values representing es to the water surface.

1. Global radiation

In the absence of direct measurements, 25 years of observations of the cloud cover at Degania A were used with the following empirical equation:

$$K\downarrow = K\downarrow\downarrow\,(0.7985 - 0.0311\,C - 0.001\,C^2)$$

where: $K\downarrow$ is mean global radiation in cal cm^2 day^{-1}
$K\downarrow\downarrow$ is mean solar radiation at the top of the atmosphere in the same units
C is mean cloud cover from observations at 08, 14 and 20 hours local time, in tenths of sky covered

The equation was derived from 94 pairs of monthly data obtained prior to 1960 from three stations in unpolluted areas of Israel (Stanhill, 1962). As no difference was found between the relationships at the three stations, despite an altitude difference of more than 700 m, it may be assumed that the relationship will also yield monthly estimates for Lake Kinneret with a mean standard error of 4.4%, as observed at the other three stations.

The annual total insolation calculated, 199.3 Kcal cm^{-2} yr^{-1}, agrees to within of the nearest measured value at Amir, 52 km to the north of the lake in the per Jordan Rift (Stanhill, 1970). The calculated mean monthly values at Lake

Kinneret, listed in Table 21, are somewhat higher in the winter and slightly lower in the summer than those measured at Amir.

2. Reflected short-wave radiation, R

The short-wave radiation reflected from the lake has not been systematically measured. In Table 21, the values presented are calculated with the mean monthly albedo values listed by Kondratyev (1972), appropriate to the latitude and mean cloud cover of the lake. Two days of measurement in the center of the lake during the early summer of 1966 gave a mean albedo of 6.0%, in good agreement with the tabulated values for that time of the year.

3. Long-wave emission, L↑

Emission was calculated as $L\uparrow = \varepsilon\sigma T^4$, where T is the water temperature on the absolute scale. The values used are mean monthly values, each based on an average of six dates of measurement, each of which is based on 15 points of measurement selected to sample the lake surface (Stanhill, 1969). σ is the Stefan–Bolzmann constant and ε is the emissivity of the water surface; the value used for ε was 0.97 (U.S. Geological Survey, 1954).

4. Net radiation balance, Q*

Data from four years of continuous measurement of the radiation balance over the water surface are available from a special station established at Ginnosar as part of the Lake Kinneret Evaporation Project, initiated by Water Planning for Israel Ltd. under the supervision of the late Dr. J. Frenkiel, and now under the supervision of F. Miro. A description of the instrumentation, exposure and calibration procedures can be found in the first report (Miro & Kahanovitz, 1969). The mean monthly values presented in Table 21 are taken from data presented in three progress reports (Miro & Kahanovitz, 1972, 1973, 1974). Fluxes for the individual periods are shown in Fig. 68.

The areal variation in the radiation balance is probably small. Measurements during August 1964 near the shore at Ginnosar and Ein Gev show a 5% difference in the mean daily total (Fig. 69), almost certainly due to the difference in water surface temperature occurring in the summer months (Stanhill, 1969).

5. Long-wave sky radiation, L↓

Values of this flux, calculated as the difference from the radiation balance equation, are listed in Table 21. It may be noted that the values calculated exceed those for the short-wave global radiation received at the water surface.

6. Heat storage change in the water, S

Four series of lake water temperature measurements are available from which this flux may be calculated. The first, presented by Ashbel (1945), is for a 14-month

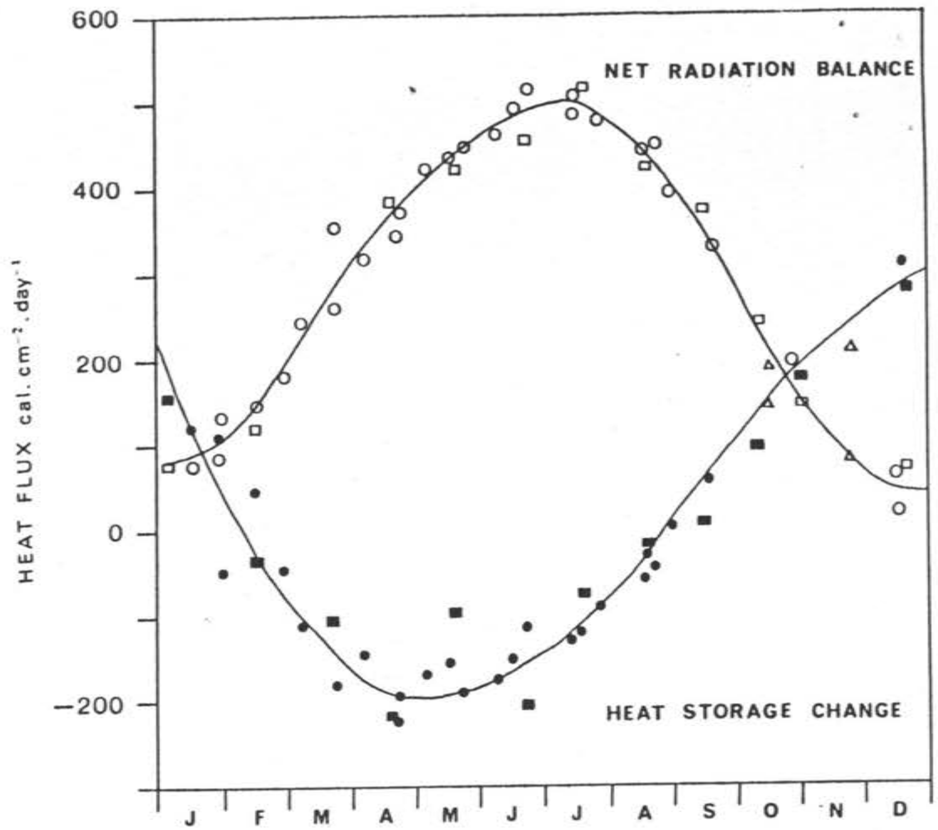

Fig. 68. Measured values of net radiation balance over Lake Kinneret at Ginnosar and heat storage changes in the Lake for corresponding periods. Original data in Miro & Kahanovitz, 1972 and 1973 and Kahanovitz & Karni, 1974.

period between 1943 and 1945 and is published as mean monthly values for 5 depths based on two fixed points of measurement near the shore at Ein Gev and Hamei Tiberias and an unspecified number of points on the lake. The annual heat storage change, i.e. the sum of changes through the calendar year neglecting signs, totalled 67,000 Kcal cm^{-2} yr^{-1}.

Oren (1962) reports the results of a series of measurements taken during 27 months between 1948 and 1951. Twenty sets of measurements were made at four depths along two transects, one from Tiberias to Ein Gev and a second from Ginnosar to El-Kursi. The annual flux totalled 47,433 Kcal cm^{-2} yr^{-1}.

A third series of measurements presented by Stanhill (1969) consists of 72 sets of data collected at ten depths at 15 stations chosen to sample representatively the lake's volume. The fluxes for the two years of measurement, from 1965 to 1967, were 40,000 and 47,240 Kcal cm^{-2} yr^{-1}. The standard deviation of temperature differences were used to calculate the error of the estimates of heat storage change. For the great majority of the periods examined, the coefficient of variation was less than 3%.

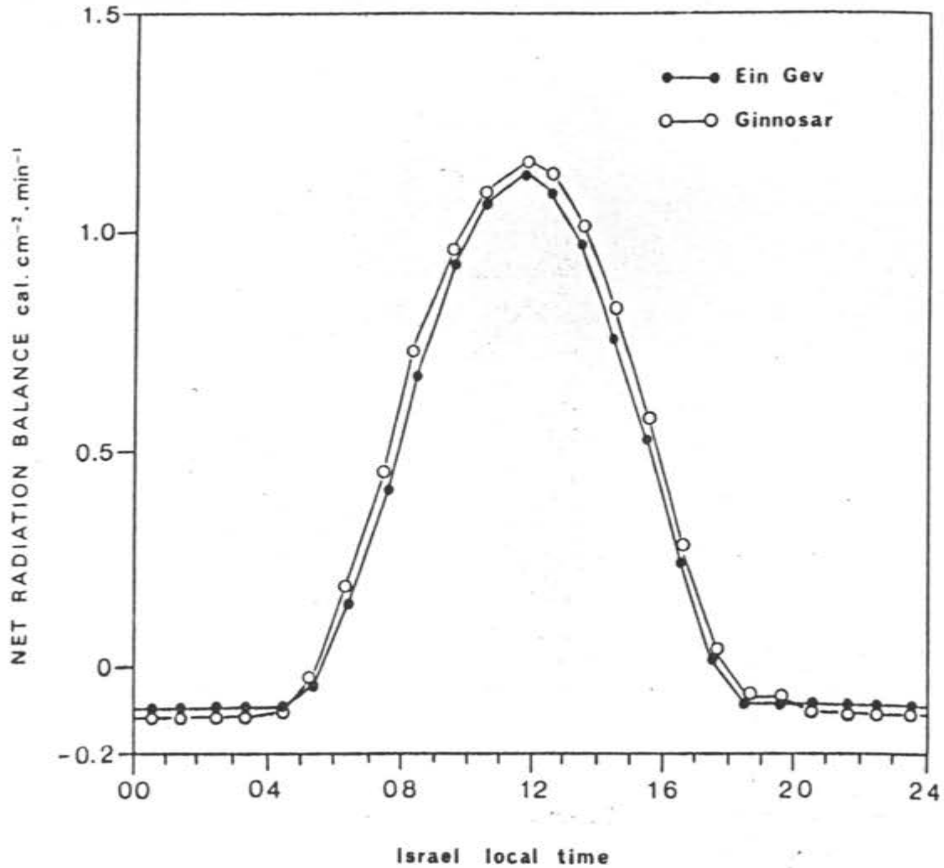

Fig. 69. Measured values of net radiation balance over Lake Kinneret at Ginnosar and Ein Gev, mean monthly values for August 1964.

The heat storage changes shown in Fig. 68 and presented as mean monthly values in Table 21 are based on the 40 sets of measurements taken over the same time periods as the net radiation measurements. During the four-year period, the number of sampling stations varied, starting at 15 and increasing to 45 during the last two years of the period. There were ten depths of measurement. The original data are presented in the same reports referred to for the net radiation data. The annual heat storage fluxes averaged 50,321 Kcal cm^{-2} yr^{-1}.

The degree of annual variation in heat storage can also be seen in Fig. 57, reproduced from Serruya (1975), which shows the isotherms measured in the center of the lake.

7. Advective heat exchange, V

Heat is advected into the lake in the water entering the lake through surface flow, rainfall and subterranean springs, and out of the lake in evaporating water vapor and in the water pumped into the National Water Carrier. Neither the

Table 21. Radiant and heat flux densities at Lake Kinneret. Mean monthly values cal cm^{-2} day^{-1}, negative values represent fluxes from the lake surface.

Flux component		J	F	M	A	M	J	J	A	S	O	N	D	Annual total Kcal cm^{-2} yr^{-1}
Global radiation	$K\downarrow$	320	406	511	622	692	769	757	705	610	482	367	307	199.34
Albedo %		9.6	7.8	6.9	6.0	5.9	5.7	5.7	5.8	6.7	7.0	8.7	10.1	6.8
Reflected short wave	R	−31	−32	−35	−38	−41	−44	−43	−41	−41	−34	−32	−31	−13.49
Emitted long wave	$L\uparrow$	−806	−801	−812	−843	−880	−921	−937	−950	−942	−915	−885	−840	−319.04
Sky radiation	$L\downarrow$	596	572	624	613	660	677	717	715	711	675	658	616	240.22
Net radiation balance	Q_*	79	145	288	354	431	481	494	429	341	208	108	52	107.03
Heat storage change	S	125	−13	−120	−190	−180	−161	−105	−55	48	140	215	292	+251.6 / −251.6
Net heat flux	Q_*-S-V-M	200	128	164	160	248	317	386	371	386	345	319	340	105.71
Evaporation, mm day^{-1}		2.9	2.9	2.7	3.9	4.4	5.0	6.8	6.8	6.7	5.3	4.0	4.8	1.716
Latent heat	LE	−171	−171	−159	−230	−260	−295	−401	−401	−336	−313	−236	−283	−101.13
Sensible heat exchange	A	−29	43	−5	70	12	−22	15	30	−50	−32	−83	−57	−4.58

temperature nor the volume of the various terms are precisely known; an estimate can, however, be made based on the estimates of the lake's water balance (Negev & Keller, 1964), measurements of water temperature in the Jordan and the assumption that the water pumped from the lake is at surface temperature. The annual totals of heat advected into the lake are 4.72 Kcal cm^{-2} lake surface in Jordan inflow, 3.05 Kcal cm^{-2} via the subterranean hot springs and 0.41 Kcal cm^{-2} in rainfall. The heat advected from the lake in evaporation was calculated to be 4.20 Kcal cm^{-2} and in the pumped water, 5.00 Kcal cm^{-2}. Thus the net advective heat exchange is 1.00 Kcal cm^{-2} yr^{-1} from the lake.

8. Metabolic heat, M

The solar radiation fixed metabolically by algal photosynthesis (primary production) forms a very small fraction of the incident global radiation, less than 0.2%, but is of great significance for the quality of the lake's water and also provides the food base for the 1,672 tons of fish harvested from the lake each year. Average values of primary production (Lake Kinneret Report, 1974), with the heat of combustion of algae (5.5 Kcal g^{-1}), gave a total annual net metabolic heat fixation of 0.32 Kcal cm^{-2} lake surface, with a maximum flux of 1.4 cal cm^{-2} day^{-1} in April.

9. Latent heat of evaporation, LE

Approximately the same volume of water leaves the lake in water vapour as is pumped from the lake into the National Water Carrier. No doubt because of its significance in the national water balance, the size of this flux has been the subject of numerous investigations using a variety of methods. The results have been summarized in Table 22 in the form of the various estimates of annual evaporation. The average of the six estimates is 175 cm yr^{-1}, equivalent to a latent heat flux of 103.25 Kcal cm^{-2} yr^{-1}. The 7% variation between the estimates includes the various errors of measurement and estimation involved in each method plus the year-to-year variation introduced by considering different periods. Data given in the references numbered 2, 4, 5 and 6 in Table 22 suggest that this year-to-year variation can be considerable, as do the values of year-to-year variation in the size of the heat storage term previously presented.

Estimates of monthly evaporation obtained by the different investigations show much more variation than do the annual totals. The first energy balance estimate, based on Ashbel's early heat storage measurements (Neumann, 1953), showed an autumn maximum and late spring minimum, whereas all other estimates indicate midsummer maxima and early winter minima. Estimates by the combined water balance and mass-transfer method (Stanhill, 1969) differed in that the midsummer maximum (353 mm in July) was almost 50% more than the amount estimated in the other three investigations (nos. 2, 3 and 6 in Table 22). These three estimates, all based on the more recent series of heat storage measurements, show a fair agreement on monthly values.

All three energy balance estimates contain a systematic error by ignoring the unmeasurable but marked diurnal variation in the heat storage term. The most re-

Table 22. Estimates of annual Evaporation from Lake Kinneret

Method of estimation	Annual evaporation, cm	Reference
1. Energy Balance Lakeside climatological data Ashbel's thermal survey data	163	Neumann 1953
2. Energy Balance Lakeside climatological data Oren's thermal survey data	178	Neumann 1961
3. Combined Energy Balance and Mass Transfer Lakeside climatological data Oren's thermal survey data	171	Stanhill 1963
4. Combined Water Balance and Mass Transfer Lakeside climatological data Lake water balance data	184	Stanhill 1969
5. Evaporation Pan Class A evaporation pan and reduction constant, mean of five lakeside stations for three years	167	Bezer 1970
6. Energy Balance Micrometerorological measurements at Ginnosar with concurrent thermal surveys, 4 year mean	187	Miro & Kahanovitz, 1969–1973 Kahanovitz & Karni, 1974

cent estimate (no. 6, Table 22) is the most precise in that micrometeorological measurements made at Ginnosar over the water surface were used to derive hourly values of Bowen's ratio needed to partition the available energy between latent and sensible heat fluxes. In contrast, the earlier estimates used mean monthly climatological values from lakeside stations and thermal survey data for the same purpose.

Unfortunately, the greater precision of the Ginnosar measurements introduces the problem of areal variation in evaporation over the lake, the Ginnosar data representing predominantly windward shore conditions. The marked increase in vapour pressure at the eastern shore, in particular during midday in the summer months, has already been referred to in a previous chapter. Further evidence for the areal differences in atmospheric evaporation potential can be found in the values of Class A evaporation measured at the different lakeside stations (Bezer, 1970). The annual value measured at Migdal, 3 km south of Ginnosar, was 18% more than that measured at Kafer Aaqeb, almost on the same latitude on the downwind, eastern bank, and 13% more than that measured at Ha'on, on the southern section of the eastern shore.

Clearly, accurate estimates of the seasonal variation in evaporation from the lake require detailed information on a diurnal basis of the areal variation in the factors controlling this flux. In the absence of such information, and because, for the previously stated reasons, evaporation at Ginnosar is believed to be higher than over the lake as a whole, the lower, earlier estimates of evaporation based on

Table 23. A Comparison of the Annual Radiation and Energy balance in three Mid-latitude Lakes

		Mean annual values in cal cm^{-2} day^{-1} Negative values represent fluxes from surface		
Lake		Kinneret	Mead*	Hefner*
Coordinates		33°N, 35°E	36°N, 114°W	35°N, 97°W
Altitude		−210 m	400 m	375 m
Flux components				
Global radiation	$K_\downarrow$	546	506	420
Reflected short wave	R	−37	−37	−26
Emitted long wave	$L_\uparrow$	−874	−842	−781
Sky radiation	$L_\downarrow$	658	672	619
Net radiation balance	Q_*	293	299	232
Advective	V	−3	52	4
Latent heat	LE	−277	−344	−222
Sensible heat	A	−13	−5	8
Evaporation mm day^{-1}		4.7	5.8	3.8

* Data from Harbeck *et al.* (1958).

lakeside climatological data (Stanhill, 1963) have been used for the monthly values given in Table 21.

10. Sensible heat exchange with the air, A

There is a small sensible heat flux from the lake to the air totalling 4.58 Kcal cm^{-2} yr^{-1}. The monthly values of this flux given in Table 21 should be regarded as an approximate indication only, being calculated by difference and incorporating all the uncertainties in the heat balance. The values suggest that the lake warms the passing air from late summer to early winter, with a marked cooling effect confined to late spring. This pattern is consistent with the previously-noted variation in air temperature around the lakeside, but it is believed that other factors, including the topographical influences discussed elsewhere, and the much greater sensible heat exchange from the land surfaces during the summer months, are probably of greater significance.

11. Conclusions

The size of the major terms in the annual heat balance of Lake Kinneret are by now well established. A comparison of these data with that of other lakes shows that the annual flux of radiant heat and the changes in its heat storage are, per unit area, among the highest recorded (Table 23). The seasonal variation of the radiation balance components and of the changes in heat storage are also satisfactorily established, but the accuracy of the latent and sensible heat fluxes is less accurately known. To obtain this information, a detailed study of the areal and diurnal variation in these heat fluxes is required, information which is also needed to model the circulation of heat, water and momentum in the lake and its surroundings.

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The geological history of Israel was determined by the position of the area between the Precambrian Arabo–Nubian crystalline massif in the south and the pre-Mediterranean Sea in the north and west.

The Precambrian massif outcrops in the region of Eilat. It is composed of a thick sedimentary formation metamorphized into gneiss and micaschists and injected with magmatic rocks. The general tendency to uplift of the massif which prevailed in Paleozoic times caused its erosion and the accumulation of continental series, the Nubian Rocks, in the area extending north of the massif.

The Mesozoic Seas transgressed over the continental series. In the Triassic and Jurassic periods, the coastline was located in the present northern Negev where shallow marine rocks of this period outcrop. Jurassic rocks of a much deeper facies constitute the core of Mount Hermon in the northern part of the Lake Kinneret watershed. The transgression which took place from early Cretaceous until Middle Eocene covered the entire Middle East.

The tectonic movements which occurred in the Eocene period brought to an end the main marine phase in Israel. The Neogene transgressions were much more limited in space and duration and were separated by freshwater episodes. After the last Pliocene regression, lakes became a permanent feature, especially in the Rift Valley, as will be described in the following sections. We see that although rocks belonging to the most ancient geological series of the Earth are found in Israel, the stratigraphy of the Lake Kinneret area concerns relatively recent formations.

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Geology

The watershed of Lake Kinneret can be divided into three areas: the northern area, mainly formed by the core of Jurassic limestone of Mount Hermon and the Cretaceous–Eocene series of Mount Naphtali; the western area, composed of Cretaceous and Eocene rocks; and the eastern area, almost completely covered with basalts (Fig. 3).

In the following, we have deliberately limited our stratigraphic description to the formations which outcrop in the vicinity of the lake (western and eastern areas (Figs. 4 and 5).

1. Upper Cenoman (Ce_3): Sakhnin formation

Grey, karstic dolomite, 200 m thick.

2. Turon (t): Bina formation

Detrital limestone, 50–80 m thick; facies from finely crystallized to lithographic, locally dolomitic. The limestone is well stratified; its high density and hardness make it valuable to the marble industry.

3. Senon (S): Mount Scopus formation

Marl, chalk, shales and bituminous shales with local horizons of flint. This group may reach a thickness of 290 m and is found in the Sfad and Ein Zeitim areas.

4. Lower–Middle Eocene (e):

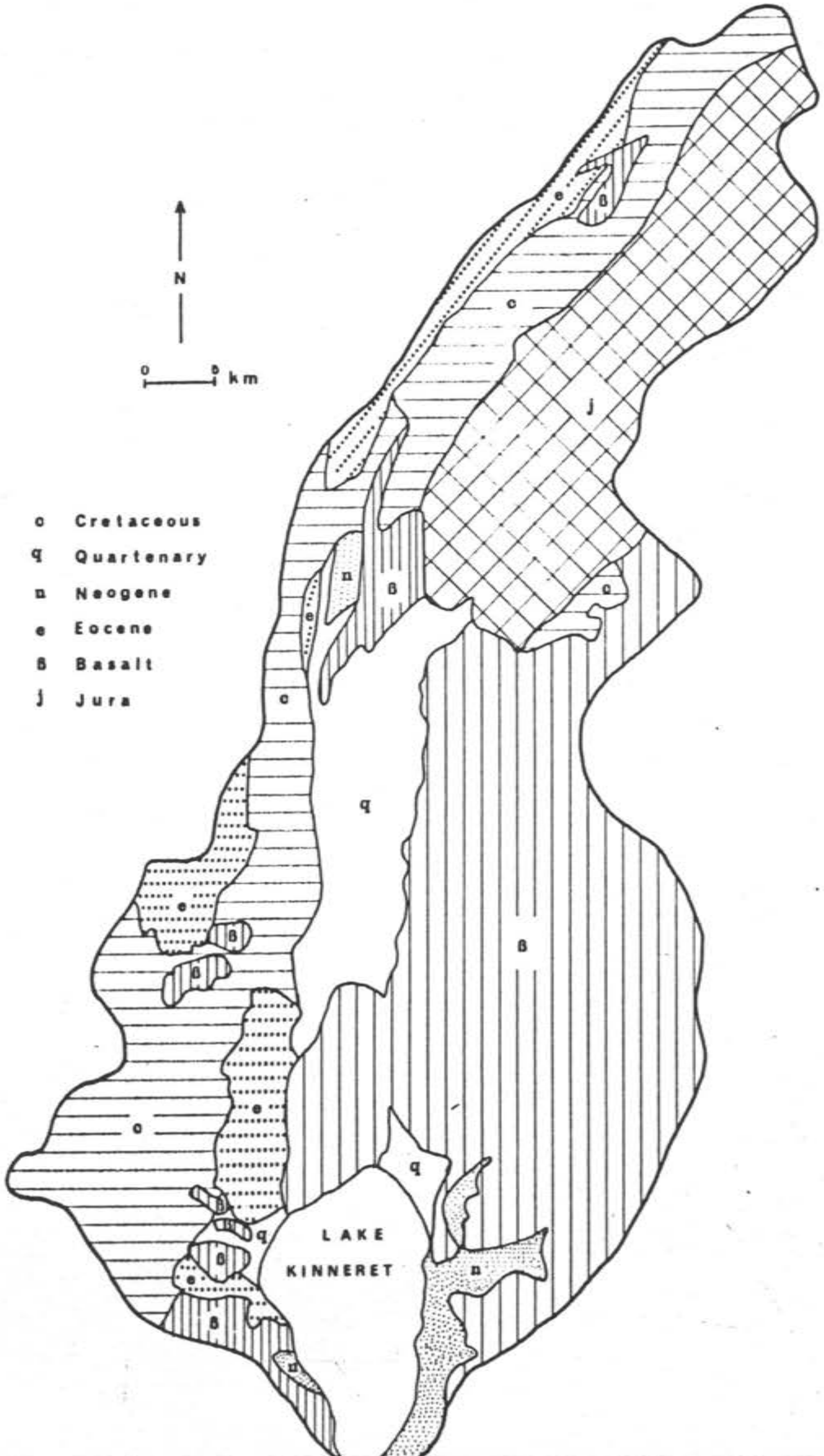
a. Bar Kochba formation

Limestone with flint horizons, especially abundant in the lower part of the formation. The limestone is finely crystallized, rich in nummulites and may be karstic. It reaches a thickness of 400 m and outcrops in the area below Sfad and in the Arbel and Cana'an mountains.

These four formations outcrop only on the western side of the lake.

b. Zora formation

Outcrops on the eastern side of the lake and is the equivalent of the Bar Kochba formation. It is divided into the lower Adulam unit (Zad), composed of chalky limestone, well stratified and including flint horizons, and the upper Maresha unit (Zma), composed of unbedded marl and chalk. The Zora formation reaches a thickness of 400 m.



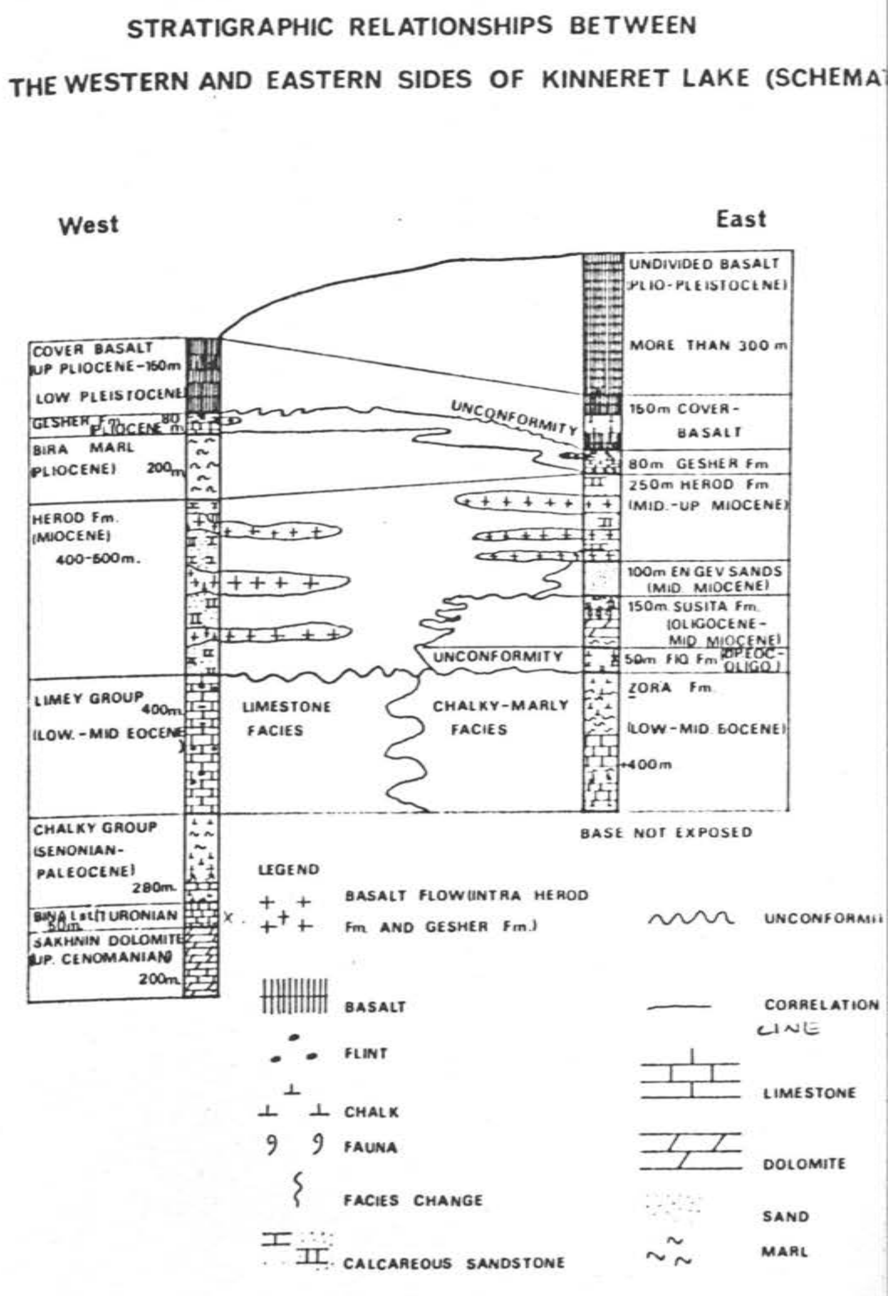


Fig. 4. Stratigraphic succession on the western and eastern sides of the lake (see text).

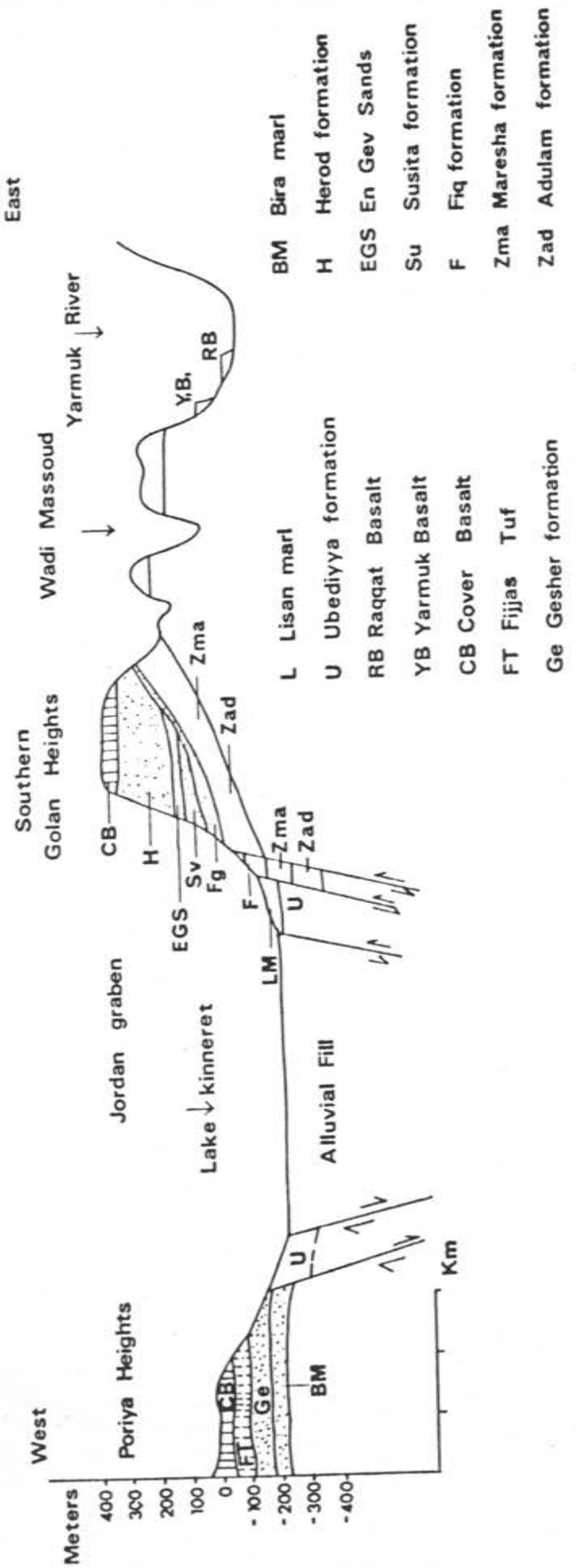


Fig. 5. Cross-section of the Lake Kinneret area.

5. Upper Eocene–Oligocene (d): Fiq formation

Shales, detrital limestone, marls and glauconitic limestone showing traces of erosion. This formation is 50 m thick and rests in unconformity on the Zora beds; it is known only on the eastern side of the lake.

6. Miocene (m):

a. Susita formation (*Su*) (*Oligocene–Middle Miocene*)

Sandy dolomite, detrital limestone, lumashels, quartzite and shales which were deposited by a marine transgression intruding from the Persian Gulf into the Jordan depression. This formation, which reaches 150 m, has been found also in South Syria but is not known in areas west of the Jordan depression.

b. Ein Gev formation (E.G.S.) (Middle Miocene)

Yellow quartz sand with a few beds of sandstone which were deposited during rainy periods in limited areas of active erosion and may reach 90 m. The Ein Gev sands are known in the southeastern bank of the lake and rest in unconformity on the Susita formation.

c. Horodus formation (*H*) (*Middle–Upper Miocene*)

Sandstone, conglomerates, limestone and reddish, yellow, green and white clays. This formation constitutes the cliffs on both sides of the southern part of the lake. The environment of deposition was fluvio lacustrine. On the eastern side of the lake, on the Golan Heights, the Horodus formation is 250 m thick. On the western side, in the Poriya area, it exceeds 400 m. Three to four basalt flows (lower basalt) are intercalated in the sediments of the Horodus formation, which rests in unconformity on older layers.

7. Pliocene–Pleistocene (p–q):

a. Bira marl formation (*BM*)

The marls and gypsum of this formation give a landscape of smooth hills. These sediments were deposited in lagoons or shallow seas which resulted from a transgression of the Mediterranean Sea through the Qishon Bay and the Jezreel Valley, and supplied marine fossils (Ostrea). This formation is known in the area southwest of the lake. On the eastern side of the lake, only relicts of Ostrea lumashels are known.

b. Gesher formation (*ge*)

This formation consists of oolithic limestone and marls with freshwater fauna

(Ostracoda, Melanopsis and Unio). These sediments were deposited in lakes on both sides of the present lake and reach 80 m in thickness.

c. Fijjas tuff (FT)

This formation corresponds to the stratified tuff outcropping between Poriya and the lake. Its thickness reaches 50–70 m.

d. Cover basalt (CB) (Upper Pliocene–Lower Pleistocene)

These basalts, which rest in unconformity on previous formations, cover the Golan Heights and the Poriya area. They reach a thickness of 200 m near Yavniel but are only a few meters thick on the hills near Huqqoq.

e. Young basalt (YB) (Middle and Upper Pleistocene)

These younger basalts are a few hundred meters thick and are found in the Yarmouk Valley and in the central and northern part of the Golan Heights.

f. Ubediyya formation (Ub) (Middle Pleistocene)

This formation, composed of layers of chalk and marls containing freshwater fauna, is restricted to the Jordan depression, where it reaches 200 m. This is the youngest layer which has been influenced by the tectonic activity of the graben.

g. Lisan marls (LM) (Upper Pleistocene: 70,000 to 20,000 years before present)

The Lisan beds are composed of varved marls and clays. The layers are horizontal and lay in unconformity on the Ubediyya formation. The Lisan formation is restricted to the Jordan depression; its northern limit is the Tiberias area.

8. Alluvium (from Pleistocene to recent) (see Section D)

Tectonics

More than a century of controversy has accompanied the tectonical interp of the Jordan–Dead Sea area. In 1869, Lartet interpreted the Jordan Val sinistral wrench, an idea which was developed later by Dubertret (19 Freund (1968, 1970, 1973). Conversely, Picard (1943, 1970) sees in the Valley a tensional rift valley. It is clear that the paleogeography of the area different in both conceptions.

Table 6. Key Stations

Station	Co-ordinates Long. E	Lat. N	Israel grid		Elev. m	No. of years during period 1931–1960
Galilee						
Kefar Gil'adi	35° 34′	33° 15′	204	294	340	30
Kefar Hananya	35° 25′	32° 56′	189	260	410	30
Nazareth	35° 18′	32° 43′	178	235	445	30
Tavor, Agr. School	35° 24′	32° 42′	188	234	145	25
Kefar Tavor	35° 25′	32° 41′	189	232	120	25
Golan						
Kuneitra	35° 49′	33° 07′	227	281	940	•
Jordan Valley						
Ayyelet HaShahar	35° 34′	33° 01′	204	269	175	30
Tiberias	35° 32′	32° 48′	200	244	−110	30
Mizpa	35° 30′	32° 47′	198	243	75	30
Deganya	35° 34′	32° 43′	204	235	−200	30

• Six years beginning in 1967/68.

3. Annual rain amount

Although this area is relatively small (2,760 km²), its diversified topography divides it into three main climatological units: Galilee Hills, Jordan Valley and Golan Heights–Mount Hermon.

Generally speaking, there are similar rain patterns in the Galilee, Golan Heights and Mount Hermon. However, in the Golan, because of its more homogeneous structure, the areal variability is smaller. The areal rain distribution is less variable in the Jordan Valley than in the other subregions except for short periods (less than one day), because of cloudburst phenomena.

Most of the rainfall differences among the subregions are due to topography, as indicated by the increases of amount of precipitation with altitude (Fig. 25).

Rain in the Kinneret area is mainly of cyclonic origin, but local conditions may produce local rain phenomena. In the mountainous part of the watershed, rainfall is mostly of cyclonic–orographic nature, whereas it is partly of convective origin in the Jordan Valley, which explains the variation of rain intensities between both areas.

a. Average (median) annual rainfall

Although it is recommended to base rainfall analysis on accumulative frequency distributions rather than on averages and standard deviations, we could use these latter parameters since, in the case of the Kinneret area, the deviation of the averages from the medians is small (Table 7). The reason is that the distribution of annual rainfall is well represented, even for extreme values, by the statistical parameters based on normal distribution. Thus, $\bar{P} \pm 1.28\sigma$ ($\bar{P}$ = average annual rainfall and σ = standard deviation) is 239–529 mm at Deganya while equivalent

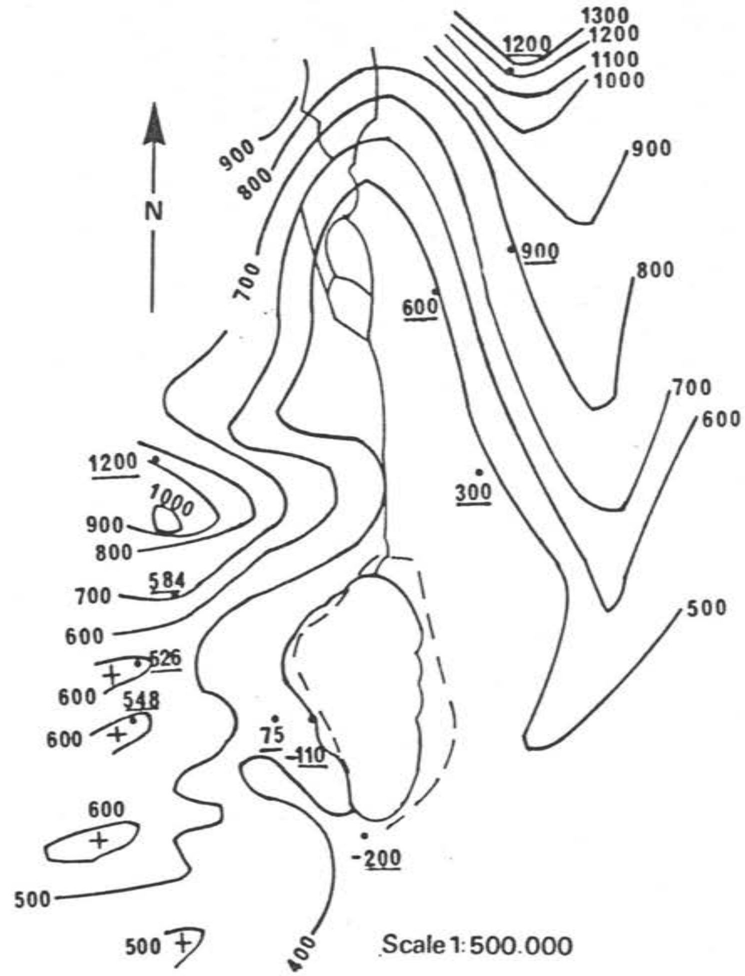


Fig. 25. Average annual rainfall (1931–1960). The underlined numbers correspond to the yearly amount of precipitation at the base stations. All results in mm per year.

percentage centered on the median (Med ± 40%) is 241–529 mm, and $\bar{P} \pm 1.65\sigma$ is 198–570 mm while the equivalent percentile interval (Med ± 45%) is 216–614 mm.

The variations of rainfall due to topography are shown in Fig. 25. In the Galilee, the annual rainfall ranges from 500 to 1,000 mm (rainfall in the mountainous Upper Galilee being usually above 800 mm). It varies from 400 to 700 mm in the Lower Golan and from 700 to 1,000 mm in the higher part of the plateau; reaching 1,000 to 1,300 mm in the Hermon area. The northern part of the Jordan Valley receives 1,000 mm; the decrease in altitude from north to south, superimposed on the general decrease of rainfall from north to south, explains the rapid drop of rainfall along the valley down to 350–400 mm in the southern part of lake Kinneret.

mostly for JK | Fm Serruya. Lake Kinneret

Water Consumption in Ha Galil Region

Serruya Book:

Lake's water reserve = 4,000 million cubic meters

Intro: 2. Role of lake in water supply of Israel :

p3: Interannual average water income of 650 million cubic m³ out of which 300-400 mill cub. met. are pumped through Nat'l Water Carrier

Lake supplies : from 1/5 to 1/4 total freshwater rqmts of Israel

* Most important role in ~~the~~ the water supply is that of Regulation Reservoir

— capacity for storage of winter flood waters of Jordan R and water fm rainy yrs to dry yrs.

using lake for reinjection in coastal aquifer is possib.

Chp 1 - Geograph:

p7 ff : Drainage Area of the Lake descr.
(∃ large range of altitudes: + 2,814 m to -210 m)

Hermon mts. in North ((Highest pts of this area) culmin. @ 2,814 m.)
Golan Heights (300-400 m in East. Plateau / 100-200 m in west. plat.)
Naftali mts - reaching 900 m in west, 500-600 m in central pt, 1200 m in south. pt (consist. of Sfad & Meron mts.)

Northern pt of Jordan Valley — 175 km² of Hula plain — @ altitude of 70 m

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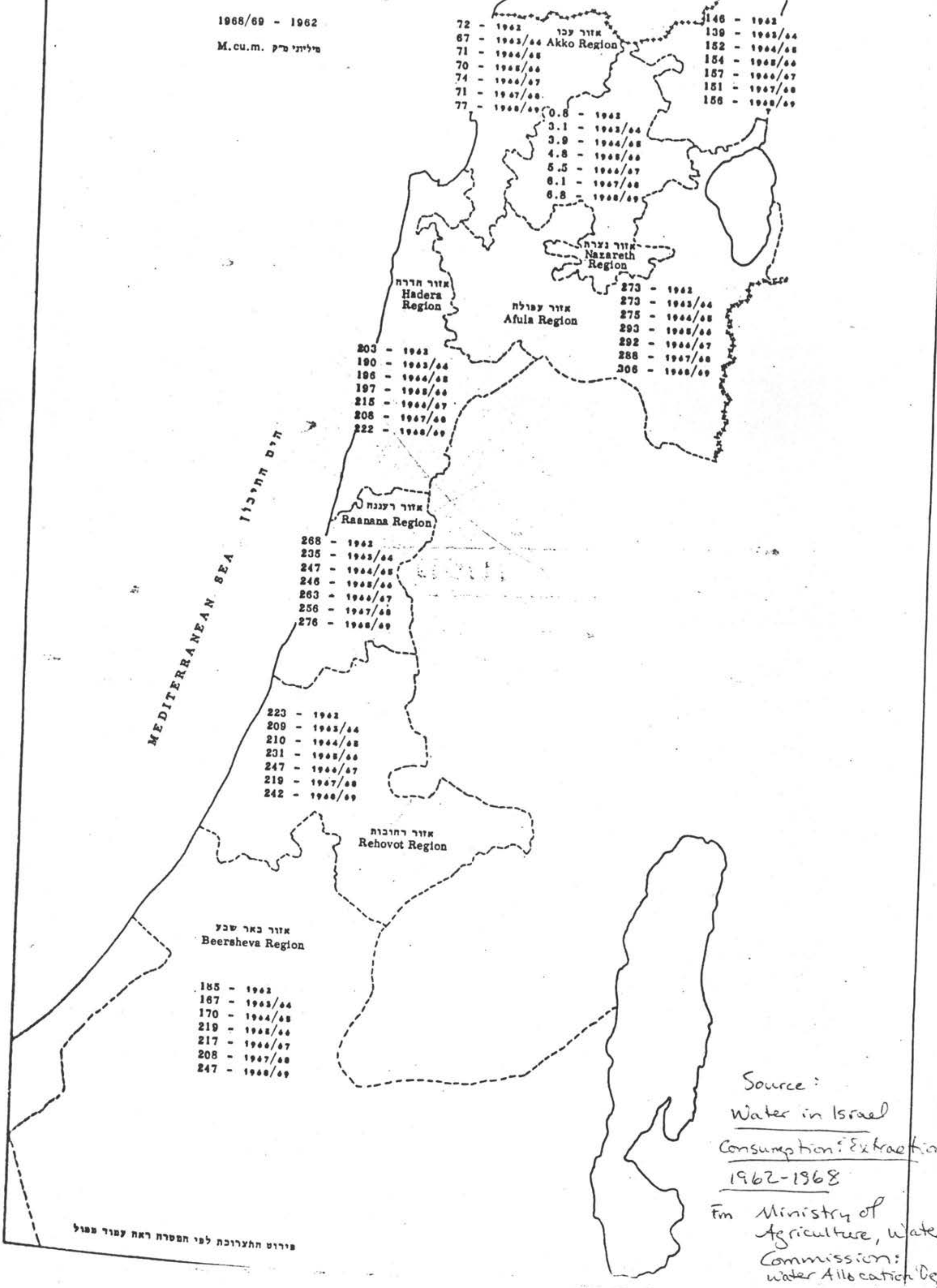
Also chpt. III → Meteorology
Chp IV → watershed, yield of superficial Waters — wadis, Jordan, springs

תצרוכת המים הכללית, לפי האזור החקלאי

Total water consumption by agricultural region

1968/69 - 1962

M.cu.m. מיליוני מ״ק



פירוט התצרוכה לפי המטרה ראה עמוד מפול

Source:
Water in Israel
Consumption: Extraction
1962-1968
Fm Ministry of Agriculture, Water Commission: Water Allocation Dep

Area & Elevation Information

★ World Book Encyclopedia, 1985

14 mi long (23 km)
8 mi wide at broadest pt. (13 km)
AREA: 64 sq. mi (166 km^2)
ELEVATION: 688 ft (210 m) Below Sea Level
DEEPEST PT: 145 ft (44 m)

★ Statesmen Yearbook
World Gazetteer, 1985

696 ft Below Sea Level

★ Webster's Geographical Dict. (1980)

13 mi long
7½ mi wide
696 ft. below Sea Level
75% inflow from Jordan River

★ Talmi, Menahem. Lake Kinneret, Sea of Galilee.
(Transl. from Hebrew by Dr. S. Applebaum) Tel Aviv:
E. Lewin-Epstein Ltd, 1965

LC#: DS 110
.G2 T313

212 m. Below Sea Level
120 sq km. spread
51 km circumference

p. 59 → greatest width of lake attained directly opposite Gennosar (near Tabgha)
7½ miles from settlement between Melchett Villa to eastern shore near Kursei

★ Geography of Israel by Efraim Orni, Elisha Efrat
Jerusalem: Israel Universities Press, 1976.

LC# - DS 107
.4
.O6813
1971

Area = 165 km^2 (64 sq mi)
Capacity = ≃3 billion m^3 water estimate

Evaporation

* Atlas Yisrael   Tel Aviv: Agaf ha-medidot, Yisrael: Karta, Yerushalayim, 1985

LC# G2235 .I79 1985

|| Evaporation from Open Water Surface
Annual Average 140-160 cm.
July Average 20-22 cm
(further beyond north shore 22-24 cm)

From: Section 12: Rainfall, Humidity, Evaporation, Climatic Regions (Maps)

* Atlas of Israel of Survey of Israel. Ministry of Labour, Jerusalem & Elsevier Publish. Co., Amsterdam 1970

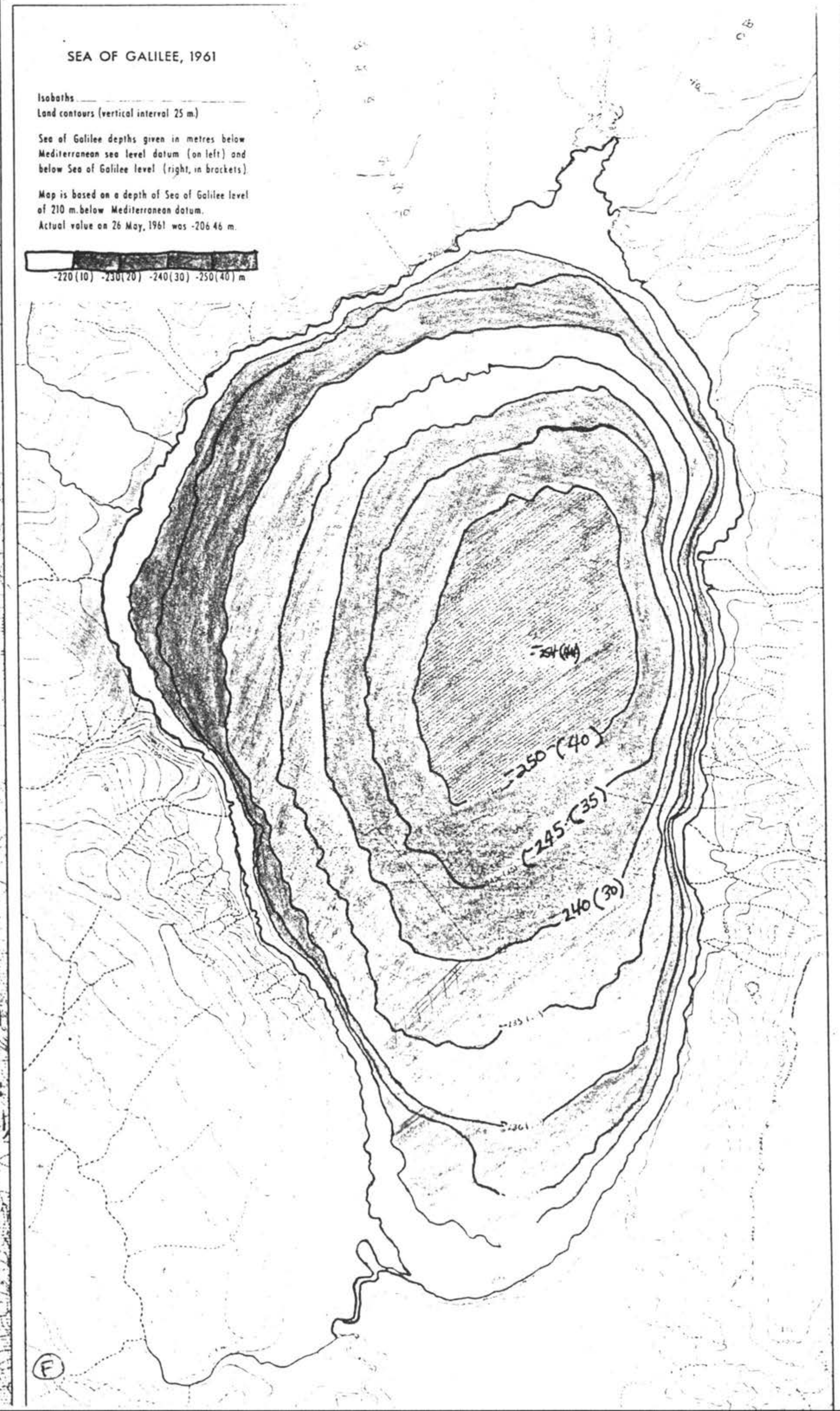
|| Evaporation from an open water surface -
January Average - under 5 cm

from Section: Maps of All of Israel [not a specific map of Lake Tiberias]

* Measure of Potential Evapotranspiration measured using US Weather Bureau Class A evaporation pan

SOURCE: Map (F) of V/2 Hydrolog Sectio in Atlas of Israel, 1970

see Back for furthe info. →



Atlas of Israel

1970

Published by:

Survey of Israel, Ministry of Labour, Jerusalem

&

Elsevier Publ. Co, Amsterdam

LC#:

G2235 .I82 1970

1 :100,00

Evaporation Info fm: Neumann, J: "Energy Balance and Evaporation fm Sweet-Water Lakes of Jordan Rift" Bull Res. Counc. Israel 2, 1953 pp 337-357

ALSO: Oren, O.H. "Physical and Chemical Characteristics of Lake Tiberias" Bull Res. Counc. Isr, 11 G, 1962, pp 1-33

Info fm. Explan. in Section

Mean Level of Sea is ≃ 210 m below Mean Sea Level of Medit.

At this level, the lake covers an area of 1168.8 sq. km,

Length fm N-S is 21 km

Maximum width is 12 km

Maximum depth is 44 m.

Volume of Water contained is 4,236 million cu. m (4.236 cu. km)

- The addition of 1.69 million cu. m. of water at level of −210 m raises level of lake by 1 cm

Level of Sea controlled by Israel Electric Corp's sluice gates near Deganya, @ southern end of Lake — has been regularly measured since 1925

Extreme values recorded up to time of writing (69)
- max. level −208.30 m (Jan, 69)
- min. level −212.38 m (Dec, 34)

Fluctuations of water level caused by variations of inflow and outflow as well as by loss due to evapor.
ALSO caused by cyclic variations and storms

Water balance of lake determined by → inflow fm Jordan R, wadis,

H_2O Entering: saline & fresh springs ~~emerging along banks~~ [which since 65, collected into diversion channel ceasing to drain into lake], springs issuing at bottom of lake & precip.

H_2O Leaving: • Evap fm. lake surface → mean loss estimated to be 162 cm per annum (≃ 270 million cu. metres, assuming water level remains stration @ −210
• Nat. Water Carrier
• Deganya sluices