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WATER BALANCE OF THE BLACK SEA AND FLOW THROUGH THE BOSPORUS

BY

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Oceanographers are interested in rivers for they discharge large quantities of fresh water into the salty sea-water; they carry great supplies of organic and particulate matter into the sea, and they play an important role in changing the coastal features. The fresh water added to the sea raises its level; seasonal changes in the amounts of discharge cause similar fluctuations of the sea level. The particulate and organic matter carried by the rivers are one of the great sources of nutrient and trace metals necessary for the living organisms in the sea.

In this paper we will discuss the total amount of continental run-off of the Black Sea basin and the influence it has on the flow through the Bosphorus.

RIVER DISCHARGE TO THE BLACK SEA

Table I shows the average monthly discharge values ($m^3/sec.$) of the major rivers emptying into the Black Sea. The values for these major Turkish rivers, Sakarya, Kızılırmak and Yeşilirmak are given monthly; other Turkish rivers were combined as miscellaneous. The values for the Turkish rivers are from the Turkish Elektrik İşleri Etüd İdaresi¹, and for the other foreign rivers from Parde². The writer was unable to obtain monthly discharge values for the Danube.

The seventy-five year average annual run-off value for the Danube at Orsova is given by Berenbeym³ as $175 km^3$ year. According to the same author this is

only 84 percent of the total run-off for the Danube, therefore the actual total would be 206 km³/year. The total continental discharge to the Black Sea is calculated to be 370 km³/year which would correspond to a rise in sea level of 88 cm/year. (The Black Sea total area is approximately 420,000 km²).

Figure 1 shows the annual variation of the mean monthly discharges into the Black Sea. The figures for the Danube are not included in this graph. According to Figure 1 the maximum discharge to the Black Sea is during the April-May period.

TABLE I
Rivers Discharges to the Black Sea* m³/sec.
Months

<i>Rivers</i>	1	2	3	4	5	6	7	8	9	10	11	12	Total (km ³ /year)
Sakarya	514	704	582	444	440	321	140	81	101	93	87	256	9.9
Kızılırmak	195	328	275	310	352	319	149	67	77	101	60	141	6.2
Yeşilirmak	172	259	259	478	422	313	106	45	48	25	31	70	5.9
Miscellaneous	353	394	464	593	615	244	218	138	117	126	111	274	10.4
Danube												206.0
Dnieper	711	804	1506	3816	5225	2120	1045	844	735	735	865	784	50.5
Don	247	296	1051	3544	1754	375	255	202	181	186	195	190	22.2
Rion	305	373	427	624	647	624	513	274	279	252	274	358	13.0
Dniester	167	216	491	591	422	374	398	326	271	245	248	223	10.3
Kuban	233	209	333	430	650	743	677	435	273	231	225	260	12.3
Others												22.6
Total												370 km ³ / year

* Values for the Turkish rivers from E.I.E. Hidrografi Yayini II, for the other rivers see Parde.

The Danube alone accounts for nearly 55 percent of the total continental run-off to the Black Sea. Year to year variations in the discharge values for the Danube would greatly change the total run-off figure of approximately 370 km³/year.

Figure 2 shows fluctuations in the annual mean run-off values of the Danube. The figure of 175 km³/year given by Berenbeym is the average of seventy-five years run-off for the Danube.

WATER BUDGET OF THE BLACK SEA

In the Black Sea, precipitation and run-off exceed evaporation. Since the sea level is in an equilibrium state, the amount of water equal to the amount added by excess run-off and precipitation over evaporation must flow out of the basin. This takes place through the only leak in the system, that is through the Bosphorus where surface layers carry the diluted Black Sea water to the Sea of Marmara. Eventually this flow reaches the Aegean Sea through the Dardanelles.

In such a system, where lighter water in the upper layer flows out of the basin, there must be a flow in the lower layer in the opposite direction. Because of the excess fresh water in the Black Sea basin the outflow in the upper layer through the Bosphorus is larger than the inflow through the lower layer. Therefore there is a net outflow.

If we write an equation for the above:

$$\text{Evaporation} + \text{Net outflow} = \text{Run-off} + \text{Precipitation}$$

Evaporation measurement at sea is a very difficult task, all values reported are calculated from the usual equations. Koclikov ⁴ gives 60 cm/year. Neuman and Rosenan ⁵ 110 cm/year and Sverdrup ⁶ estimates 84 cm/year. Here we will use Sverdrup's estimate of 84 cm. Annual average precipitation is 58 cm. (Neuman) and annual run-off as calculated above is 88 cm.

Therefore,

$$\begin{aligned} \text{New outflow} &= 88 + 58 - 84 \\ &= 62 \text{ cm/year} \\ &= 260 \text{ km}^3/\text{year} \text{ or } 8,300 \text{ m}^3/\text{sec}. \end{aligned}$$

If we take the Baltalimani-Çubuklu cross section in the Bosphorus where the width is 850 meters and the average thickness of the upper layer is about 30 meters, a net outflow of 8,300 m³/sec. would mean a current of:

$$\frac{8300}{850 \times 30} = 0.34 \text{ m/sec. or } 0.7 \text{ knots.}$$

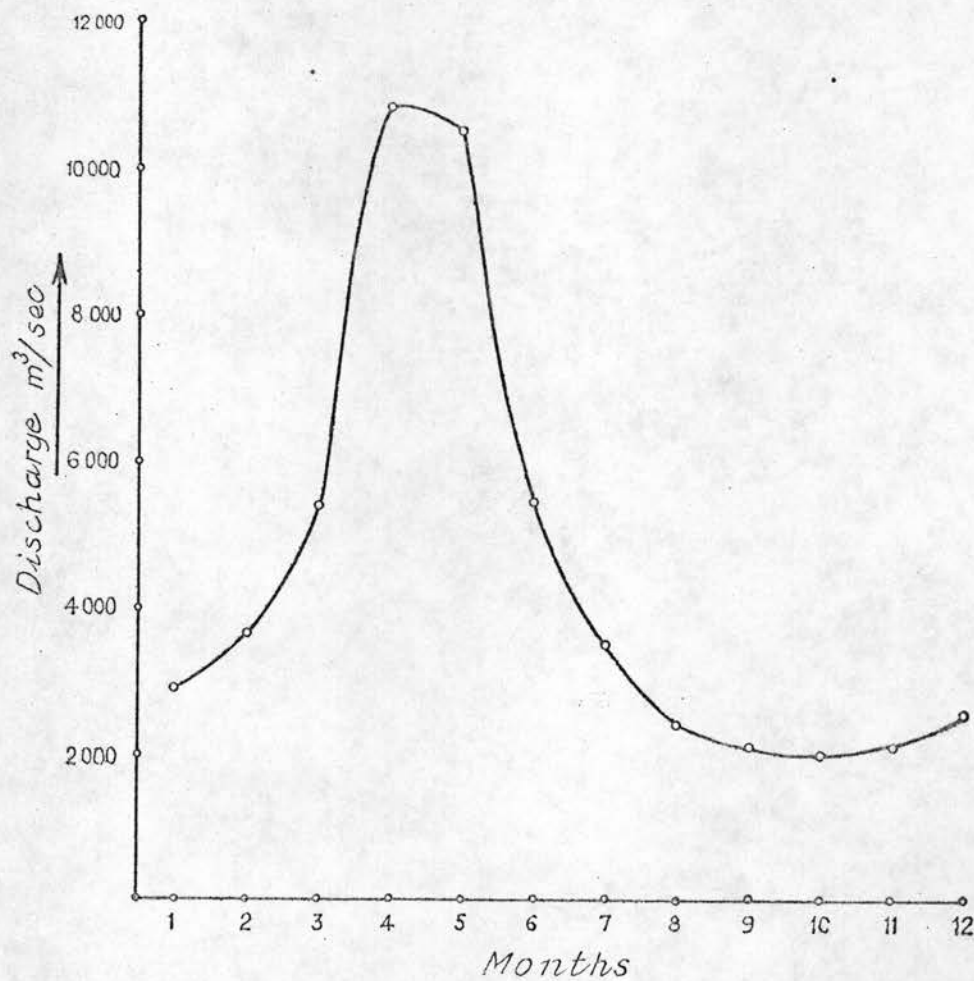


FIGURE 1 - Mean monthly discharge of the Black Sea rivers (except the Danube)

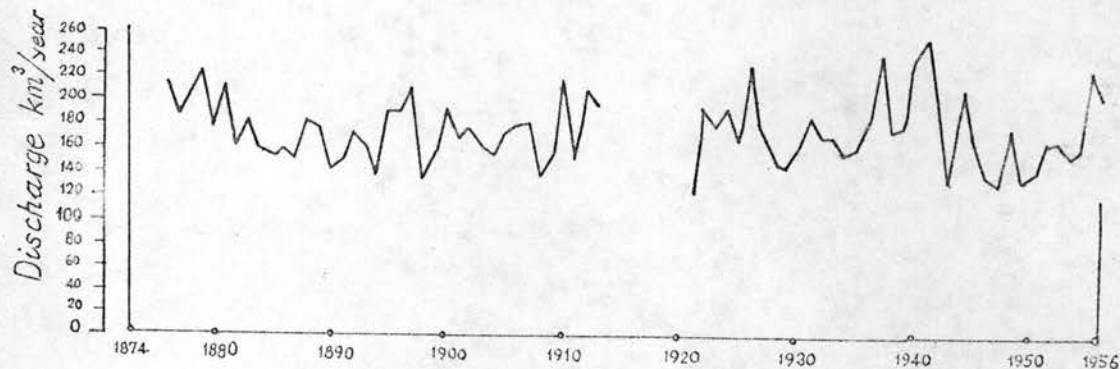


FIGURE 2 - The annual Danube discharge at Orsova (After BERENBEYM)

This is an average current for the whole year. During the April-June period when we have maximum run-off the current speed would probably reach 1.5-2 knots at the cross section.

Observations made in the Bosphorus indicate that the current reaches maximum speed near the surface and decreases with depth down to the boundary layer. Near the boundary, current speed is zero and, below this depth, current is in the reverse direction. Such studies of the currents in the Bosphorus in connection with the changes in sea level and other oceanographic variables are being made by the Hydrographic Office.

Continuous current measurements for at least one year have started, and only after such measurements will we be able to make a direct comparison with the annual run-off diagrams.

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