Suspended and solute loads on the Lower Diyala River

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ABSTRACT The Diyala weir which is about 11 Km downstream from Hemrin reservoir, distributes the outflow of Hemrin reservoir to the Lower Diyala River and the irrigation cannals (Khalis and Sadr Al-Mushtarak).

Suspended sediment and solute loads associated with the Lower Diyala River were evaluated for the period June/1984 - May/1985. During the studied period the mean discharge reached 128 cumecs and the maximum and minimum were 505 and 1.72 cumecs respectively. The annual suspended load reached 64589 tonnes (rate of erosion 2.17 ton/km^2) forming five percent of the total load. The annual solute load reached 1.24 x 10^6 tonnes (rate of erosion 42.00 ton/km^2) which forms 95 percent of the total load. The rate of transport was not uniform throughout the studied period, where most of the load (51.02 percent of the suspended load and 54.68 percent of the solute load) was transported during the Winter.

INTRODUCTION

The River Diyala, a tributary of River Tigris, is one of the important rivers in Iraq draining an area reaching 32600 km^2. Two dams were constructed on the river, Derbendikhan and Hemrin (360 and 188 km upstream the confluence with the Tigris river south Baghdad respectively)(Figure 1). In addition to the two dams, the Diyala wier was constructed on the river (11 km downstream from Hemrin Dam) and it distributes the outflow of Hemrin reservoir to the Lower Diyala River and the irrigation cannals (Al-Khalis canal and Sadr Al-Mushtarak).

A total of 314 samples were collected at the Hemrin station at daily intervals.

FLOW CHARACTERISTICS

Derbendikhan and Hemrin stations are the oldest stations on Diyala River with records dating back to 1957 and 1932 respectively (Ministry of Irrigation, 1976; & 1983).

Derbendikhan Station

It drains an area of 17800 km^2 and the hydrological records indicate that the mean daily discharges for the period 1957 - 1984 reaches 170 cumecs while the maximum and minimum daily discharges were 2280 and 1 cumecs respectively. Through the same period 10 years were wet with an average annual discharge of 244 cumecs and 18 dry years with an average annual discharge of 129 cumecs.

The slope of the river between Derbendikhan and Diyala weir is relatively steep (1.6 m/km).

Hemrin Station

It drains an area of 29700 km^2 and the hydrological records indicate that the mean daily discharges for the period 1932 - 1984 reaches 179 cumecs

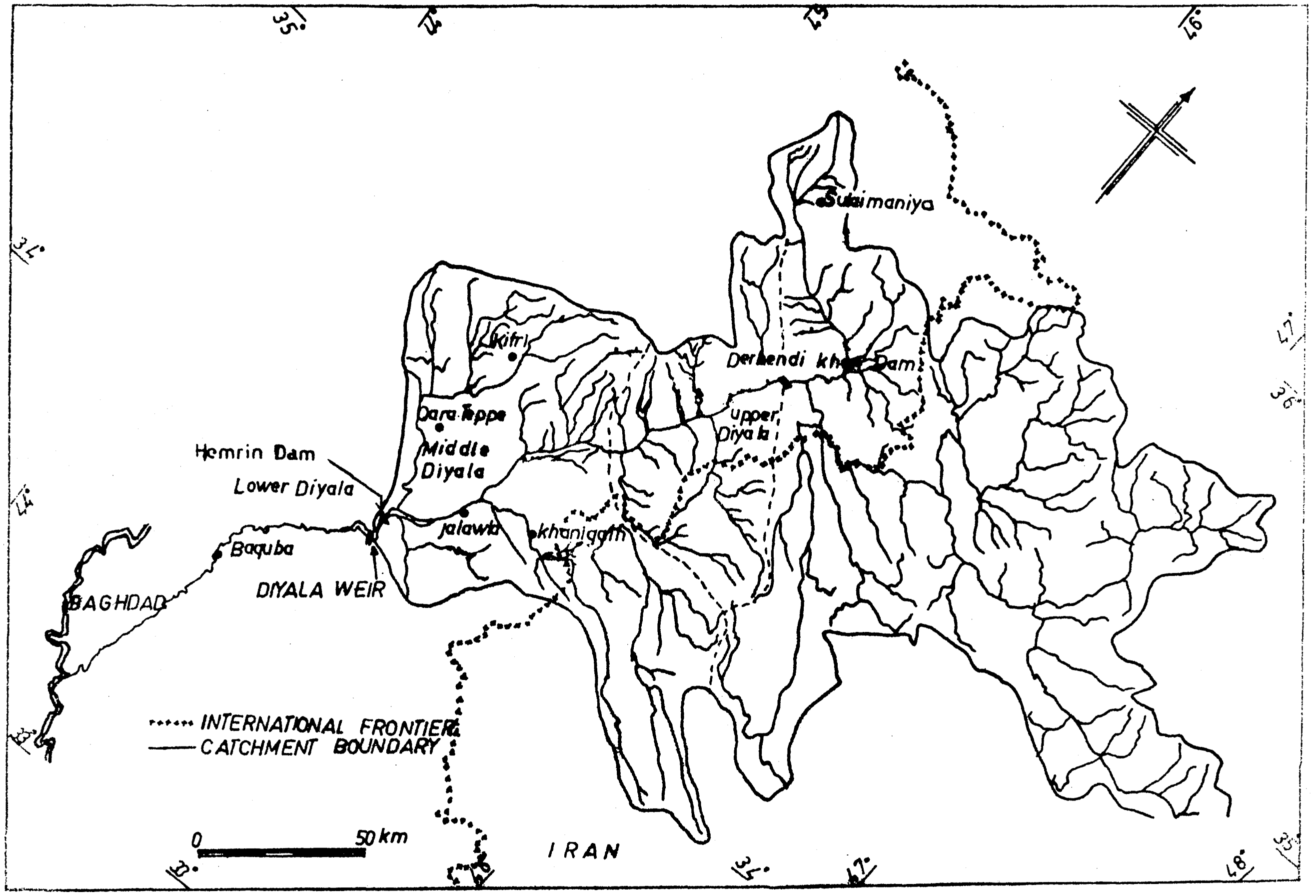

Figure 1: Diyala River basin.

Table 1 Suspended and solute concentration at Hemrin site (Lower Diyala River) for the period June/1984 - May/1985.

Year	Month	Sus. Sed. Conc. ppm	Solute Conc. ppm	Water Discharge m^3/sec
1984	June	18.08	456.270	9.50
	July	3.45	424.900	8.47
	Aug.	4.65	325.806	6.12
	Sep.	4.09	302.200	4.246
	Oct.	5.84	273.900	4.553
	Nov.	51.28	532.640	56.211
	Dec.	16.01	296.96	231.584
1985	Jan.	13.79	324.800	216.318
	Feb.	14.73	317.330	441.250
	March	8.73	327.083	279.645
	April	23.45	306.300	231.324
	May	11.61	357.200	51.190

while the maximum and minimum daily discharges were 3340 and 12 cumecs respectively. Through the same period 19 years were wet with an average annual discharge reaching 262 cumecs and 35 dry years with an average annual discharge reaching 135 cumecs.

The slope of the river for the strech between Diyala weir and its confluence with Tigris River south of Baghdad is relatively gentle (0.11 m/km).

The tributaries which flow into the river within the stretch between Derbendikhan and Hemrin caused an increase of the water discharge at Hemrin station between 1 - 34 percent. It should be mentioned however, that 11 years of the record are exceptional in that the discharge at Derbendikhan was higher than Hemrin. This period represents either dry years or impounding by Hemrin dam.

SUSPENDED MATTER

The concentrations and loads of the suspended matter in the river was established during the studied period.

Suspended Sediment Concentration

The mean daily concentration at Hemrin station reached 13.8 ppm and the maximum and minimum concentrations were 230 ppm (14/11/1984) and 0.4 ppm (10/6/1984). The mean monthly concentrations ranged between 3.48 ppm during July/1984 and 51.28 ppm during Nov./1984 (Table 1). The sudden increase in water discharge (about 12 fold) at Nov./1984 caused an increase of the suspended sediment concentration to about 9 fold which is a normal case in natural rivers (Allen, 1974 and Bagnold, 1980).

No significant relationship between water discharge and suspended sediment concentration was recognized (Figure 2) due to the effect of Hemrin reservoir which is the logical case in rivers effected by reservoirs (Smith and Alexander, 1984). It should be noted that a clear

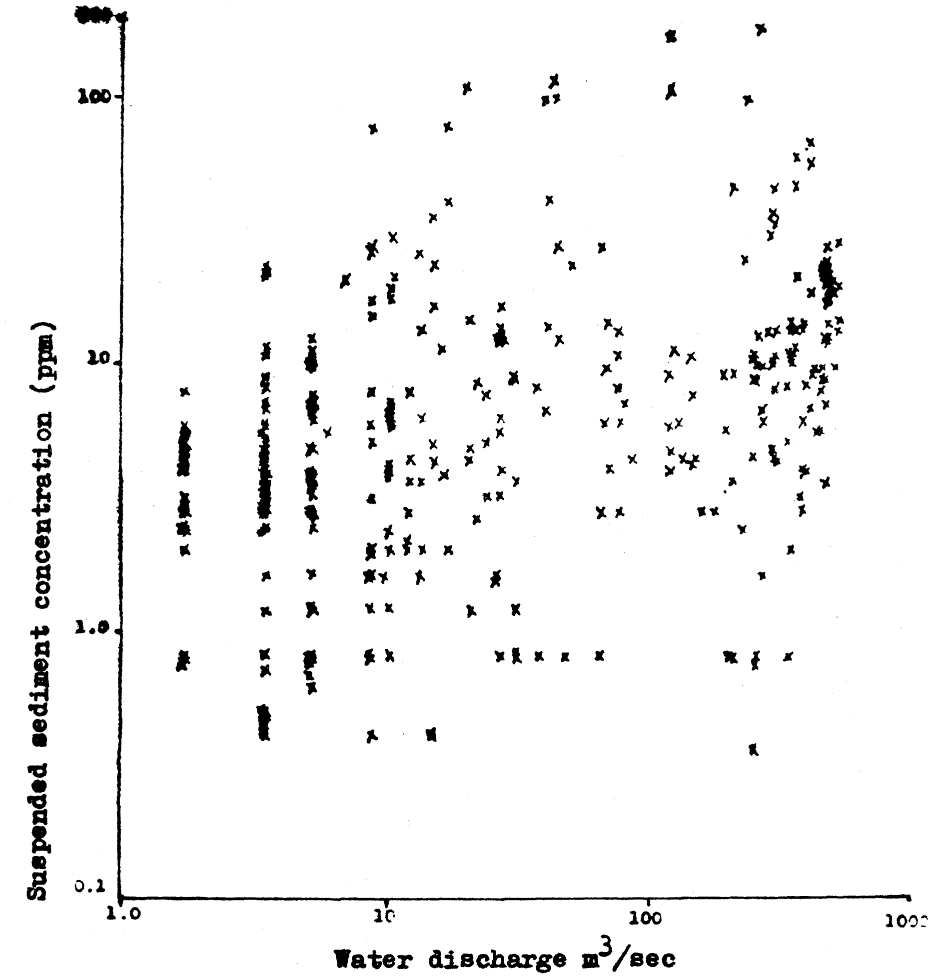

Figure 2: The relationship between suspended sediment concentration and water discharges at Hemrin station.

relationship was recognized by Assad (1978) for the same site before the construction of Hemrin dam.

Suspended Sediment Load

The total suspended sediment load associated with the lower Diyala River reached 64589 tonnes (rate of erosion 2.17 ton/km^2) with a daily average of 177 ton/day which forms 65.5 percent of the suspended sediment load leaving Hemrin reservoir. The maximum and minimum loads were 4568 ton/day (30/4/1985) and 0.12 ton/day (2-22/9/1984) respectively. The monthly load ranged between 46.6 tonnes during Sep./1984 and 15561 tonnes during Feb./1985 (Table 2). These values were very low relative to those found by Assad (1978) and Al-Ansari et al. (1983c) before the construction of Hemrin Dam and are lower than those found for other catchments in Iraq (See Al-ansari et al., 1983a,b; Al-Ansari and Toma,

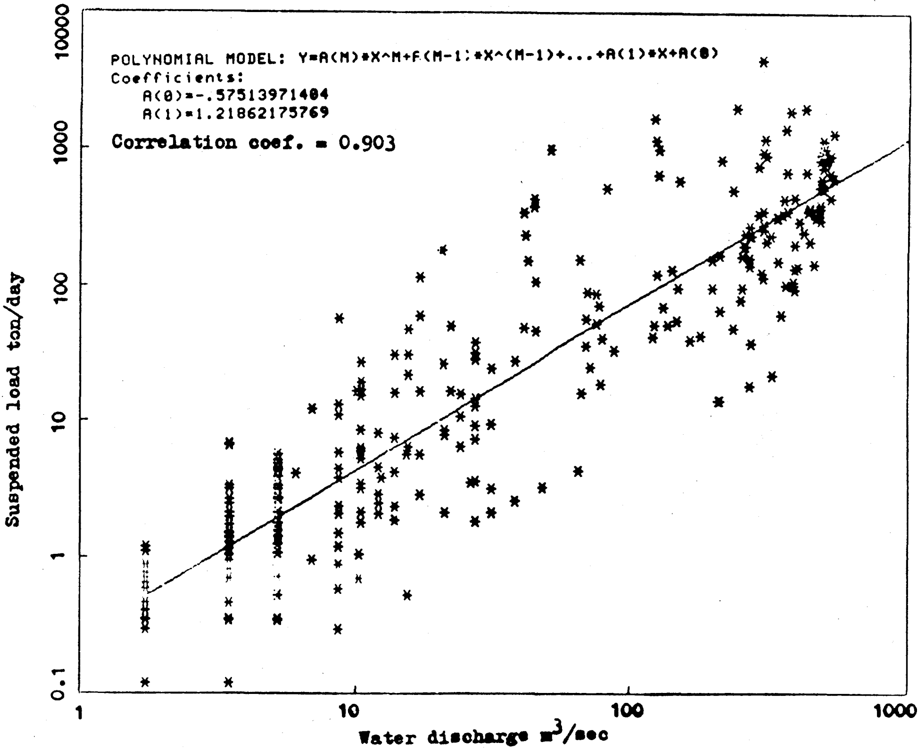

Figure 3: Relationship between water discharge and suspended load at lower Diyala River.

1985; Al-Jabbari and Mansour, 1986; Al-Ansari and Ali, 1986; and Al-Ansari et al., 1986). These differences are due to the effect of Hemrin reservoir and different geological, geomorphological and hydrological conditions. The data also indicate that 0.7 percent were transported during summer, 12.4 percent during autumn, 51 percent during winter and 35 percent were transported during spring. A direct linear relationship was established for the relationship between water discharge and suspended sediment load (Figure 3) as represented in equation (1).

$$\text{Log } y = A_1 \log x + A_o \qquad ....(1)$$

where

x = water discharge
y = sediment discharge
A_o = -0.575 and A = 1.218

SOLUTE MATTER

Concentrations and loads of solute matter for Diyala River were established during the studied period.

Solute Concentration

The mean daily concentration at Hemrin station reached 354.12 ppm and the maximum and minimum concentrations were 902 ppm (28/11/1984) and 36 ppm

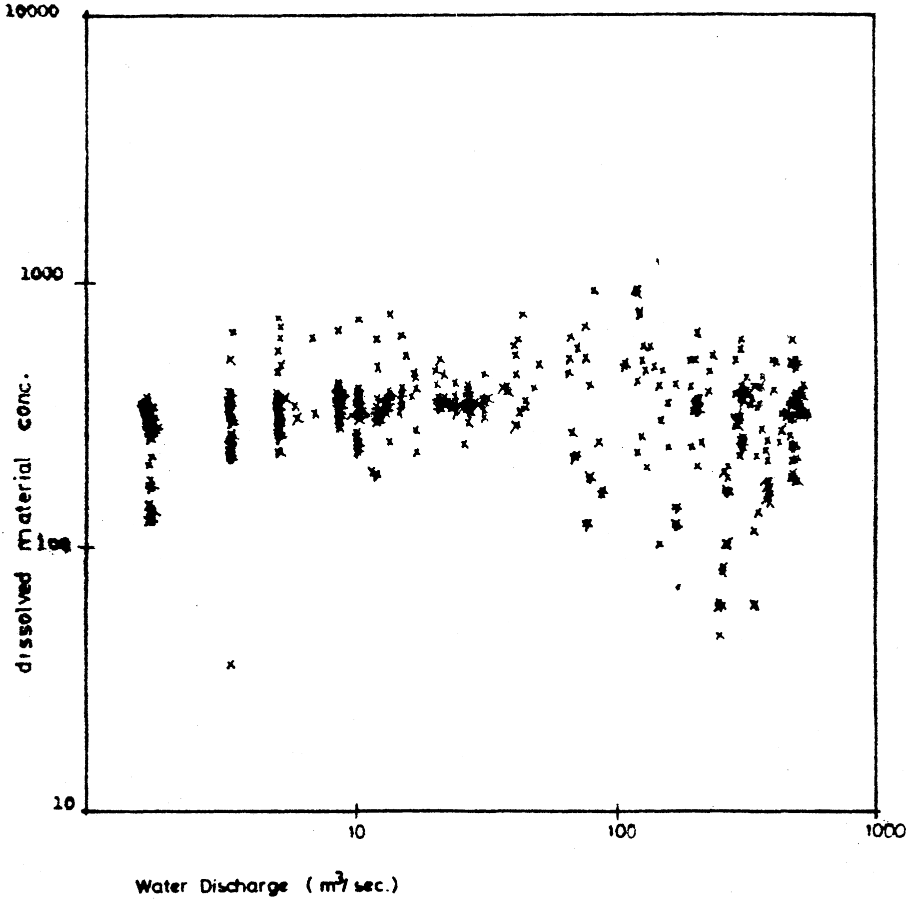

Figure 4: Relationship between water discharge and dissolved material at Hemrin station.

(30/9/1984) respectively. The mean monthly concentration ranged between 273.9 ppm during Oct./1984 and 532.64 ppm during Nov./1984 (Table 1). The solute concentration was almost uniform for all water discharges (Figure 4) but showed a slight indication of direct relationship at low discharges (less than 40 cumecs). This reflects the effect of Hemrin reservoir and the low velocity of the out flow on the solute concentration. At higher discharges however the points are more scattered and show an inverse relationship due to the effect of rainfall and snowmelt.

Solute Load

The total solute load associated with lower Diyala River reached 1246002 tonnes (rate of erosion 41.949 ton/km^2) with an average daily rate of 3414 ton/day. The maximum and minimum loads were 25122 ton/day (6/2/1985) and 11 ton/day (30/9/1984) respectively. The total monthly load ranged between 3345 ton/month during Sep./1984 and 324671 ton/month during Feb./1985 (Table 2), which differs from the solute load in other

Table 2 Suspended sediments and solute loads associated with the Lower Diyala River for the period June/1984 - May/1985.

Year	Month	Sus. Load Ton/month	Sus. Load Ton/ Km^2/month (Ts)	Solute Load Ton/month	Solute Load Ton/ Km^2/month (Td)	Ts/Td
1984	June	321	0.011	10189	0.343	0.032
	July	72.3	0.0024	9151	0.308	0.0077
	Aug.	73.6	0.0025	5350	0.180	0.013
	Sep.	46.6	0.0015	3345	0.112	0.013
	Oct.	70.4	0.0023	3725	0.125	0.018
	Nov.	7907.0	0.2660	87152	2.934	0.090
	Dec.	8549.0	0.287	172393	5.804	0.049
1985	Jan.	8866.0	0.298	184111	6.199	0.048
	Feb.	15561.0	0.523	324671	10.931	0.047
	March	7890.0	0.265	228549	7.695	0.034
	April	13291.0	0.447	171508	5.774	0.077
	May	1942	0.065	45858	1.544	0.042

basins in Iraq (Al-Ansari and Ali, 1986; and Al-Jabbari and Mansour, 1986) due to different geological and morphological conditions and the presence of Hemrin reservoir.

The data also indicate that 1.98 percent of the load was transported during summer, 7.56 percent during autumn, 54.68 percent during winter and 35.78 percent was transported during spring. The solute rating curve (Figure 5) showed a direct but not linear relationship where the increase rate of water discharge was greater than that of solute discharge for high water discharge conditions. In addition the relationship was more correlated at low discharges which suggests that dilution processes occur during wet months. The relationship between water discharge and solute discharge was presented in equation (2).

$$\text{Log } y = A_2 \log x^2 + A_1 \log x + A_o \qquad ....(2)$$

where

x = water discharge
y = solute discharge
A_o = 1.3305
A_1 = 1.269 and
A_2 = -0.0986

THE RELATIVE MAGNITUDE OF DISSOLVED AND SUSPENDED LOADS

The total load associated with the Lower Diyala River during the studied period was 1310600 tonnes where 95 percent was solute load.

The ratio between suspended load (Ts) and solute load (Td) ranged between 0.0077 (July/1984) and 0.090 (Nov./1984) (see Table 2).

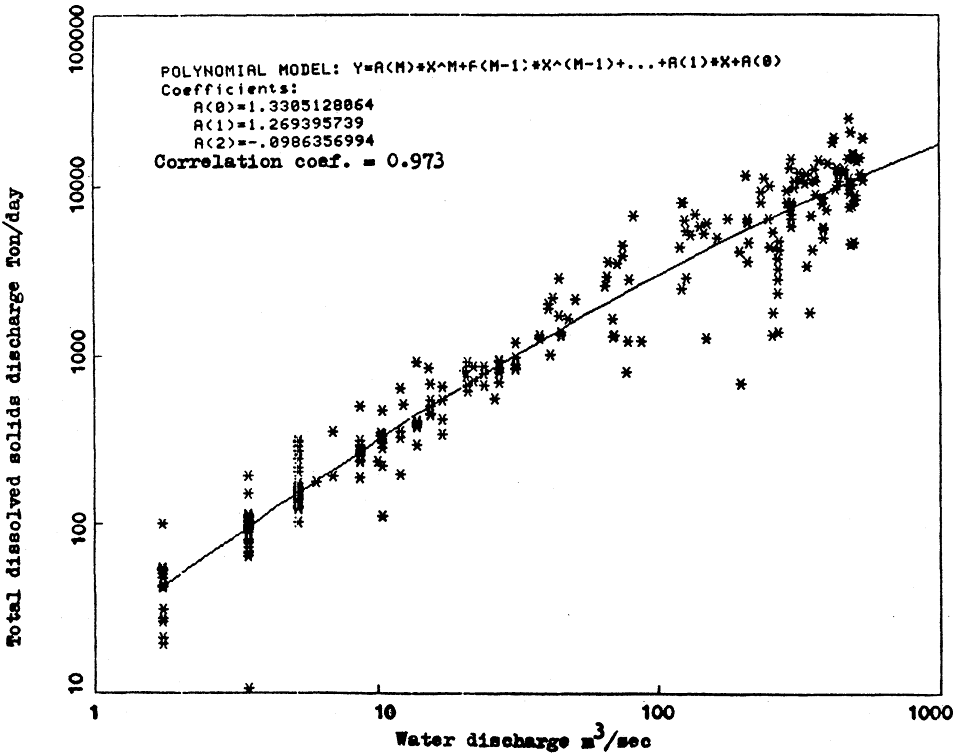

Figure 5: Relationship between water discharge and total dissolved solids discharge at lower Diyala River.

A linear direct relationship between suspended and solute loads is shown in Figure 6 and presented in equation (3).

$$\log y = A_1 \log x + A_o \qquad ....(3)$$

where

x = suspended load
y = solute load
A_o = 1.113 and
A_1 = 0.721

This type of relationship agrees with that found by Meybeck (1976). The data indicate a direct relationship between water discharge and the ratio Ts/Td also as it is shown in Figure 7. Such relations indicate that both loads have similar response to the influence of external processes.

CONCLUSIONS

Suspended sediment and solute loads were investigated at Hemrin station for the period June, 1984 - May, 1985. Throughout this period 314 samples were collected and analyzed.

The mean daily suspended sediment concentration at Hemrin station reached 13.8 ppm ranging from 0.4 ppm (10/6/1984) to 230 ppm

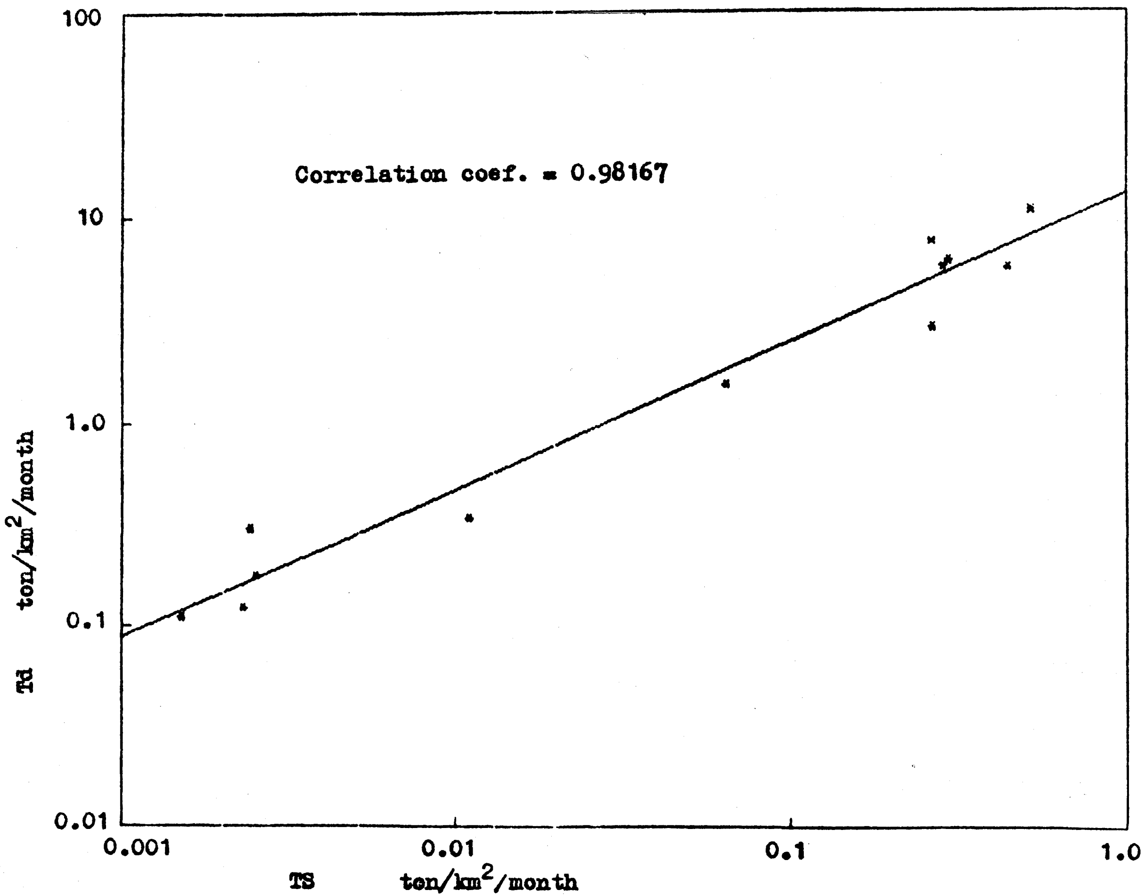

Figure 6: Relationship between suspended and solute load.

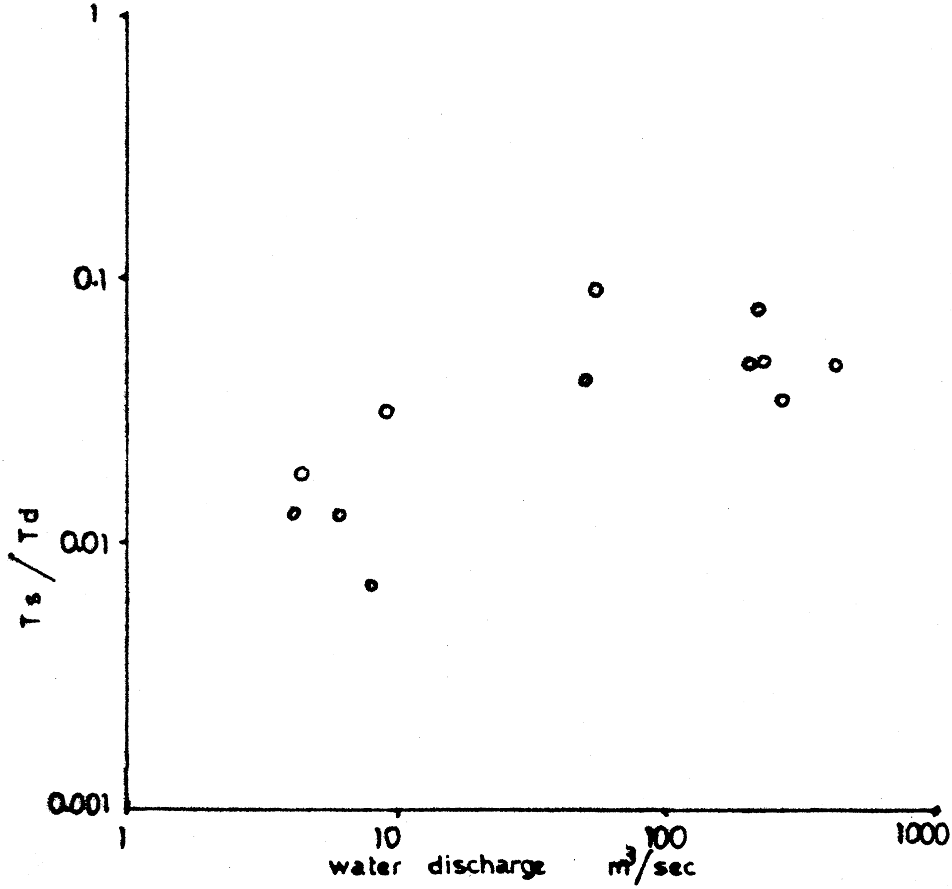

Figure 7: Relationship between average monthly discharge and the ratio between suspended and dissolved loads (Ts/Td).

(14/11/1984). The suspended sediment load associated with lower Diyala River reached 64589 tonnes (rate of erosion 2.17 ton/km^2) with an average daily rate of 177 tonnes. The maximum and minimum daily loads were 4568 ton/day (30/4/1985) and 0.12 ton/day (2-22/9/1984) respectively. Most of the suspended load (51 percent) was transported during winter.

The mean daily solute concentration at Hemrin station reached 354.12 ppm ranging from 36 ppm (30/9/1984) to 902 ppm (28/11/1984). The solute load associated with Lower Diyala River reached 1.246 x 10^6 tonnes (rate of erosion 42.00 ton/km^2) with an average daily rate of 3414 tonnes. The maximum and minimum daily loads were 25122 ton/day (6/2/1985) and 11 ton/day (30/9/1984) respectively. About 54 percent of the solute load was transported during winter.

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