Arabian Journal of Geosciences (2020) 13:900
https://doi.org/10.1007/s12517-020-05862-1

ARABGU2016

Supplies of suspended matter by surface water of the Mazafran drainage basin (western Algiers, Algeria)

Ali Eddine Foudil Bouras[1] · Nassereddine Messaoud Nacer[2] · Roselyne Buscail[3] · Nemer Zoubida[4]

Received: 25 March 2020 / Accepted: 13 August 2020

Abstract

The Mazafran wadi is characterized by a strong connection of the solids flow in kilograms per second to the liquid flow in cubic meters per second. However, high solids flow can also be associated to low liquid flow after severe summer storms. We also note that high water flows generate low solids transport; this is probably because of the groundwater draining after major floods. The relation between the daily solids flow and the average daily liquid flow varies from 50 to 600 $m^3 s^{-1}$. It is represented as follows: $Qs = 2.03\ Qmj^{2.626}$. The correlation of suspended matter and liquid flow concentrations follows the Serrat model which is presented as a second-degree logarithmic-based polynomial equation. Both equations show that the Total Suspended Solid (TSS) increases with the downstream and upstream flow. The suspended solids transport occurs mainly in the winter and to a less extent in the spring and autumn.

Keywords Wadi Mazafran · Solids flow · Liquid flow · Suspended matter

Introduction

Suspended matter concentrations are usually a function of the flow rates. High water flows correspond to high suspended matter concentrations (Amiotte Suchet and Probst 1995). This occurs most frequently in the Mediterranean fluvial systems during the winter or in spontaneous runoff in autumn or even in spring (Serrat 1999).

Thus, the transportation of suspended matter is often brief and occurs only during very short flood episodes. As a result, it is difficult to determine the extent of sediment supply carried by the rivers in both the northern and southern parts of the Mediterranean region.

Serrat (2001) developed a model linking flow and suspended matter to quantify the flow of suspended matter in the Agly and Têt rivers (France).

The aim of our study is to use this model for an Algerian coastal hydrosystem: Oued Mazafran. We used the water flow data and the concentration values collected from the National Water Resources Agency of Blida to determine the flow of suspended matter during the periods 1990–1995 and 2005–2006, with the aim of extending this model to the principal coastal rivers of the Mediterranean region.

The geographical location of the study area

The drainage basin of Oued Mazafran is located in the western part of the Mitidja plain at about 45 km from Algiers between 36° 15′ and 36°45′ North latitude and 2° 15′ and 3° East longitude. The surface of the Mazafran drainage basin itself is 427.5 km^2. It has 3 main tributaries: the Djer River which flows from the SW to the NE, the Bou-Roumi wadi overhung by a dam

This article is part of the Topical Collection on Current Advances in Geology of North Africa

✉ Ali Eddine Foudil Bouras
afoudilbouras@gmail.com

Nassereddine Messaoud Nacer
n_messaoudnacer@yahoo.fr

Roselyne Buscail
buscail@univ-perp.fr

Nemer Zoubida
znemer@usthb.dz

1 Geo-Environmental Laboratory, University of Science and Technology Houari Boumediene, Bab Ezzouar, Algeria

2 Saad Dahlab Blida University, Blida, Algeria

3 Cefrem UMR 5110 CNRS, University of Perpignan V.D, Perpignan, France

4 Laboratoire de Géophysique, University of Science and Technology Houari Boumediene, Aix-en-Provence, France

under its name and flowing in the central part of the Mitidja from the South to the North, and in the East the Chiffa river.

The surface area of the entire Mazafran basin, including its tributaries, is about 1900 km^2. These tributaries originate in the Tellian atlas and meet in the north to form a single river, the Mazafran, which flows directly into the sea in Bou-Ismail Bay (Fig. 1).

Characteristics of the Mazafran River tributaries

The 50-km-long Djer wadi is the most important affluent. It represents the natural border between Attatba and Ameur El Ain municipalities. A part of its flow has been transformed into a drainage channel following the departmental road N° 7. Then, at the latitude of Kandoury, it regains its normal water flow and receives the Bou Roumi. Its drainage basin has a total area of 396 km^2.

The Bou Roumi wadi flows close to the Djer wadi. It extends over a length of 72 km and its catchment area is evaluated as 680 km^2. A dam was constructed and commissioned in 1985 in the upstream part of the river between Gebel Chekirène in the south and Gebel Draa El Ouest in the north.

The Chiffa wadi originates from the upstream of the Chiffa gorges and crosses the Chréa massif on both sides, and to the west Mouzaia massif to form the Mazafran wadi. Its length is about 35 km and the surface area of its drainage basin is 316 km^2.

Methods

We received from the ANRH, n.d. (National Agency for Water Resources of Blida) the available values of liquid flows (Qmj in m s^{-1}) and solids (Qs in kg s^{-1}) daily from 1990 to 1995 and those from 2005 to 2006. The ANRH determines the liquid flow by gauge at the reel, which measures the point speed of the flow. The suspended material is recovered by filtration on fiberglass GF/F filters with a diameter of 47 mm and porosity 0.7 m. The amount of suspended material (MES) was calculated in milligrams per liter. To determine the solids flow, the ESM is multiplied with the liquid flow. In order to determine the possible relationship between these two parameters, each MES concentration is associated with the average daily liquid flow (C/Q mj).

Results

Liquid flows

Mazafran wadi is distinguished by a permanent flow, flood periods in winter and low water levels in summer where the flow approaches zero.

The annual average flows of the Mazafran and its tributaries (Djer, Bou Roumi, and Chiffa) vary from 1 to 10 m^3 s^{-1}. The annual average input of Oued Mazafran is

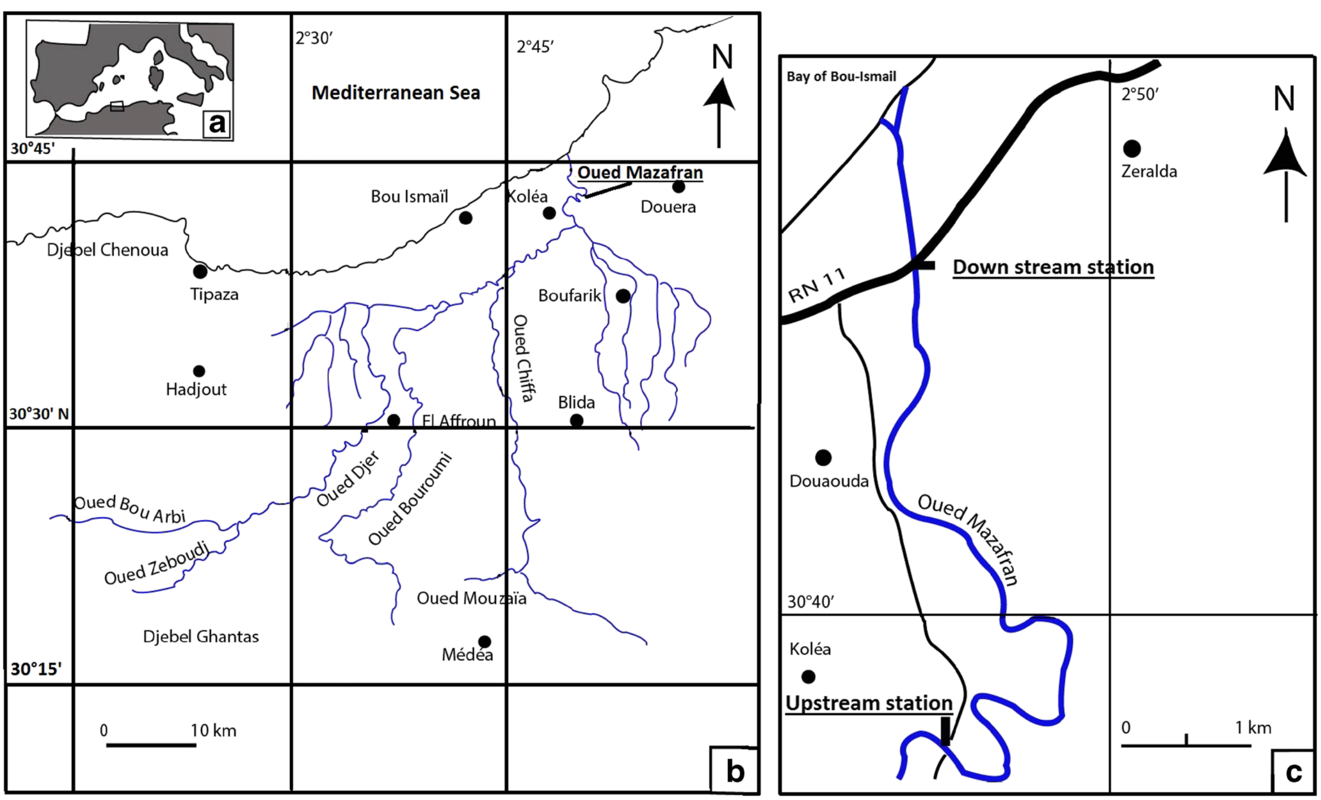

Fig. 1 (a) Location of the Mediterranean Sea. (b) Location map of the Mazafran wadi and its hydrographic network. (c) Location of the samples' stations

Table 1 Annual average flow rates of the Mazafran wadi and its tributaries

Affluents	The basin area (Km2)	Annual average supplies and flows	
		10^6 m^3	m^3 s^{-1}
Djer	395	53.6	1.7
Bou Roumi	680	107.2	3.4
Chiffa	316	117	3.7
Mazafran	1893	320	10.14

estimated at 320,106 m^3 (Messaoud Nacer et al. 2006) (Table 1).

Concentration of suspended material from the tributaries of the Mazafran wadi

From the suspended matter concentration values recorded during the flood monitoring by the ANRH of Blida during the 1990–1998 period in the Djer wadi, the 1990–1997 period in the Bou Roumi wadi, and the 1988–1999 period in the Chiffa wadi, we have established a graph illustrating the maximum point values for each of these wadis.

Wadi Djer

Heavy floods, reflected by the high total suspended solid (TSS) concentrations recorded from April 1991 to April 1998, occurred 3 times during this period, mainly in autumn and winter 1991, in autumn 1994, when the TSS concentration was at its highest level (49,360 mg l^{-1}), and in winter (Fig. 2 and Table 2).

Wadi Bou Roumi

The concentrations of suspended solids in the Bou Roumi wadi show two maximum values that exceed 90,000 mg l^{-1}.

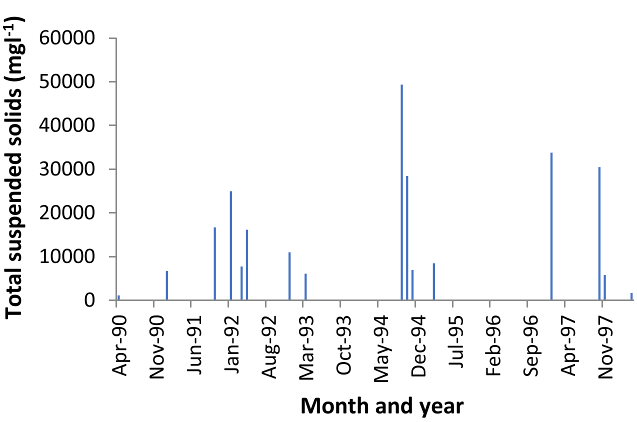

Fig. 2 Monthly average variation of the TSS from 1990 to 1998 in the Djer wadi

Table 2 TSS Concentrations from Wadi Djer (1991–1997)

Month/year	TSS (mg l^{-1})
January 1991	6703
October 1991	16,707
January 1992	24,966
March 1992	7757
April 1992	16,135
December 1992	10,983
March 1993	6110
September 1994	49,360
October 1994	28,446
November 1994	6953
March 1995	8490
January 1997	33,806
October 1997	30,500
November 1997	5765

One recorded in October 1991 (129,000 mg l^{-1}) and the other in October 1994 (98,400 mg l^{-1}). During the autumn of the 1990s (above 60,000 mg l^{-1}), 1991 and 1994, the highest values are recorded, in relation to relatively significant floods, except for 1997, when a significant flood (August) is recorded (Fig. 3 and Table 3).

Wadi Chiffa

The TSS data recorded during the floods from 1988 to 1999 in Chiffa wadi show a succession of high and low values (Fig. 4 and Table 4). We usually observe the most important flooding in the autumn or in spring, but only briefly in the winter, which is often observed in Maghreb rivers.

We note that the TSS concentrations during the flooding periods of Bou Roumi Wadi recorded from 1990 to 1997 are significantly higher than those of Djer Wadi and Chiffa Wadi for the same periods as they exceed 120,000 mg l^{-1}. This appears unusual since, as we have seen previously, the liquid flows of the Bou Roumi, before the dam was opened, are much lower than those of the other Mazafran tributaries (less than 45 $m^3 s^{-1}$). The values recorded by ANRH in Bou Roumi in October 1991 and 1994 may be incorrect.

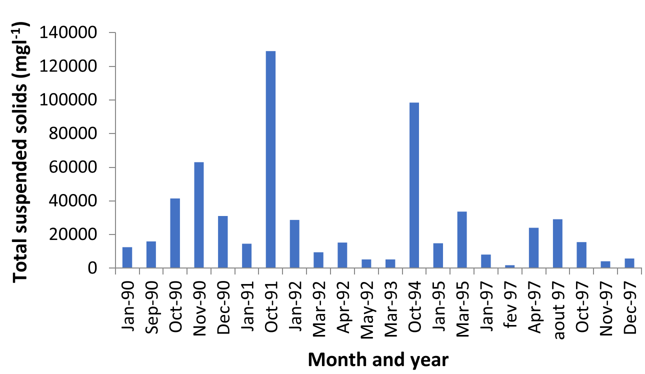

Fig. 3 Monthly average TSS values of Bou Roumi wadi from 1990 to 1997

Table 3 TSS concentrations from Wadi Bou Roumi (1990–1997)

Month/year	TSS (mg l^{-1})
January 1990	12,500
September 1990	15,836
October 1990	41,450
November 1990	63,000
December 1990	31,000
January 1991	14,500
October 1991	129,000
January 1992	28,700
March 1992	9500
April 1992	15,200
May 1992	5200
March 1993	5250
October 1994	98,400
January 1995	14,750
March 1995	33,670
January 1997	8020
February 1997	1812
April 1997	24,009
August 1997	29,045
October 1997	15,490
November 1997	4122
December 1997	5760

The inputs of wadis or rivers in the Mediterranean barely compensate the impact of hydrodynamic agents (Bourrin 2007).

Discussion

The relation between suspended solids and liquid flow

The suspended solids concentrations are usually a function of the flow rates. High liquid flows correspond to high suspended matter concentrations (Amiotte Suchet and Probst 1995). This occurs mostly in the Mediterranean River basins during winter or during spontaneous torrential flows in the autumn or even in the spring (Serrat 1999).

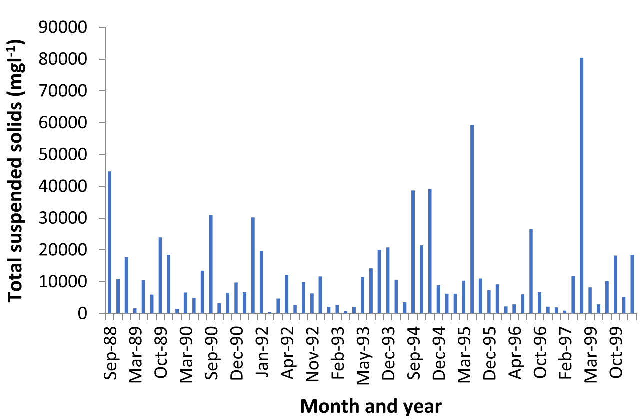

Fig. 4 Monthly average TSS variation in Wadi Chiffa from 1988 to 1999

Table 4 TSS concentrations from Wadi Chiffa (1988–1999)

Month/year	TSS (mg l^{-1})
September 1988	44,710
October 1988	10,780
December 1988	17,750
April 1989	10,580
August 1989	6000
October 1989	23,970
November 1989	18,450
March 1990	6600
April 1990	4970
May 1990	13,530
September 1990	30,960
October 1990	3250
November 1990	6540
December 1990	9750
January 1991	6720
October 1991	30,260
January 1992	19,700
March 1992	4740
April 1992	12,130
May 1992	2700
October 1992	9950
November 1992	6350
December 1992	11,670
February 1993	2730
April 1993	2070
May 1993	11,540
October 1993	14,210
November 1993	20,830
December 1993	20,830
January 1994	10,650
April 1994	3560
September 1994	38,730
October 1994	21,450
November 1994	39,190
December 1994	8920
January 1995	6280
February 1995	6260
March 1995	10,350
October 1995	59,320
November 1995	11,030
December 1995	7360
February 1996	9210
March 1996	2230
April 1996	2870
May 1996	6030
September 1996	26,580
October 1996	6670
January 1997	1960
April 1997	11,830
September 1997	80,450
March 1999	8220
May 1999	2890
August 1999	10,180
October 1999	18,230
November 1999	5240
December 1999	18,460

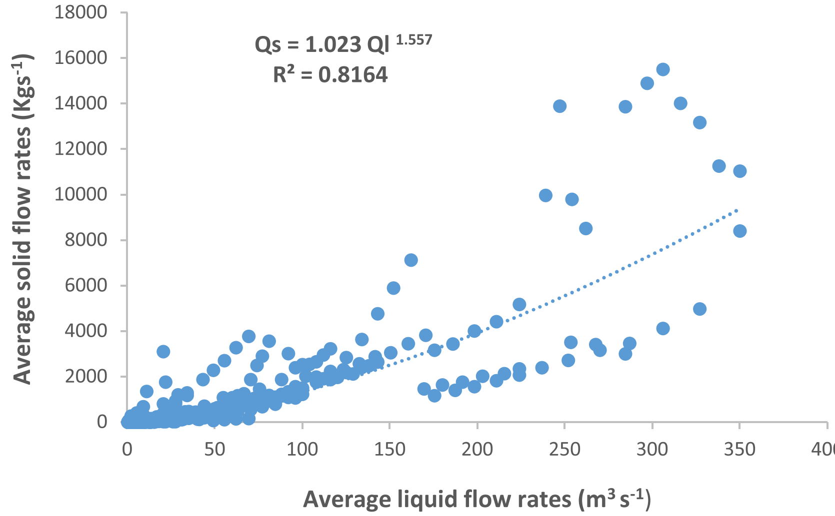

Fig. 5 The relationship between the average solid and liquid flow rate of the Mazafran wadi for the 1990–1995 period

Thus, suspended solids transportation is of short term and occurs rarely outside of flood events.

We correlated the solids and liquid flows in the Mazafran wadi during the 1990–1995 period based on the relatively complete data obtained from the Blida ANRH (Fig. 5).

For the Mazafran wadi as for most Algerian rivers (Terfous et al. 2001; Bourouba 2002; Bouanani 2004), there exists a well-established correlation between the solids flow (kg s^{-1}) and the liquid flow (m^3 s^{-1}). The figure shows that the solids flow increases with the liquid flow, but there may be high solids flows associated with lower liquid flows. Likely to occur because of severe thunderstorms in summer, and, as in the study on Mouilah wadi by Terfous et al. In 2001, high liquid flow values result in lower solids transport. This is explained by the draining of the groundwater after major flooding periods. This is expected to occur during severe summer rainstorms and, as in the Wadi Mouilah study by Terfous et al. in 2001, high liquid flow values lead to lower solids transport. This is explained by the draining of the groundwater after major flooding periods.

We also established the relationship between the daily solids flows (Qs) and the daily average liquid flows (Qmj) exceeding 50 m^3 s^{-1} from the 1994 and 1995 data collected by the ANRH (Fig. 6). This is illustrated in the following equation: Qs = aQmjb (Linslet and Franzini 1979). The equation only applies to flows less than 600 m^3 s^{-1} beyond which the correlation is poor (Serrat 1999). In January 1994, the amount of suspended matter discharged in 24 h during the flooding in the Mazafran river was 623,939 tons, while that of the following year, 1995, on 08 January 08, reached 1,200,633 tons, the most important in that year. The very next day, January, a lower value of 88,179 tons was registered, then in March the value of 278,823 tons. The binding functions Qs and Qmj, in this case, are of the form:

$$Qs = 2.03Qmj^{2.626}$$

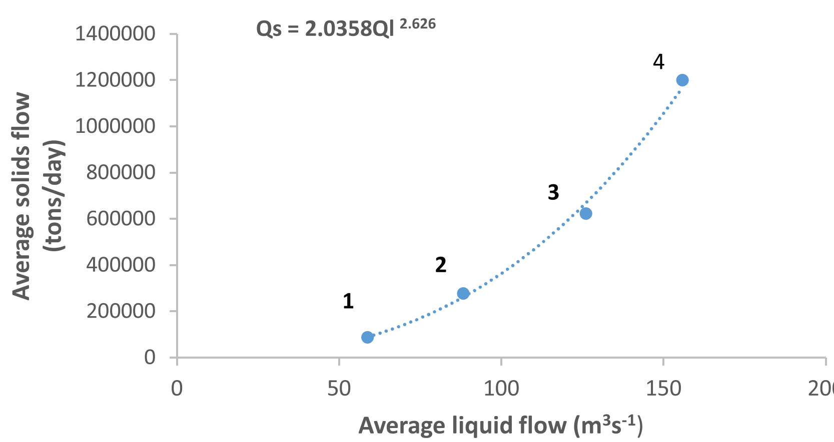

Fig. 6 Relationship between daily solid (Qs) and liquid (Ql) flow rates > 50 m^3 s^{-1}. Episode 24 hour flood: (1) (09/01/95) 88,179 tons; (2) (13/03/95) 278,823 tons; (3) (20/01/94) 623,939 tons; (4) (08/01/95) 1,200,633 tons

Table 5 Second order logarithmic equations between the TSS (mg l^{-1}) and the liquid flow rates ($m^3 s^{-1}$) upstream and downstream of the Mazafran wadi

Stations	Second-degree logarithmic equation	Correlation coefficient r^2
Upstream	Log (TSS) = 0.63 (Log Q)^2 + 0.71 (Log Q) + 1.81	0.88
Downstream	Log (TSS) = 0.62 (Log Q)^2 + 0.54 (Log Q) + 1.78	0.81

These relationships show that during the flooding, when the liquid flows are significant, a large amount of suspended matter passes through the river. Such conditions can cause a strong temporal dichotomy in these transports: one being continuous, associated with chemical erosion, and the other being impulsive and violent, discharging the circumscribed mechanically eroded products (Serrat 1998).

Serrat et al. (2001) established a correlation between the concentrations of suspended solids and liquid flow. It is a second-degree-based logarithmic polynomial equation of the form:

$$y = ax^2 + bx + c \text{ or } \mathrm{Log(MES)} = \alpha(\mathrm{Log\ Q})^2 + b(\mathrm{Log\ Q}) + c$$

Based on this equation, we can calculate the average flow of suspended matter for the 2005–2006 data both upstream and downstream of the Mazafran wadi.

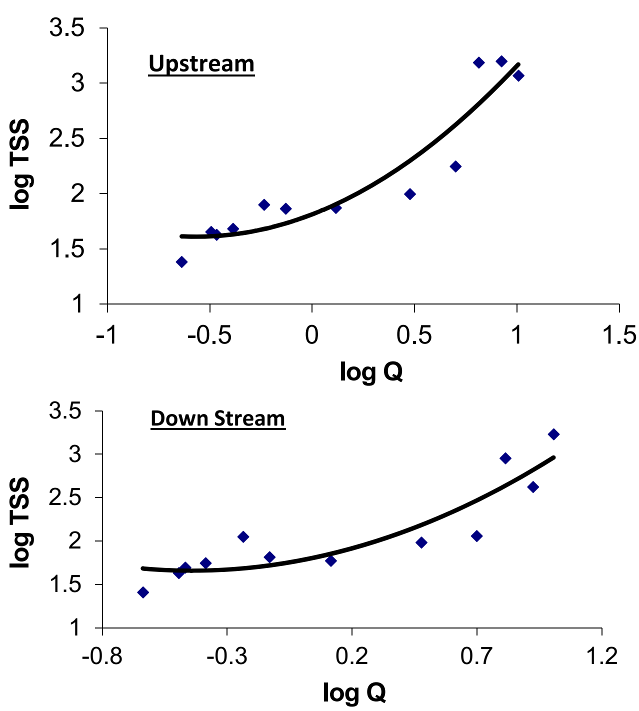

Fig. 7 The relationship between liquid flow and TSS upstream and downstream of the Mazafran wadi during the 2005–2006 period

The relationships between liquid flow and TSS found, in this case, confirm and are consistent with the results and the model established by Serrat et al. (2001).

The two equations applied to the upstream and downstream have important correlation coefficients as they are relatively high, 0.88 for the upstream and 0.81 for the downstream of the wadi (Table 5 and Fig. 7). It is known that the Mazafran wadi can carry large quantities of sediment during flood period by stripping the banks (Boudjadja et al. 2003). It is now well established that the concentration of suspended solids increases with the flow (Meybeck 1985).

Based on the liquid and suspended matter flow values and the liquid and solids flows recorded in the Mazafran wadi from 1990 to 1995 and from 1990 to 1994 by the ANRH of Blida, we examined the correlation between these two sets of parameters. We observe that heavy floods, with the high liquid flow, are associated with high concentrations of suspended solids and solids flow (greater than 15,000 kg s^{-1}) resulting from watershed erosion, mainly at the banks, and the scouring of the movable part of the riverbed, a well-documented phenomenon (Foudil Bouras 2012). Similarly, Serrat (1999), in the study of Agly (France), found that the distribution of both suspended matter and dissolved matter reflects a morphoclimatic context that combines a carbonated substrate with a contrasted Mediterranean climate. Also, most TSS transfer occurs during flash floods, which usually happen in autumn (Serrat et al. 2001).

The plot in the figure shows that the TSS increases with the flow. However, some exceptions are recorded upstream of the wadi where a load of suspended material is significant even in summer (325 mg l^{-1} in July and 705 mg l^{-1} in August).

Table 6 Seasonal models linking suspended solids flow rates to liquid flow in the Mazafran wadi

Season	Correlation model	Correlation coefficient R
Autumn	$Qs = 2.284Ql^{1.709}$	0.65
Winter	$Qs = 0.759Ql^{1.581}$	0.89
Spring	$Qs = 0.176Ql^{2.009}$	0.85
Summer	$Qs = 6.271Ql^{1.492}$	0.80

These high concentrations are due to the abundance of algal and phytoplanktonic material in the wadi's water, which proliferates during the summer.

Seasonal analysis of solids flows as a function of liquid flows from 1990 to 1995

To analyze the correlation linking the liquid flows to the suspended solids flows in the Mazafran basin, during the 1990–95 hydrological period, we grouped the flow values by seasons (fall, winter, spring, and summer). Table 6 illustrates the relationship between the two parameters with different models adapted for each season.

The examination of the seasonal plots highlights the seasonal differences in flow values. There are high liquid flows during winter (350 m^3 s^{-1}) and spring (170 m^3 s^{-1}) with a highly condensed point cloud where maximum solids flows exceed 15,500 kg s^{-1} and 3800 kg s^{-1}. Yet, in the autumn, the liquid flows are less than 100 m^3 s^{-1} and in the summer 10 m^3 s^{-1} (Figs . 5 and 8).

There are specific features for each season. In autumn, for example, the point cloud is scattered, a season characterized by relatively rare precipitations after the major dry season of summer. The first rainfall in autumn comes on a dry, hard, and difficult-to-erode soil, which results in a low supply of suspended matter from the drainage basin. But it is also in the autumn that heavy rainfall can occur, often in October and November, which will remove large amounts of solids from the catchment area and discharge into the Mazafran wadi.

In the Mediterranean, for all Maghreb wadis or those of southern Europe, hydroclimatic conditions are very heterogeneous between the different basins (Lespinas 2008). The spring is characterized by rainfall that would destabilize the soil structure of the drainage basin by making it highly vulnerable to erosion, and consequently, the runoff water is very charged with solids debris and suspended matter (Terfous et al. 2001) (Probst 1992) (Garcia-Estève et al. 2003) (Pauc 2005).

The analysis of the seasonal solids flow variations shows that the suspended solids transports in the Mazafran drainage basin occur mostly in winter, which is a rainy period, and to a lower extent in spring and autumn.

In both summer and autumn, the values are dispersed with low liquid flows under 10 m^3 s^{-1} and high solids flows up to 1000 kg s^{-1}. These are less frequent and occur exceptionally during spontaneous summer storms that cause flash floods. The correlation coefficients that characterize the relationships between liquid and solids flows in each season are significant enough, particularly for the winter period (0.89) (Table 6).

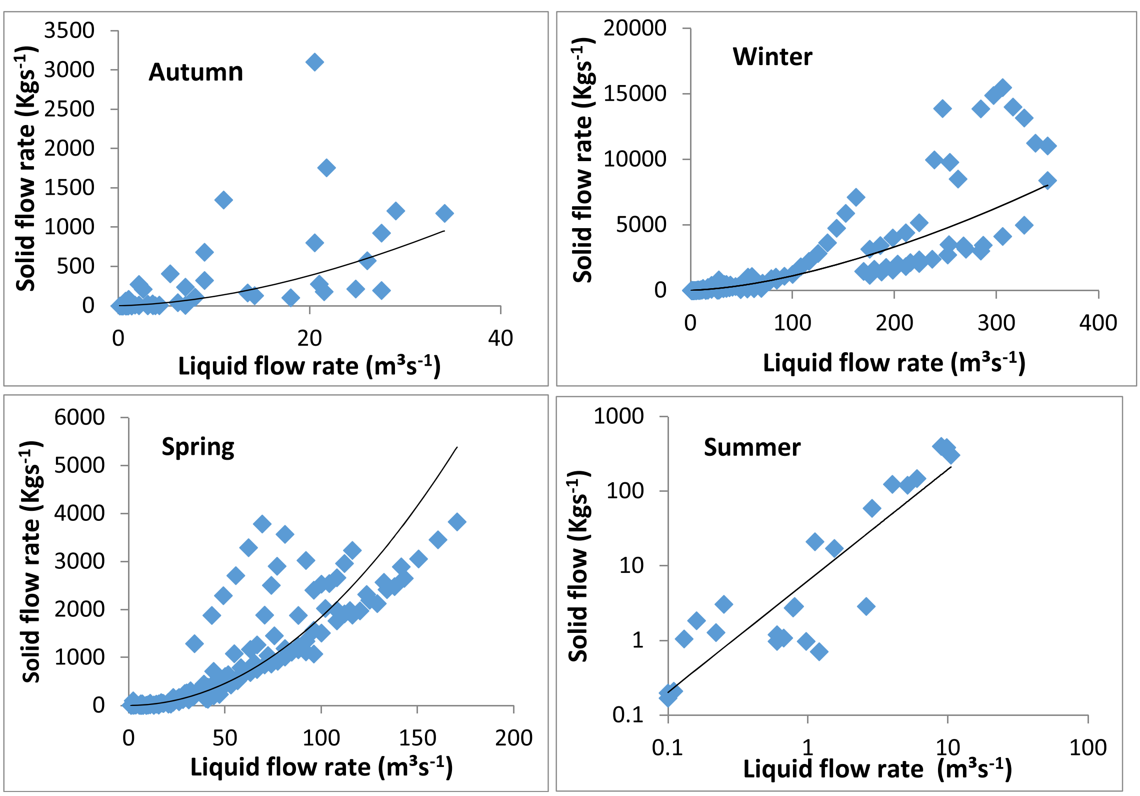

Fig. 8 Seasonal variations of solid flow rates as a function of liquid flow rates

Conclusion

For the Mazafran wadi as for most Algerian wadis (Terfous et al. 2001; Bourouba 2002; Bouanani 2004), there is a good correlation between the solids flow in kilograms per second and the liquid flow in cubic meters per second.

We can associate the solids flow's intensification to the liquid flow increase, but also to low liquid flows after heavy summer storms. It is also noted, as in the study conducted on the Mouilah wadi by Terfous et al. in 2001, that high values of liquid flows generate low solids transport. This is most likely because of the growndwater's drainage after flooding.

The relationship between the daily solids flows (Qs) and average daily liquid flows (Qmj) greater than 50 $m^3\ s^{-1}$ is presented as Qs = aQmjb (Linslet and Franzini 1979). This equation only applies to flows below 600 $m^3\ s^{-1}$ above which the correlation is poor (Serrat 1999). In our case:

$$Qs = 2.03Qmj^{2.626}$$

These correlations show that during floods, when liquid flows are high, a large quantity of suspended matter passes through the Mazafran wadi. These conditions can lead to a strong temporal dichotomy in these transports: one is of a continuous nature, linked to chemical erosion, and the other impulsive and violent, discharging mechanically eroded products (Serrat 1998).

A correlation between suspended matter concentrations and the liquid flow has been established by Serrat et al. (2001). It is a second-degree logarithmic polynomial equation:

$$y = ax^2 + bx + c \text{ or } \mathrm{Log(MES)} = \alpha(\mathrm{Log}\ Q)^2 + b(\mathrm{Log}\ Q) + c$$

As a result, the second-degree Logarithmic equations for the MES ($mg\ l^{-1}$) and the liquid flow ($m^3\ s^{-1}$) upstream and downstream of the Oued Mazafran are respectively:

$$\mathrm{Log\ (MES)} = 0.63(\mathrm{Log}\ Q)^2 + 0.71(\mathrm{Log}\ Q) + 1.81$$

and

$$\mathrm{Log\ (MES)} = 0.62(\mathrm{Log}\ Q)^2 + 0.54(\mathrm{Log}\ Q) + 1.78$$

These equations allowed us to calculate the average suspended matter flows for the 2005–2006 data. During this period, the Mazafran wadi provided an average flow of around *11 t/km²/year* upstream and *8.8 t/km²/year* downstream.

Examination of the seasonal plots shows the differences in flow values over the seasons. High liquid flows are observed during winter (350 $m^3\ s^{-1}$) and spring (170 $m^3\ s^{-1}$) with a highly condensed point cloud where maximum solids flows exceed 15,500 kg s^{-1} and 3800 kg s^{-1}. In autumn, the liquid flows are less than 100 $m^3\ s^{-1}$ and in summer 10 $m^3\ s^{-1}$.

Acknowledgments The authors especially thank the heads of the National Agency for Blida Hydraulic Resources (ANRH) Messrs Tabet and Imessoudene who have made numerous hydrological and chemical data available to us and who have also well wanted to analyze the samples.

References

Aminot-Suchet P, Probst JL (1995) A global model for present-day atmospheric soil CO2 consumption by chemical erosion of continental rocks (GEM-CO2). Tellus 47B:273–280

ANRH n.d.. Agence Nationale des Ressources Hydrauliques de Blida: Liquid and solid flow old and 2005–2006 MES data

Bouanani A (2004) Hydrology, solid transportation, and modeling. Study of some sub-basins of the Tafna River (NW - Algeria). State Thesis. Abu Bakr Belkaid Tlemcen University. 250 p

Boudjadja A, Messahel M, Pauc H (2003) Water resources in Northern Algeria. Revue des Sciences de l'Eau 16/3 pp 285–304

Bourouba M (2002) Comparison of the suspended solid charge in Algerian wadis: synthesis test. Bulletin Reseau Erosion 21, IRD Montpellier (France). pp 358–374

Bourrin F (2007) Variability and fate of sedimentary inputs by coastal rivers: the case of the Têt-Littoral Roussillonnais system in the Gulf of Lion. Doctoral thesis. The University of Perpignan. 305 pages

Foudil Bouras A E (2012) A geochemical approach of an Algerian coastal hydro system: organic matter transfer from the Mazafran wadi to Bou Ismail Bay. Ph.D. thesis. USTHB. 188 pages

Garcia-Esteve J, Ludwig W (2003) Suspended matter and particulate carbon transfer in the Têt basin (South of France). IAHS Publishing No. 278 pp. 442–447

Lespinas F (2008) Impact of climate change on the hydrology of coastal rivers in the Languedoc-Roussillon region. The Ph.D. thesis University of Perpignan. 339 pages

Linsley RK, Franzini JB (1979) Water Resources Engineering, 3rd edn. McGraw-Hill, New York

Messaoud Nacer N, Remini B, Hadj Kadour B, Habi M (2006) Water pollution problems. Methodological and legislative aspects. The case of surface waters of the Mazafran plain (Mitidja, Algeria). TSM number 5:89–97

Meybeck M (1985) Time variability in the chemical composition of rivers and their solution and suspension transportation. Revue Française des Sciences de l'Eau Vol. 4 pp 93-121

Pauc H (2005) Formation of the Aude, Orb and Herault prodeltas and their characterization using physicochemical and sedimentological parameters. Mar Geol 222–223:335–343

Probst JL (1992) Geochemistry and hydrology of continental erosion. Mechanisms, current global balance sheet and fluctuations over the last 500 million years. Geol science, Memo, Strasbourg 94:161

Serrat P (1998) Spatial analysis of the erodibility of a watershed through the integration of multi-source data, in 17 Réunion des Sciences de la Terre, BRGM Brest, 194

Serrat P (1999) Current sediment dynamics of a Mediterranean river system: the Agly (France). CR Acad Sci 329:189–196

Serrat P, Ludwig W, Navarro B, Blazi JL (2001) Spatio-temporal variability of suspended matter flows in a Mediterranean coastal river: the Têt (France). CR Acad Sci Paris, Sciences de la Terre et des Planètes 333:389–397

Terfous A, Megnounif A, Bouanani A (2001) Study of solid transport in suspension in the Mouilah wadi (North West Algeria). Revue des Sciences de l'eau 14:173–185