Analysis of the River Isonzo discharge (1998-2005)

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ABSTRACT The River Isonzo is the largest river flowing into the Gulf of Trieste, a semi-enclosed basin located in the northeastern corner of the Adriatic Sea. Eight years of discharge and rainfall data (1998-2005) were collected from within the Isonzo watershed. Discharge was obtained at two locations, one at about 300 m downstream from the Solkan hydropower plant (Slovenia) and the other at Turriaco (Italy), at 13 km from the mouth. During 1998-2001, the mean flow was 91.2 m^3/s at Solkan and 123.1 m^3/s at Turriaco, with an annual cycle characterized by distinct maxima in spring and fall. From 2002 to 2005, the mean flow was weaker (about 68.7 m^3/s at Solkan, 59.3 m^3/s at Turriaco) and the peaks in the annual cycle were less distinct. Omitting the year 2003, that was exceptionally dry, similar results (74.4 m^3/s at Solkan, 66.6 m^3/s at Turriaco) were observed for the same period 2002-2005. Rainfall data was obtained at 6 locations (5 in Slovenia and 1 in Italy), and significant correlations between annual discharge and rainfall were found at most locations. The best correlations were found at stations with the highest annual rainfall (Soča and Kobarid), evidencing that, despite the damming, the River Isonzo discharge is strongly subject to the rainfall in the Slovenian territory.

1. Introduction

In recent years, there has been a growing interest in the hydrological and hydraulic studies of watercourses. Increasing attention to hydro-geological risk assessment and a broad concern for the preservation of freshwater resources have led Italian and European institutions to begin a number of actions and projects aiming at providing effective tools for the correct management of river areas. The Isonzo River (Fig. 1), a watercourse shared by Slovenia and Italy, is of particular environmental interest (SIMIS, 2005). The River Isonzo waters contribute greatly to the nourishment of the groundwaters of the eastern Friuli alluvial plain, where the wells supply drinking water for the 230,000 inhabitants of Trieste. The Isonzo also plays an important role in the production of energy, since some of the main Slovenian hydroelectric power plants are placed along its course. In addition, the Isonzo represents, by far, the main freshwater source for the Gulf of Trieste (northern Adriatic Sea), greatly exceeding the combined discharge of other freshwater inputs (the River Timavo, Ospo and Rosandra torrents, minor karstic springs on the Italian side, and the Rivers Rižana and Dragonja on the Slovenian side). Finally, the Isonzo is of interest because it was, for a long time, where the mercury in the Gulf of Trieste came from, due to cinnabar mining activity since the sixteenth century (Faganeli *et al*., 1991; Horvat *et al*., 1999; Covelli *et al*., 2001, 2006) in the upper River Isonzo drainage basin.

Consequently, an understanding of the seasonal and interannual variability of the River Isonzo is important for the sustainable management of local freshwater supplies, and represents an important tool for understanding the physical and biogeochemical variability in the Gulf dynamics (Accerboni and Mosetti, 1967; Stravisi and Crisciani, 1986; Barbieri *et al.*, 1999; Malačič and Petelin, 2001, Malačič *et al.*, 2006).

Previous studies (Širca *et al.*, 1999; Covelli *et al.*, 2004) demonstrated that the river discharge usually shows two typical flood periods: one in spring, mainly due to the snowmelt, and one in autumn, caused by the heavy rainfalls. The former lasts from March to June while the latter is shorter (October to November), though in these months the River Isonzo discharge usually reaches its annual maximum, occasionally exceeding 2500 m^3/s.

However, an accurate assessment of the River Isonzo discharge is a fairly difficult task because of its extremely complex hydrology (Mosetti, 1983). The losses and contributions due to the karstic system are virtually unknown. When the riverbeds of the tributaries are dry, the River Isonzo can still discharge a small amount of freshwater into the Gulf, fed by the spring line located about 15 km upstream from the mouth. The presence of the dam for the hydroelectric plant at Solkan (Slovenia), built in 1984, further complicates the estimations of the River Isonzo discharge, since the plant basin affects the downstream water flow. Despite these complicating factors, the river discharge in the Gulf of Trieste is thought to depend mainly on the discharge of its principal tributaries: the Koritnica, Torre-Natisone, Idrijca and Vipacco. The Torre-Natisone, Idrijca and Vipacco annual mean flow are about 53 m^3/s, 34 m^3/s and 38 m^3/s, respectively (Regione Friuli Venezia Giulia, 1986). A considerable number of different estimates of the mean annual flow rate of the River Isonzo are available: Mosetti (1983) estimated a rate of 165 m^3/s at Pieris (a village close to Turriaco); a study performed by the Friuli Venezia Giulia Region estimated the annual mean flow rate to be about 234 m^3/s (Regione Autonoma Friuli Venezia Giulia, 1986); in the same year Olivotti *et al.* (1986) issued an approximate mean annual discharge of about 80-110 m^3/s; Raicich (1994) reported a value of about 204 m^3/s; Širca and Rajar (1997) estimated the annual mean flow to be about 115 m^3/s. Later, Širca *et al.* (1999) gave an annual mean flow rate of about 170 m^3/s, extrapolated from the River Isonzo discharge (about 94 m^3/s) observed at about 40 km before the River Isonzo discharges into the Gulf (Solkan dam, Slovenia), and from the Vipacco discharge (about 18 m^3/s) at Miren (Slovenia). Unfortunately, aside from the estimates of Mosetti (1983) and Raicich (1994), the time ranges considered for the annual averages given in the afore-mentioned works are not provided.

In February 2004, the National Institute of Oceanography and Experimental Geophysics (OGS) set up a monitoring station, equipped with an ADCP Nortek 1000 kHz Aquadopp profiler (Deponte, 2005), to provide accurate measurements of the River Isonzo discharge. However the results of this monitoring station (Querin *et al.*, 2006) are still preliminary.

Moreover, in 2002 a partnership with several partners (the Civil Protection of the Friuli Venezia Giulia Region, the Basin Authority of the Rivers Isonzo, Tagliamento, Livenza, Piave, Brenta-Bacchiglione, the Environmental Agency of the Republic of Slovenia, the Department of Civil Engineering and the Department of Electrical, Electronic and Computer Engineering of the University of Trieste, the Environmental Protection Agency of Veneto Region and the Faculty of Civil Engineering and Geodesy of the University of Ljubljana) started the SIMIS (Soča-Isonzo integrated Monitoring System) project, whose main objective was the implementation of a joint monitoring system of the whole River Isonzo basin. The project tasks included the hydrologic and

Fig. 1 - Isonzo river watercourse.

hydraulic study of the Isonzo basin, based on the analysis of the historic data series available from all partners (SIMIS, 2005). However, the final results of the project have not been published yet.

Nevertheless, the River Isonzo discharge data computed from hydrometric level measurements, collected from 1998 to 2005 in Solkan and in Turriaco (Fig. 1), are available and discussed in this work, so as to provide new information about the interannual variability of the river discharge as well as the presence of trends. A further point of interest is that Turriaco is the last gauging station before the river flows into the Gulf of Trieste, thus providing the best estimate of the River Isonzo freshwater load entering the basin.

Finally, rainfall data from 6 meteorological stations situated along the river course (Fig. 1) are analysed and put into correlation with the discharge data.

2. Materials and methods

2.1. Study area

The Isonzo Alpine river (Soča in Slovenian) rises in Dolina Trenta (north-western Slovenia) at

Table 1 - Technical characteristics of water level gauges; n.a.: not available; f.s.: full scale.

	Turriaco	Solkan
Measurement range	0 - 10 m	n.a.
Working temperature range	± 30 °C	-25 °C…+60 °C
Accuracy	± 1 cm (0.1% f.s.)	< 1 cm
Drift	± 1 cm/year	n.a

an altitude of 935 m above sea level. Its drainage basin covers 3452 km^2, of which 1115 km^2 in Italian territory (Autorità di Bacino dei fiumi Isonzo, Tagliamento, Livenza, Piave, Brenta-Bacchiglione, 2004).

The river flows on a Mesozoic limestone formation in its upper course and near Kanal runs on Paleocene–Eocene flysch formation (marl and sandstone) that continues into Italian territory (Stefanini, 1976; Geodetski Zavod Slovenije, 1993). Then the river flows across the eastern part of the Friuli alluvial plain that is formed by the Isonzo, Torre-Natisone and Vipacco river alluvial deposits; finally, it flows into the Gulf of Trieste.

2.2. Data collection and analysis

From 1998 to 2005 the River Isonzo outflow was measured hourly as a hydrometric level at the Turriaco gauging station, placed at 13 km from the river mouth (Fig. 1). The measurements, provided by the "Unità Operativa Idrografica di Udine - Direzione Regionale per l'Ambiente" (Udine Hydrographic Task Group - Regional Environment Bureau) of the Friuli Venezia Giulia Region, were performed by means of a CAE PLM10 pressure gauge, whose technical characteristics are reported in Table 1. Checks for the gauge drift were performed, approximately, every 4 months; if marked differences were observed, the instrument was re-calibrated. Data were successively converted into discharge values using a rating curve that was computed by Regional Environment Bureau in 1985 and updated in 1995.

A comparison between the stream flow obtained by the rating curve and the one measured by the OGS ADCP current-meter was done for two different 20-day-long periods (Summer 2002, Spring 2004): the agreement was fairly good, with the exception of particularly high values (> 600 m^3/s) with the major mismatches of up to 25 % (Querin *et al.*, 2006).

An analysis of discharge data indicated that the Turriaco gauging station could be affected by errors induced by the presence of the Torre confluence near the station (SIMIS, 2005); more specifically, in order to correct the exceptional discharge values (>2500-3000 m^3/s) that have been occasionally recorded, Zorba (2005) proposed to subtract 0.84 m from the hydrometric level measurements of Turriaco. However, since more evidence is presumably needed to confirm such results, this correction was not applied in the present analysis.

Daily mean discharge data at the Solkan gauging station, placed at about 40 km from the river mouth (Fig. 1), were provided by the Agencija Republike Slovenije za Okolje (Environmental Agency of the Republic of Slovenia). The measurements were performed by means of a SEBA-OMEGA pressure gauge, placed about 300 m downstream from the Solkan plant dam. Its technical characteristics are reported in Table 1.

Hourly discharge values measured at Turriaco were averaged to daily means. Then monthly means and medians were computed for both Solkan and Turriaco data. Descriptive statistics included both the mean and the median as estimators for a central tendency because of the marked skewness of the frequency distribution of discharge data. Moreover, for each year annual mean, median, minimum and maximum values were computed starting from daily means. Finally, data of corresponding months were gathered in order to provide monthly mean and median cycles as well as minimum and maximum values for each mean/median month.

Daily total precipitation for the Slovenian stations was provided by the Environmental Agency of the Republic of Slovenia – Ministry of the Environment and Special Planning, while daily total precipitation for the Gradisca station was downloaded from the website of the Osservatorio Meteorologico Regionale OSMER of the Regional Environmental Protection Agency of Friuli Venezia Giulia (Regional Meteorological Observatory; http://www.osmer.fvg.it).

3. Results and discussion

3.1. River Isonzo discharge

Tables 2 to 5 and 6 to 9 report monthly mean, median, minimum and maximum values of the River Isonzo discharge computed on daily mean values measured at the Turriaco and Solkan stations, respectively, for each year of the 1998-2005 period; the annual mean and median cycle and the overall annual mean and median for the whole period are also given. The 1998-2005 annual mean measured at Turriaco, 91.2 m^3/s (Table 2), is remarkably lower than what was estimated by other authors (Mosetti, 1983; Regione Autonoma Friuli Venezia Giulia, 1986; Raicich, 1994; Širca and Rajar, 1997), but consistent with Olivotti *et al*. (1986). At Solkan the 1998-2005 annual mean is 80.4 m^3/s (Table 6), slightly lower than the value of 94 m^3/s reported by Širca *et al*. (1999). The 1998-2005 annual median values, 44.4 m^3/s (Table 3) and 47.4 m^3/s (Table 7) at Turriaco and Solkan respectively, are much lower than the corresponding mean values, since they are less affected by extremely high discharge values; moreover, the median value at Turriaco is unexpectedly lower than that calculated for Solkan, but this result is moderately reversed (Turriaco: 49.9 m^3/s ; Solkan: 48.7 m^3/s) if year 2003, that was exceptionally dry, is removed.

Monthly mean and median cycles confirm the well-known annual cycle, consisting of two maxima (April and October-November) and two minima (February and August), though a marked interannual variability is present, especially at Turriaco. In fact, at this station very high daily discharge rates are occasionally observed in months usually included in the drought period, as in January 2001 (1061.5 m^3/s) and August 2002 (730.2 m^3/s); on the other hand, extremely low daily discharge rates are observed also in April 1998 (0.2 m^3/s), 2002 (4.2 m^3/s), 2003 (1.3 m^3/s) and 2005 (3.8 m^3/s), October 2003 (0.0 m^3/s) and November 2005 (1.1 m^3/s). At Solkan the interannual variability is still present though the differences between maximum and minimum values are smaller than at Turriaco. The discharge values of the monthly mean cycle at Turriaco are always greater than the corresponding values observed in Solkan, with the sole exception of July and August, when the water discharge from the plant basin is likely to damp the outflow decrease that occurs in summer. The effect of the dam on the river discharge can probably explain why the median cycle values at Solkan are usually greater than those measured at Turriaco, with

Table 2 - Monthly mean values of the River Isonzo discharge at Turriaco for each year of the period 1998-2005 were computed on daily mean discharge values. Overall mean, median, minimum and maximum values were computed including all the monthly values. Units are m^3/s.

Mean-T	1998	1999	2000	2001	2002	2003	2004	2005	Mean	Median	Min	Max
Jan	62.4	74.4	38.4	351.1	10.0	59.4	67.8	16.6	85.0	60.9	10.0	351.1
Feb	23.2	47.6	27.4	124.7	38.9	12.7	73.3	1.1	43.6	33.2	1.1	124.7
Mar	15.5	129.1	122.7	320.0	52.5	4.5	75.0	12.2	91.4	63.7	4.5	320.0
Apr	137.0	223.3	173.9	147.6	56.7	34.7	96.7	107.7	122.2	122.3	34.7	223.3
May	60.7	163.7	127.9	94.5	71.5	12.2	127.7	47.3	88.2	83.0	12.2	163.7
Jun	51.5	105.4	65.9	74.8	65.6	2.1	62.9	4.3	54.1	64.2	2.1	105.4
Jul	112.4	48.7	113.2	55.0	29.6	6.7	29.3	26.3	52.7	39.1	6.7	113.2
Aug	30.8	51.1	43.0	10.2	124.1	2.4	13.1	34.7	38.7	32.7	2.4	124.1
Sep	175.0	49.9	52.0	124.4	29.9	4.2	39.0	57.6	66.5	50.9	4.2	175.0
Oct	395.3	173.0	178.2	92.7	138.7	45.8	192.1	57.1	159.1	155.8	45.8	395.3
Nov	194.6	123.2	665.9	37.9	221.4	173.0	136.9	29.9	197.9	154.9	29.9	665.9
Dec	51.5	120.6	242.0	4.4	72.0	89.9	79.0	97.6	94.6	84.5	4.4	242.0
Mean	109.2	109.2	154.2	119.8	75.9	37.3	82.7	41.0	91.2			
Median	61.5	113.0	117.9	93.6	61.1	12.5	74.1	32.3		62.6		
Min	15.5	47.6	27.4	4.4	10.0	2.1	13.1	1.1			1.1	
Max	395.3	223.3	665.9	351.1	221.4	173.0	192.1	107.7				665.9

Table 3 - Monthly median values of the River Isonzo discharge at Turriaco for each year of the period 1998-2005 were computed on daily mean discharge values. Overall mean, median, minimum and maximum values were computed including all the monthly values. Units are m^3/s.

Med-T	1998	1999	2000	2001	2002	2003	2004	2005	Mean	Median	Min	Max
Jan	57.4	76.1	18.8	256.3	0.7	38.9	30.0	11.1	61.2	34.4	0.7	256.3
Feb	24.8	29.9	17.0	116.5	31.7	7.8	11.8	0.9	30.0	20.9	0.9	116.5
Mar	17.6	126.0	103.5	279.9	31.8	3.3	53.0	0.3	76.9	42.4	0.3	279.9
Apr	107.1	209.7	170.6	139.0	43.6	27.0	83.5	88.3	108.6	97.7	27.0	209.7
May	57.4	164.2	124.9	90.5	59.7	9.7	72.5	40.1	77.4	66.1	9.7	164.2
Jun	48.8	105.7	67.4	67.4	43.8	1.5	45.0	3.1	47.8	46.9	1.5	105.7
Jul	70.6	49.4	108.2	39.2	20.9	2.3	17.6	10.5	39.8	30.1	2.3	108.2
Aug	23.3	19.8	26.2	9.3	69.1	0.0	9.0	30.8	23.5	21.6	0.0	69.1
Sep	105.0	28.9	47.2	50.4	14.8	0.6	24.7	16.1	35.9	26.8	0.6	105.0
Oct	243.2	143.8	162.5	86.9	72.3	22.6	123.3	24.2	109.8	105.1	22.6	243.2
Nov	127.7	118.0	565.1	20.8	110.2	63.8	72.3	4.4	135.3	91.3	4.4	565.1
Dec	51.3	117.8	225.4	3.1	45.8	26.6	29.5	29.8	66.2	37.8	3.1	225.4
Mean	77.9	99.1	136.4	96.6	45.4	17.0	47.7	21.6	67.7			
Median	57.4	111.8	105.8	77.1	43.7	8.7	37.5	13.6		44.4		
Min	17.6	19.8	17.0	3.1	0.7	0.0	9.0	0.3			0.0	
Max	243.2	209.7	565.1	279.9	110.2	63.8	123.3	88.3				565.1

Table 4 - Monthly minimum values of the River Isonzo discharge at Turriaco for each year of the period 1998-2005 were computed on daily mean discharge values. Overall mean, median, minimum and maximum values were computed including all the monthly values. Units are m^3/s.

Min-T	1998	1999	2000	2001	2002	2003	2004	2005	Mean	Median	Min	Max
Jan	30.1	17.9	2.7	122.6	0.0	15.8	13.1	2.7	25.6	14.5	0.0	122.6
Feb	10.8	11.3	1.8	65.5	1.9	2.5	2.5	0.3	12.1	2.5	0.3	65.5
Mar	0.5	77.9	20.6	64.1	7.1	1.4	23.5	0.1	24.4	13.9	0.1	77.9
Apr	0.2	112.8	126.9	86.6	4.2	1.3	50.7	3.8	48.3	27.4	0.2	126.9
May	37.9	128.0	97.6	72.1	41.5	4.0	43.3	17.6	55.2	42.4	4.0	128.0
Jun	26.2	76.4	14.6	33.8	14.0	0.1	22.4	1.3	23.6	18.5	0.1	76.4
Jul	20.7	15.1	13.5	17.9	7.2	0.0	3.7	2.5	10.1	10.3	0.0	20.7
Aug	10.7	6.3	2.7	3.5	14.3	0.0	2.7	1.5	5.2	3.1	0.0	14.3
Sep	19.1	4.3	2.4	3.5	4.6	0.0	5.3	4.5	5.5	4.4	0.0	19.1
Oct	123.2	65.4	51.9	12.6	9.6	0.0	8.3	6.4	34.7	11.1	0.0	123.2
Nov	89.9	89.6	276.1	9.7	25.9	18.1	16.5	1.1	65.9	22.0	1.1	276.1
Dec	18.7	83.7	130.0	0.4	19.3	7.1	10.7	6.0	34.5	14.7	0.4	130.0
Mean	32.3	57.4	61.7	41.0	12.5	4.2	16.9	4.0	28.8			
Median	19.9	70.9	17.6	25.9	8.4	1.4	11.9	2.6		11.0		
Min	0.2	4.3	1.8	0.4	0.0	0.0	2.5	0.1			0.0	
Max	123.2	128.0	276.1	122.6	41.5	18.1	50.7	17.6				276.1

Table 5 - Monthly maximum values of the River Isonzo discharge at Turriaco for each year of the period 1998-2005 were computed on daily mean discharge values. Overall mean, median, minimum and maximum values were computed including all the monthly values. Units are m^3/s.

Max-T	1998	1999	2000	2001	2002	2003	2004	2005	Mean	Median	Min	Max
Jan	116.2	127.2	113.9	1061.5	66.6	188.9	358.6	55.1	261.0	121.7	55.1	1061.5
Feb	35.9	118.9	92.4	217.0	158.8	55.0	645.1	2.6	165.7	105.6	2.6	645.1
Mar	44.3	269.1	428.5	878.0	191.6	14.4	238.9	72.3	267.1	215.3	14.4	878.0
Apr	377.2	620.0	234.9	348.5	303.9	117.6	278.3	388.4	333.6	326.2	117.6	620.0
May	110.3	211.0	197.8	146.2	149.4	27.9	501.4	132.5	184.6	147.8	27.9	501.4
Jun	94.5	125.8	137.9	145.5	360.6	6.1	301.0	12.3	148.0	131.9	6.1	360.6
Jul	718.4	114.1	361.8	219.4	146.7	53.1	146.6	114.6	234.3	146.6	53.1	718.4
Aug	83.1	139.7	123.8	28.1	730.2	42.5	53.1	128.0	166.1	103.5	28.1	730.2
Sep	930.3	137.3	144.3	592.9	179.7	64.3	199.1	471.2	339.9	189.4	64.3	930.3
Oct	1850.4	587.1	469.2	326.7	573.5	188.2	939.6	208.4	642.9	521.3	188.2	1850.4
Nov	1059.6	173.3	1703.2	187.8	839.6	939.6	1267.3	276.8	805.9	889.6	173.3	1703.2
Dec	87.0	220.3	531.5	17.1	262.6	832.4	490.4	565.4	375.8	376.5	17.1	832.4
Mean	458.9	237.0	378.3	347.4	330.3	210.8	451.6	202.3	327.1			
Median	113.2	156.5	216.4	218.2	227.1	59.6	329.8	130.2		190.2		
Min	35.9	114.1	92.4	17.1	66.6	6.1	53.1	2.6			2.6	
Max	1850.4	620.0	1703.2	1061.5	839.6	939.6	1267.3	565.4				1850.4

Table 6 - Monthly mean values of the River Isonzo discharge at Solkan for each year of the period 1998-2005 were computed on daily mean discharge values. Overall mean, median, minimum and maximum values were computed including all the monthly values. Units are m^3/s.

Mean-S	1998	1999	2000	2001	2002	2003	2004	2005	Mean	Median	Min	Max
Jan	66.9	37.1	27.3	231.3	23.3	63.9	69.2	33.9	69.1	50.5	23.3	231.3
Feb	26.5	25.3	24.1	74.6	42.8	25.1	73.3	20.8	39.1	25.9	20.8	74.6
Mar	24.5	90.2	75.3	223.8	55.7	22.0	98.9	35.5	78.2	65.5	22.0	223.8
Apr	151.9	161.0	110.4	110.1	55.6	54.4	126.2	105.3	109.4	110.3	54.4	161.0
May	76.9	97.3	81.4	84.4	69.5	36.3	126.1	67.5	79.9	79.2	36.3	126.1
Jun	60.5	48.6	38.0	80.0	61.9	24.8	87.4	29.7	53.9	54.6	24.8	87.4
Jul	115.5	26.6	71.2	59.9	43.9	30.0	58.8	55.2	57.6	57.0	26.6	115.5
Aug	39.7	45.1	34.8	24.0	95.1	23.6	88.5	58.2	51.1	42.4	23.6	95.1
Sep	144.4	42.3	39.4	102.7	35.4	26.3	66.9	67.6	65.6	54.6	26.3	144.4
Oct	312.4	129.1	129.5	73.0	110.7	72.6	175.6	69.9	134.1	119.9	69.9	312.4
Nov	148.6	51.0	486.3	38.6	183.1	148.5	111.7	44.4	151.5	130.1	38.6	486.3
Dec	26.9	84.7	149.2	18.7	75.6	93.0	75.1	79.1	75.3	77.4	18.7	149.2
Mean	99.6	69.9	105.6	93.4	71.0	51.7	96.5	55.6	80.4			
Median	71.9	49.8	73.3	77.3	58.8	33.1	87.9	56.7		67.6		
Min	24.5	25.3	24.1	18.7	23.3	22.0	58.8	20.8			18.7	
Max	312.4	161.0	486.3	231.3	183.1	148.5	175.6	105.3				486.3

Table 7 - Monthly median values of the River Isonzo discharge at Solkan for each year of the period 1998-2005 were computed on daily mean discharge values. Overall mean, median, minimum and maximum values were computed including all the monthly values. Units are m^3/s.

Med-S	1998	1999	2000	2001	2002	2003	2004	2005	Mean	Median	Min	Max
Jan	60.0	32.6	23.6	145.0	15.4	46.2	48.7	28.9	50.1	39.4	15.4	145.0
Feb	25.7	19.5	22.3	64.1	36.8	23.0	32.0	20.8	30.5	24.3	19.5	64.1
Mar	22.1	81.5	40.3	162.0	39.4	20.7	87.4	25.6	59.9	39.9	20.7	162.0
Apr	140.5	136.0	109.0	103.0	47.3	49.0	121.0	97.8	100.4	106.0	47.3	140.5
May	69.1	92.6	77.0	78.2	60.0	32.7	97.0	61.1	71.0	73.1	32.7	97.0
Jun	55.1	48.7	32.9	62.0	48.2	22.4	69.3	28.3	45.8	48.4	22.4	69.3
Jul	87.3	25.0	52.6	43.9	36.8	21.0	51.0	38.0	44.5	41.0	21.0	87.3
Aug	32.3	28.5	29.6	22.9	61.6	16.6	44.8	44.7	35.1	31.0	16.6	61.6
Sep	117.5	27.0	28.3	47.6	27.0	21.3	50.2	33.2	44.0	30.8	21.3	117.5
Oct	198.0	94.5	101.0	69.9	66.5	44.9	130.0	40.9	93.2	82.2	40.9	198.0
Nov	94.1	41.5	384.0	26.5	109.0	102.2	76.1	25.0	107.3	85.1	25.0	384.0
Dec	25.0	69.1	121.0	17.6	56.4	59.0	43.3	42.2	54.2	49.9	17.6	121.0
Mean	77.2	58.0	85.1	70.2	50.4	38.2	70.9	40.5	61.3			
Median	64.6	45.1	46.5	63.0	47.7	27.8	60.1	35.6		47.4		
Min	22.1	19.5	22.3	17.6	15.4	16.6	32.0	20.8			15.4	
Max	198.0	136.0	384.0	162.0	109.0	102.2	130.0	97.8				384.0

Table 8 - Monthly minimum values of the River Isonzo discharge at Solkan for each year of the period 1998-2005 were computed on daily mean discharge values. Overall mean, median, minimum and maximum values were computed including all the monthly values. Units are m^3/s.

Min-S	1998	1999	2000	2001	2002	2003	2004	2005	Mean	Median	Min	Max
Jan	32.9	17.4	15.6	72.6	14.2	32.2	25.0	22.4	29.0	23.7	14.2	72.6
Feb	21.8	14.6	15.1	40.3	14.6	16.9	21.0	18.9	20.4	17.9	14.6	40.3
Mar	18.5	34.5	23.1	40.3	21.5	15.6	40.5	18.9	26.6	22.3	15.6	40.5
Apr	23.4	68.3	73.5	70.2	19.8	25.8	65.5	26.4	46.6	46.0	19.8	73.5
May	46.2	58.2	49.4	61.6	43.3	25.4	62.3	37.4	48.0	47.8	25.4	62.3
Jun	34.8	25.0	20.2	38.3	30.7	17.9	49.5	19.4	29.5	27.9	17.9	49.5
Jul	31.9	14.4	20.6	30.7	24.1	16.6	29.6	22.7	23.8	23.4	14.4	31.9
Aug	19.8	17.4	19.1	13.7	28.7	15.6	24.5	20.5	19.9	19.5	13.7	28.7
Sep	22.5	17.4	18.4	16.9	18.1	15.6	29.1	23.1	20.1	18.3	15.6	29.1
Oct	110.0	29.1	37.4	13.2	22.5	20.4	30.8	26.0	36.2	27.6	13.2	110.0
Nov	34.5	30.8	134.0	19.6	36.8	51.8	36.0	21.1	45.6	35.3	19.6	134.0
Dec	19.8	34.5	77.9	13.2	39.4	35.2	29.1	25.2	34.3	31.8	13.2	77.9
Mean	34.7	30.1	42.0	35.9	26.1	24.1	36.9	23.5	31.7			
Median	27.7	27.1	21.9	34.5	23.3	19.2	30.2	22.6		25.0		
Min	18.5	14.4	15.1	13.2	14.2	15.6	21.0	18.9			13.2	
Max	110.0	68.3	134.0	72.6	43.3	51.8	65.5	37.4				134.0

Table 9 - Monthly maximum values of the River Isonzo discharge at Solkan for each year of the period 1998-2005 were computed on daily mean discharge values. Overall mean, median, minimum and maximum values were computed including all the monthly values. Units are m^3/s.

Max-S	1998	1999	2000	2001	2002	2003	2004	2005	Mean	Median	Min	Max
Jan	124.0	90.7	47.1	846.0	92.4	226.0	215.0	65.4	213.3	108.2	47.1	846.0
Feb	40.5	90.7	47.9	154.0	146.0	39.3	398.0	23.4	117.5	69.3	23.4	398.0
Mar	47.6	200.0	321.0	951.0	171.0	30.3	236.0	99.7	257.1	185.5	30.3	951.0
Apr	317.0	501.0	190.0	277.0	225.0	113.0	252.0	247.0	265.3	249.5	113.0	501.0
May	148.0	151.0	174.0	133.0	156.0	76.2	374.0	124.0	167.0	149.5	76.2	374.0
Jun	130.0	70.9	83.3	171.0	228.0	58.9	254.0	53.9	131.3	106.7	53.9	254.0
Jul	428.0	67.4	264.0	259.0	131.0	99.7	181.0	142.0	196.5	161.5	67.4	428.0
Aug	132.0	202.0	94.5	34.9	460.0	94.6	400.0	136.0	194.3	134.0	34.9	460.0
Sep	529.0	146.0	105.0	529.0	132.0	90.6	235.0	289.0	257.0	190.5	90.6	529.0
Oct	1670.0	640.0	484.0	260.0	497.0	221.0	671.0	208.0	581.4	490.5	208.0	1670.0
Nov	893.0	101.0	1220.0	148.0	678.0	424.0	546.0	262.0	534.0	485.0	101.0	1220.0
Dec	39.6	191.0	384.0	38.6	198.0	392.0	313.0	294.0	231.3	246.0	38.6	392.0
Mean	374.9	204.3	284.6	316.8	259.5	155.5	339.6	162.0	262.1			
Median	140.0	148.5	182.0	215.0	184.5	97.2	283.5	139.0		185.5		
Min	39.6	67.4	47.1	34.9	92.4	30.3	181.0	23.4			23.4	
Max	1670.0	640.0	1220.0	951.0	678.0	424.0	671.0	294.0				1670.0

the exception of October and, to a much lesser extent, March and November. In fact, medians are much less sensitive to the extremely high values that are occasionally observed at Turriaco; in addition, at Solkan the river discharge never falls to exceptionally low values because the water flow is controlled by the dam.

Finally, in both stations a clear decrease of the river discharge occurs starting from 2002, as demonstrated in Figs. 2a and 3a (Turriaco) and Figs. 2b and 3b (Solkan), where the time series of the daily mean discharge are given. In particular, Figs. 2c and 3c show that the differences between Turriaco and Solkan are mostly positive for years 1998-2001, while the reverse occurs in 2002-2005. Moreover, the exceptionally prolonged drought period that characterised the winter, spring and summer of year 2003 is evident. Although discharge peaks are rather scattered along the temporal axis, Figs. 2 and 3 also show the presence of the well-known annual cycle: maximum flow rates occur mainly in autumn, when the higher values are observed, and in spring; on the contrary, the summer months usually represent drought periods as well as winter months, though the latter can be occasionally characterised by fairly high discharges (winter 2001).

The rather neat distinction between the 1998-2001 and 2002-2005 periods has been further investigated (Tables 10 and 11). In order to remove the effects of the anomalous discharge values observed in 2003, the same statistics studied for the years 1998-2001 and 2002-2005 were also computed for the 2002-2005 period, excluding year 2003 (2002-2005*). The annual mean and median values recorded in both stations highlight the strong decrease during the study period: at Turriaco the annual mean and median are, respectively, 123.1 m^3/s and 81.5 m^3/s for 1998-2001, 59.3 m^3/s and 26.8 m^3/s for 2002-2005, 66.6 m^3/s and 30.4 m^3/s when 2003 is excluded from 2002-2005 (Table 10); at Solkan these values are 92.1 m^3/s and 57.6 m^3/s for 1998-2001, 68.7 m^3/s and 44.8 m^3/s for 2002-2005, 74.4 m^3/s and 46.0 m^3/s for 2002-2005, when 2003 is excluded (Table 11).

In the 1998-2001 years, the maximum daily mean at Turriaco was observed on 7 October 1998 with 1850.4 m^3/s, when an exceptionally high hourly mean was observed on 6 October 1998 at 14:00 with 3284.1 m^3/s; very low values (< 1 m^3/s) were recorded only from 29 March 1998 to 5 April 1998, following the dry winter season; from November 2000 to early February 2001, the daily mean discharge was uninterruptedly greater than 100 m^3/s. At the Solkan station, between 1998 and 2001 mean daily discharges never fell below 13.2 m^3/s (26 January 2001 and 29 December 2001), probably because of the tempering effect of the plant basin; the maximum daily mean value (1670 m^3/s) was observed on 6 October 1998.

During years 2002-2005, the seasonal variation is less evident and the river discharge is markedly lower than in the previous four years. At Turriaco the maximum value was observed on 1 November 2004 with 1267.3 m^3/s; very low values (< 1 m^3/s) were rather diffuse during this period: 123 days against only 15 days in 1998-2001. In particular, during the exceptionally dry year 2003, at Turriaco 75 days with very low discharge (< 1 m^3/s) were recorded and 312 days had mean discharges lower than the 2002-2005 mean value (59.3 m^3/s). At Solkan, discharge values were never lower than 14.2 m^3/s (January 2002) and, more generally, the daily mean values for 2002-2005 did not show the strong decrease observed at Turriaco with respect to the 1998-2001 years. Moreover, the results suggest that the exclusion of year 2003 does not introduce any substantial modification to the results of the comparison between 1998-2001 and the 2002-2005 periods.

The boxplots, reporting the monthly distribution of river discharge daily mean values, (Figs.

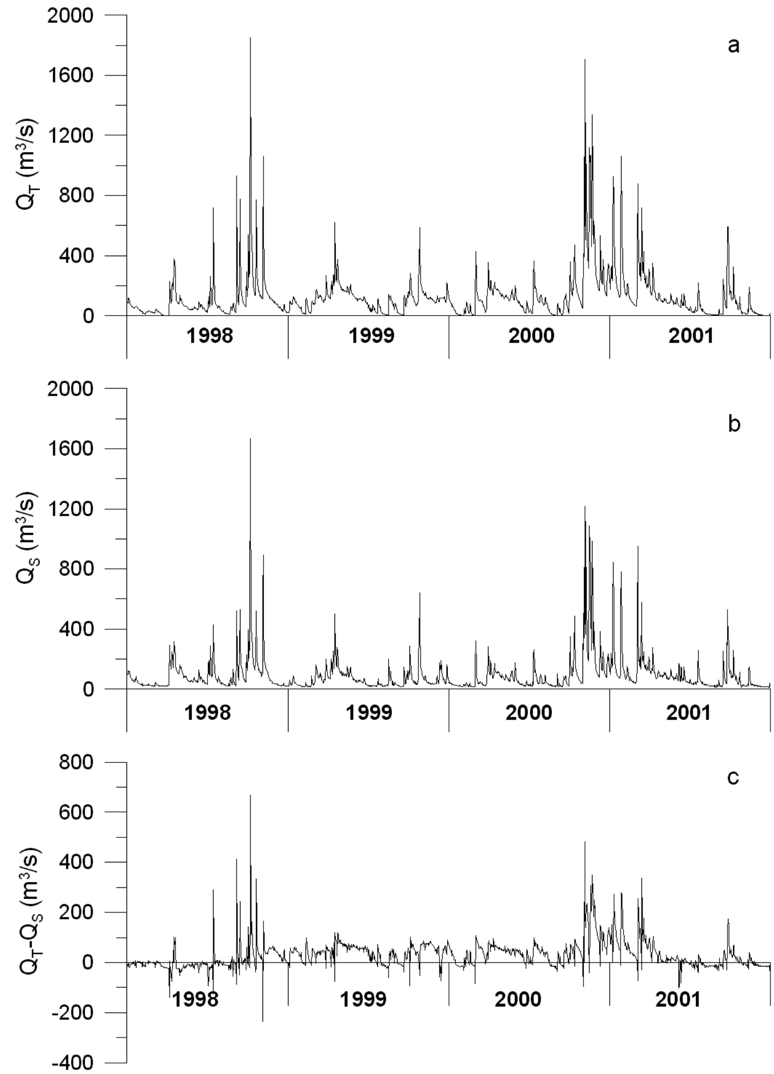

Fig. 2 - Time series of daily mean values of Isonzo river discharge at Turriaco (a) and Solkan (b) and difference between the two stations (c) for years 1998-2001.

4 and 5) confirm the marked decrease of river discharge that occurred starting in 2002 and the remarkable difference between the variability of the data collected at Turriaco and Solkan. Actually, the 2002-2005 annual cycle (Figs. 4b and 5b) resembles that of 1998-2001 (Figs. 4a and 5a), but the values are much lower and the dry periods last longer. Moreover, at Turriaco the range of variation of discharge data (Fig. 4) is much wider than at Solkan (Fig. 5), with minimum values often close to 0 m^3/s especially in the 2002-2005 period, while at Solkan minimum values never fall below 10 m^3/s. This pattern is due to the different frequency distributions of discharge values for the two stations (Table 12): at Turriaco the measurements are more spread out and low values are particularly abundant; a marked difference is present also in the upper tails (>300 m^3/s) of the frequency distribution, the Turriaco data being about twice as much as the Solkan data.

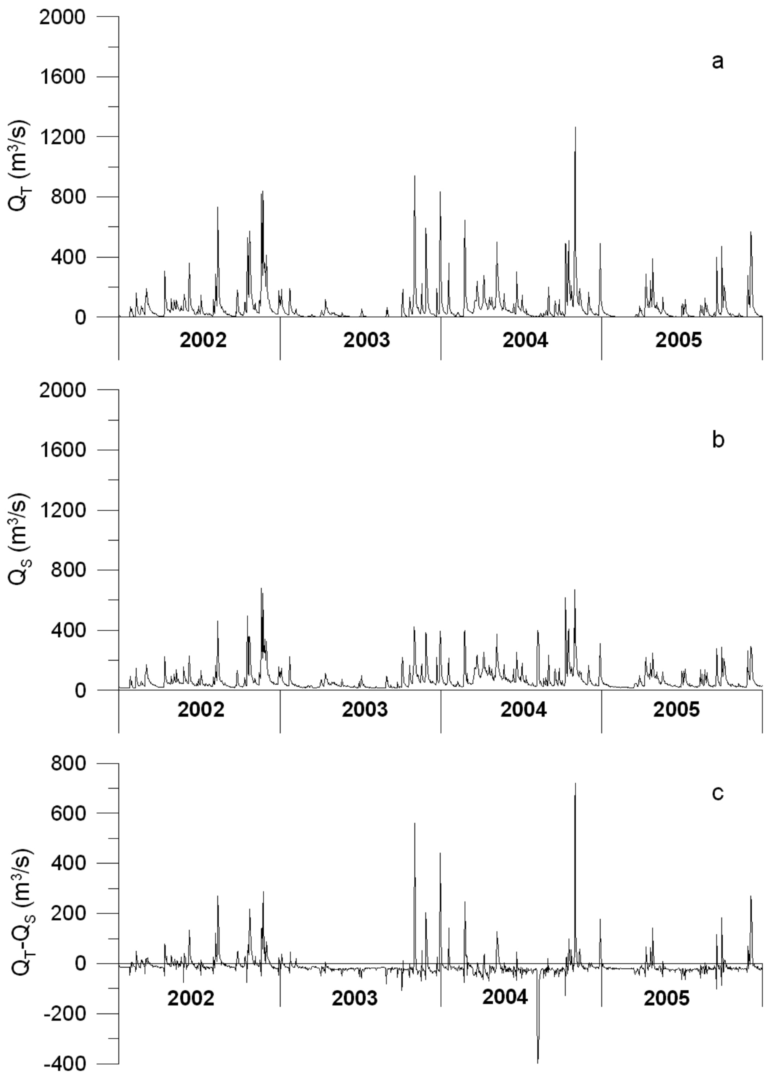

Fig. 3 - Time series of daily mean values of Isonzo river discharge at Turriaco (a) and Solkan (b) and difference between the two stations (c) for years 2002-2005.

The lower discharges, with respect to Solkan, observed occasionally at Turriaco are supposedly caused both by the water loss absorbed by the alluvial deposits downstream from the city of Gorizia and by the irrigation canals placed along the tract between Solkan and Turriaco. Near Sagrado, for example, the canal "Canale de Dottori", drains a minimum discharge of 17 m^3/s; the canal "Consorzio di Bonifica Pianura Isontina" (formerly called "Consorzio Cormonese Gradiscano"), close to Gorizia, subtracts 12-13 m^3/s up to 18 m^3/s, according to the needs of the local farmers, and at Farra it returns about 10 m^3/s to the River Isonzo (Consorzio di Bonifica Pianura Isontina, personal commmunication).

3.2. Rainfall-discharge correlations

Annual mean discharge values were put into correlation with annual means of total

Table 10 - Monthly mean, median, minimum and maximum values of the River Isonzo discharge at Turriaco for years 1998-2005, 1998-2001, 2002-2005, and 2002-2005 excluding 2003 (2002-2005*); for each month and period, overall means and medians were computed, respectively, from monthly mean and median values; minimum and maximum values represent, respectively, the minimum and maximum daily mean values over the whole considered period. Units are m^3/s.

Turriaco	1998-2005				1998-2001				2002-2005				2002-2005*			
Month	Mean	Median	Min	Max	Mean	Median	Min	Max	Mean	Median	Min	Max	Mean	Median	Min	Max
Jan	85.0	34.4	0.0	1061.5	131.6	66.7	2.7	1061.5	38.5	20.5	0.0	358.6	31.5	11.1	0.0	358.6
Feb	43.7	20.9	0.3	645.1	55.5	27.4	1.8	217.0	31.9	9.8	0.3	645.1	37.8	11.8	0.3	645.1
Mar	91.4	42.4	0.1	878.0	146.8	114.8	0.5	878.0	36.0	17.6	0.1	238.9	46.6	31.8	0.1	238.9
Apr	122.2	97.7	0.2	620.0	170.4	154.8	0.2	620.0	74.0	63.6	1.3	388.4	87.0	83.5	3.8	388.4
May	88.2	66.1	4.0	501.4	111.7	107.7	37.9	211.0	64.7	49.9	4.0	501.4	82.2	59.7	17.6	501.4
Jun	54.1	46.9	0.1	360.6	74.4	67.4	14.6	145.5	33.7	23.4	0.1	360.6	44.3	43.8	1.3	360.6
Jul	52.7	30.1	0.0	718.4	82.3	60.0	13.5	718.4	23.0	14.1	0.0	146.7	28.4	17.6	2.5	146.7
Aug	38.7	21.6	0.0	730.2	33.8	21.6	2.7	139.7	43.6	19.9	0.0	730.2	57.3	30.8	1.5	730.2
Sep	66.5	26.8	0.0	930.3	100.3	48.8	2.4	930.3	32.7	15.4	0.0	471.2	42.2	16.1	4.5	471.2
Oct	159.1	105.1	0.0	1850.4	209.8	153.2	12.6	1850.4	108.4	48.2	0.0	939.6	129.3	72.3	6.4	939.6
Nov	197.9	91.3	1.1	1703.2	255.4	122.9	9.7	1703.2	140.3	68.0	1.1	1267.3	129.4	72.3	1.1	1267.3
Dec	94.6	37.8	0.4	832.4	104.6	84.6	0.4	531.5	84.6	29.7	6.0	832.4	82.9	29.8	6.0	565.4
Mean	91.2				123.1				59.3				66.6			
Median		44.4				81.5				26.8				30.4		
Min			0.0				0.2				0.0				0.0	
Max				1850.4				1850.4				1267.3				1267.3

Table 11 - Monthly mean, median, minimum and maximum values of the River Isonzo discharge at Solkan for years 1998-2005, 1998-2001, 2002-2005, and 2002-2005 excluding 2003 (2002-2005*); for each month and period, overall means and medians were computed, respectively, from monthly mean and median values; minimum and maximum values represent, respectively, the minimum and maximum daily mean values over the whole considered period. Units are m^3/s.

Solkan	1998-2005				1998-2001				2002-2005				2002-2005*			
Month	Mean	Median	Min	Max	Mean	Median	Min	Max	Mean	Median	Min	Max	Mean	Median	Min	Max
Jan	69.1	39.4	14.2	846.0	90.7	46.3	15.6	846.0	47.6	37.6	14.2	226.0	42.1	28.9	14.2	215.0
Feb	39.2	24.3	14.6	398.0	37.5	24.0	14.6	154.0	40.8	27.5	14.6	398.0	45.6	32.0	14.6	398.0
Mar	78.2	39.9	15.6	951.0	103.5	60.9	18.5	951.0	53.0	32.5	15.6	236.0	63.4	39.4	18.9	236.0
Apr	109.4	106.0	19.8	501.0	133.4	122.5	23.4	501.0	85.4	73.4	19.8	252.0	95.7	97.8	19.8	252.0
May	79.9	73.1	25.4	374.0	85.0	77.6	46.2	174.0	74.8	60.6	25.4	374.0	87.7	61.1	37.4	374.0
Jun	53.9	48.4	17.9	254.0	56.8	51.9	20.2	171.0	51.0	38.2	17.9	254.0	59.7	48.2	19.4	254.0
Jul	57.6	41.0	14.4	428.0	68.3	48.3	14.4	428.0	47.0	37.4	16.6	181.0	52.6	38.0	22.7	181.0
Aug	51.1	31.0	13.7	460.0	35.9	29.1	13.7	202.0	66.3	44.8	15.6	460.0	80.6	44.8	20.5	460.0
Sep	65.6	30.8	15.6	529.0	82.2	37.9	16.9	529.0	49.1	30.1	15.6	289.0	56.6	33.2	18.1	289.0
Oct	134.1	82.2	13.2	1670.0	161.0	97.8	13.2	1670.0	107.2	55.7	20.4	671.0	118.7	66.5	22.5	671.0
Nov	151.5	85.1	19.6	1220.0	181.1	67.8	19.6	1220.0	121.9	89.1	21.1	678.0	113.1	76.1	21.1	678.0
Dec	75.3	49.9	13.2	392.0	69.9	47.1	13.2	384.0	80.7	49.9	25.2	392.0	76.6	43.3	25.2	313.0
Mean	80.4				92.1				68.7				74.4			
Median		47.4				57.6				44.8				46.0		
Min			13.2				13.2				14.2				14.2	
Max				1670.0				1670.0				678.0				678.0

Table 12 - Frequency distribution of daily mean values of the River Isonzo discharge at Turriaco and Solkan. Discharge units are m^3/s, time units are days.

Discharge range	Turriaco	Solkan	Δ
0-10	586	0	586
10-20	294	232	62
20-30	265	579	-314
30-40	161	425	-264
40-50	154	273	-119
50-60	138	227	-89
60-70	130	150	-20
70-80	113	132	-19
80-90	122	126	-4
90-100	84	114	-30
100-110	97	91	6
110-120	115	79	36
120-130	74	70	4
130-140	70	55	15
140-150	50	45	5
150-160	42	32	10
160-170	37	33	4
170-180	40	16	24
180-190	35	23	12
190-200	23	27	-4
200-210	17	11	6
210-220	20	16	4
220-230	18	10	8
230-240	19	11	8
240-250	10	8	2
250-260	11	16	-5
260-270	7	9	-2
270-280	13	7	6
280-290	12	9	3
290-300	5	5	0
>300	160	91	69

precipitations over the drainage basin, both in Slovenian (5 stations: Trenta, Soča, Log pod Mangartom, Kal nad Kanalom, Kobarid) and in Italian territory (1 station: Gradisca) (Fig. 1). The results (Table13) show that for the 1998-2005 period an either significant ($p<0.05$) or highly significant ($p<0.01$) correlation exist, according to the hydrometric level monitoring station, between the annual means of discharge and annual means of total precipitation in almost all Slovenian stations, with the exception of Kal nad Kanalom for which the correlations with the Turriaco data is not significant. In particular, rainfall data measured at Kobarid show the best correlations both with the Turriaco and the Solkan discharge data, as confirmed also by the fairly narrow 95% confidence interval of the correlation coefficient. On the contrary, precipitations recorded at Gradisca seem to be definitely uncorrelated with discharge data from both Turriaco and Solkan.

These results suggest that the Isonzo discharge is very sensitive to the precipitation that occurs along its upper course. In fact, Table 13 shows that the best correlations are found at the Kobarid and Soča meteorological stations, where the total annual rainfall is the highest (Table 14). This is also confirmed by the data recorded at Gradisca where the worst correlation coefficient is found in correspondence to the lowest amount of total annual rainfall.

Actually, the marked difference of the River Isonzo discharge between the 1998-2001 and 2002-2005 periods can be partially attributed to the decrease of precipitation observed in the 5 Slovenian meteorological stations in the corresponding years (Table 14). In particular, the precipitation in the upper drainage basin of the river has dropped, on average, by about 18%,

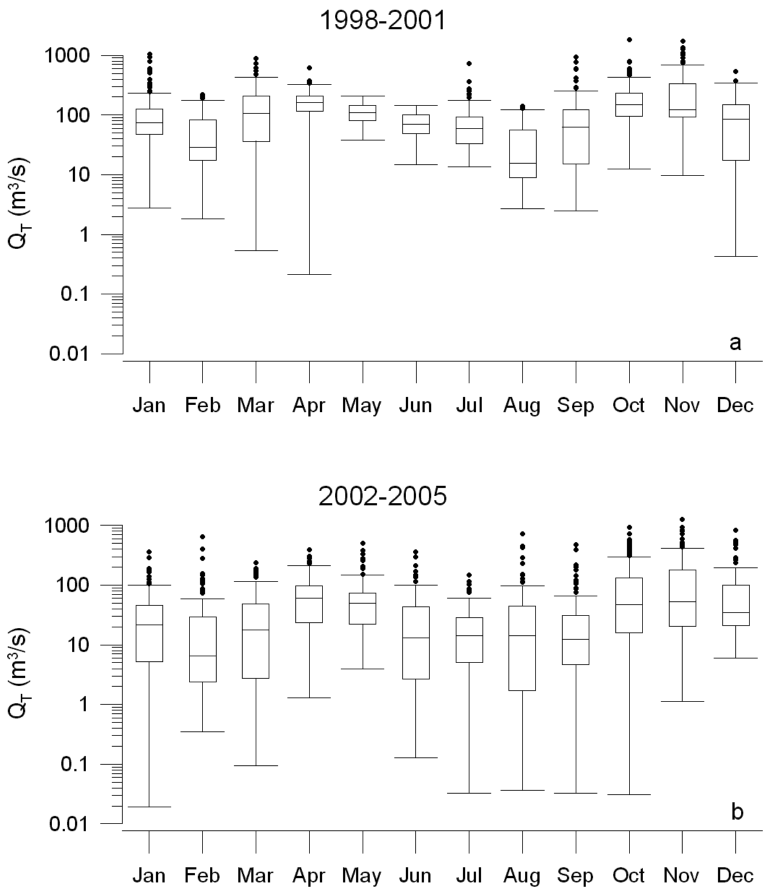

Fig. 4 - Boxplots of daily mean values of Isonzo river discharge at Turriaco for years 1998-2001 (a) and 2002-2005 (b). Lower and upper ends of boxes represent first and third quartile, respectively, while the in-between line is the median value. Black dots are outliers, lying more than 1.5 times the interquartile difference below the first quartile or above the third quartile. Lower and upper whiskers indicate the smallest and the largest values, respectively, that are not outliers.

which is consistent with the decrease of the mean discharge observed at Solkan (-25%) but substantially lower than that recorded at Turriaco (-52%). However, between Solkan and Turriaco, the River Isonzo waters are drained by irrigation channels that probably subtract a larger amount of water for agricultural demands in dry periods.

3.3. Influence of the Solkan dam as observed at the Turriaco gauging station

The availability of hourly measurements at the Turriaco station for the period 1998-2005, permitted us to assess the possible influence of the Solkan dam on the River Isonzo discharge in the lower part of its course. To a high degree of approximation, the analysis of the hourly discharge values evidenced the following points:

1) when discharge values are comprised between lower limit about 10-20 m^3/s and the higher limit 100-170 m^3/s the diurnal variations are observed, which range between 10 m^3/s to 90 m^3/s, according to the daily mean discharge value;
2) when discharge values are not included in the range 10-170 m^3/s, diurnal oscillations are not detected.

This pattern is evident in Fig. 6, where the diurnal oscillations due to the dam of the Solkan

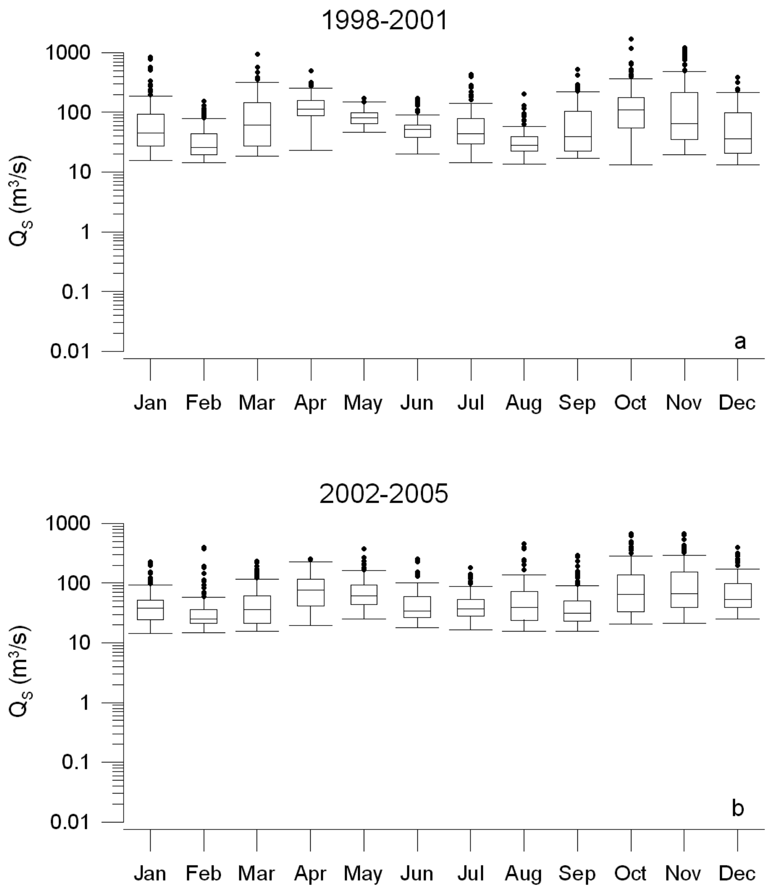

Fig. 5 - Boxplots of daily mean values of Isonzo river discharge at Solkan for years 1998-2001 (a) and 2002-2005 (b). Lower and upper ends of boxes represent first and third quartile, respectively, while the in-between line is the median value. Black dots are outliers, lying more than 1.5 times the interquartile difference below the first quartile or above the third quartile. Lower and upper whiskers indicate the smallest and the largest values, respectively, that are not outliers.

power plant are clearly visibile.

4. Conclusions

In this work, the River Isonzo discharge data, collected at the Turriaco and Solkan hydrometric level monitoring stations during the years 1998-2005, have been studied. The data analysis evidenced a marked decrease of the river discharge starting from 2002 and lasting through all of 2005. These results were confirmed by omitting year 2003, when discharge values were exceptionally low. Interestingly, the annual mean river discharge at Turriaco turned out to be noticeably lower than that reported by many previous works, but consistent with the estimate provided by Olivotti *et al*. (1986); the annual mean discharge at Solkan was only slightly lower than the previous estimate given by Širca *et al*. (1999).

The measurements collected at the two gauging stations ranged differently: from the analysis of the frequency distribution of river discharge, it clearly emerged that droughts and floods were more frequent at the Turriaco station, while at Solkan the presence of the power plant basin was likely to dampen the effects of dry periods. Water loss due to the alluvial deposits downstream

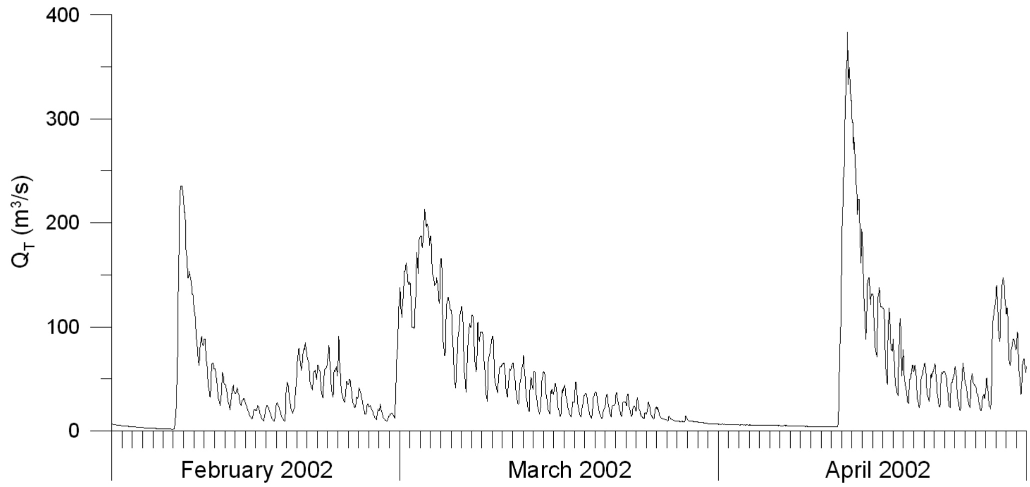

Fig. 6 - Effect of Solkan hydropower plant dam on hourly discharge values measured at Turriaco from February to April 2002.

from the city of Gorizia and to the irrigation canals placed between Solkan and Turriaco could also explain the decrease of the river discharge that was occasionally recorded at Turriaco with respect to Solkan.

The differences observed between the Turriaco and Solkan discharges could be better explained if an intercalibration between the methods of estimation of the flow rates of the two gauging stations was performed, possibly involving the scientific institutions of the neighbouring countries. The mismatches between the OGS-ADCP currentmeter and the rating curve method confirm the necessity to perform an accurate recalibration of the rating curves.

However, despite these differences and notwithstanding the marked seasonal and interannual variability that affect the river discharge, the presence of an annual cycle characterised by two maxima (April and October-November) and two minima (Februry and August), is clearly evident at both stations.

Correlations between the River Isonzo discharge and precipitation, measured at Slovenian and Italian meteorological stations distributed along the river course, were also computed. The results showed that the decrease of river discharge could be related to the decrease of precipitation in the upper drainage basin and the best correlations were found for the stations with the highest annual rainfall (Soča and Kobarid). This result could suggest that, despite the damming due to the Solkan hydropower plant, the river discharge is still greatly controlled by rainfall in the Slovenian territory.

However, the study of the influence of the Solkan dam on the river discharge evidenced the presence of a diurnal signal at the Turriaco station (the only one for which hourly measurements were available). The effect of the diurnal signal on the daily mean river discharge seemed to be nearly negligible, though hourly deviations could be more than 50% of the daily mean discharge. Consequently, a deeper analysis of this important source of perturbation of the river discharge should be performed when data about the running of the hydropower plant becomes available.

Table 13 - Correlations between total annual rainfall and Isonzo annual mean discharge. (r: correlation coefficient; p: p-value; 95% C.I.: 95% confidence interval).

Station	Turriaco			Solkan		
	r	p	95% C.I.	r	p	95% C.I.
Trenta	0.83	0.010	0.31 0.97	0.71	0.049	0.007 0.94
Soča	0.80	0.018	0.21 0.96	0.85	0.007	0.37 0.97
Log pod Mangartom	0.88	0.003	0.48 0.98	0.71	0.048	0.01 0.94
Kobarid	0.93	0.001	0.66 0.94	0.95	<0.001	0.75 0.99
Kal nad Kanalom	0.62	0.102	-0.15 0.92	0.91	0.002	0.56 0.98
Gradisca	0.25	0.556	-0.55 0.81	0.41	0.315	-0.42 0.86

Finally, due to the great importance that the River Isonzo holds also in the dynamics of the ecological system represented by the Gulf of Trieste, the marked modifications that have been observed in its hydrological characteristics during the last few years could greatly affect the biogeochemical processes that take place in the basin. In particular, the decrease of fresh water inputs could involve a reduction of the availability of nutrients and organic matter and, consequently, influence the trophic food web. These considerations could be equally applied to

Table 14 - Total annual rainfall (mm) for 6 meteorological stations placed along the River Isonzo course for each year of the period 1998-2005 and mean total precipitation (mm) for the periods 1998-2005, 1998-2001, 2002-2005, and 2002-2005 excluding 2003 (2002-2005*).

	Trenta	Soča	Log pod Mangartom	Kobarid	Kal nad Kanalom	Gradisca
1998	1852	2547	2259	2748	2642	1432
1999	1983	2234	2437	2328	1916	1156
2000	2520	3759	3470	3252	2587	1560
2001	2091	2864	2536	2637	2226	1194
2002	2111	2541	2359	2308	2063	1814
2003	1726	2149	2010	1720	1968	890
2004	2021	3048	2277	2635	2481	1534
2005	1419	1665	1442	1596	1975	1413
1998-2005	1965	2601	2348	2403	2232	1374
1998-2001	2112	2851	2675	2741	2343	1336
2002-2005	1819	2351	2022	2064	2122	1413
2002-2005*	1850	2418	2026	2179	2173	1587

all the main rivers that flow into the northernmost part of the Adriatic Sea (principally Tagliamento and Piave) and that could have undergone a similar decrease of discharge. On these grounds, further investigations both about the discharge modifications of the rivers flowing into Gulf of Trieste and, more generally, into the northern Adriatic Sea and the resulting effects upon the marine ecosystems, should be carried out.

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