THE TIMAVO HYDROGEOLOGIC SYSTEM: AN IMPORTANT RESERVOIR OF SUPPLEMENTARY WATER RESOURCES TO BE RECLAIMED AND PROTECTED

HIDROGEOLOŠKI SISTEM TIMAVE: POMEMBEN DODATNI VODNI VIR, KI MORA BITI UPORABLJEN IN ZAŠČITEN

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M. Civita[1] & F. Cucchi[2] & A. Eusebio[3] & S. Garavoglia[4] & F. Maranzana[5] & B. Vigna[6]: Hidrogeološki sistem Timave: pomemben dodatni vodni vir, ki mora biti uporabljen in zaščiten

Hidrogeološki sistem Reka-Timava sestavljata površinski in podzemeljski del. Tako velik sistem je pomemben vodni vir. Zato je izredno pomembno vzpostaviti okoljevarstveni program za njegovo varovanje. Prispevek končuje z vrsto sklepov in napotkov za polno izkoriščanje znanih virov ter za njihovo varovanje pred onesnaževanjem.

Ključne besede: hidrogeologija krasa, vodni viri, varstvo voda, Italija, Slovenija, Kras, Reka - Timava.

Abstract

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M. Civita[1] & F. Cucchi[2] & A. Eusebio[3] & S. Garavoglia[4] & F. Maranzana[5] & B. Vigna[6]: The Timavo hydrogeologic system: an important reservoir of supplementary water resources to be reclaimed and protected

The Reka - Timavo hydrogeologic system consists of surface und subsurface parts. Such a system presents a noteworthy water supply source. It is therefore of paramount importance to establish a sound environmental programme for its protection. The paper ends with a serie of conclusions and suggestions for the full exploitation of identified resources and their protection from contamination.

Key words: karst hydrogeology, water resources, water protection, Italy, Slovenia, Carso, Reka - Timavo.

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INTRODUCTION

The Reka-Timavo hydrogeologic system, consists of two parts, the first one surficial and the second subsurficial (Fig. 1). The first corresponds to the drainage basin (407 km^2) of the Reka river (54 km) completely flowing toward WNW in Slovenian territory over flyschoid formations. Stream losses begin near Vreme, where the river flows well over highly karstified limestone and down to S. Canziano aven where losses are total. Starting from this point, the subsurficial part of the system, named Timavo river, begin to flow underground for 41 km till S. Giovanni di Duino where the watercourse re-appears at the ground surface discharging by a number of important springs. This is

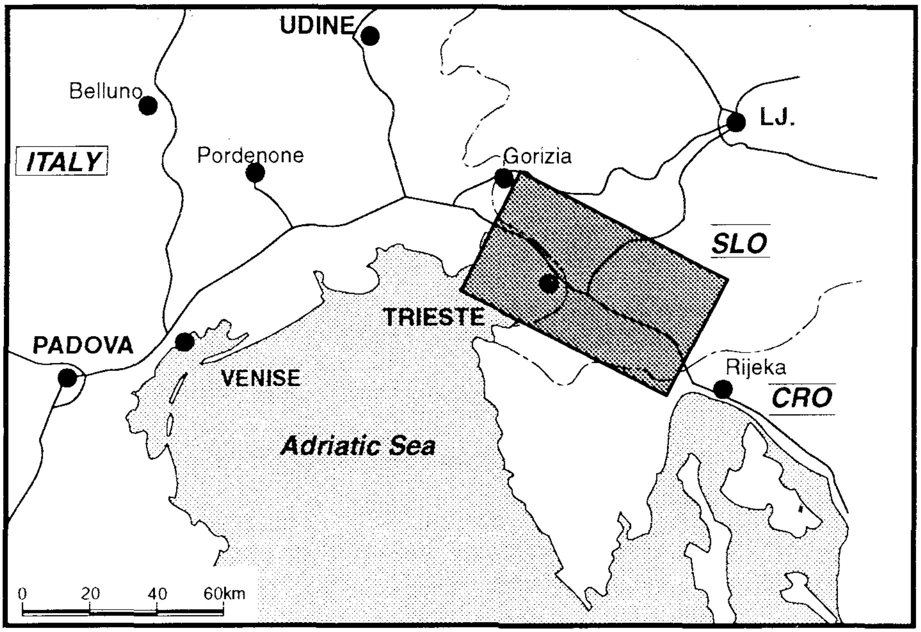


Fig. 1 Location of Reka-Timavo System

one of the main karstic phenomena of Mediterranean region which roused the interest of ancient and modern scientists (Pliny the Old, Strabo, T. Livius etc.), from the second century AD up the last century and the present.

In spite of this great interest, the phenomenon is, however, not well understood from both the scientific and the water resource planning point of view. On the other hand, it is clear that such a system represents a noteworthy water supply source, fed not only by the surficial stream going underground but also by an important diffuse (direct) recharge. It is also evident that the whole hydrogeologic system is vulnerable to contamination, quite ubiquitous in both courses.

It is therefore of paramount importance and of extreme urgency to carry out an in depth investigation aimed at establishing a sound environmental programme for the recovery and protection of such a valuable water resource.

This work represents a preliminary synthesis of known data with special reference to the geometry of the system, to its dynamic processes and qualitative charges which make nowadays the resource itself scarcely exploited.

OUTLINE OF HYDROGEOLOGIC BOUNDARIES

Various sources converge in feeding the ground water flow of the hydrogeologic system (Fig. 2). Among some subsystems called here *external tributaries* (Reka, Vipava, high Raša and others), the Reka basin is the major contributor. At the hydrometric station of Cerkvenikov mlin it shows an average yearly discharge of about 8 m^3/s, reaching a maximum at about 305 m^3/s.

According to IDROGEA (1993), the average value needs to be increased by 18% for a better estimate of the average discharge contributing to the subsurficial course. It must be stressed however that the global spring discharge, even in the case of extreme and prolonged hydrologic low, is of the order of 9 m^3/s (Gemiti, 1984) against the 4.2 m^3/s recorded under the same conditions at Cerkvenikov mlin (IDROGEA, 1993). The system must obviously add a considerable amount of recharge on top of the one supplied by the losses of Reka river.

In the north and south-east sectors, the boundary of the system corresponds to the stratigraphic contact between limestone of the "Comeno Platform" and Eocene flysch. From Kačiče (limit of outcropping flysch) the positioning of the boundary towards the east going to Trieste is not clear. It is however located within Palaeocene limestone, where a somehow mobile ground water divide exists between the Timavo's structure and that feeding the springs of Bagnoli, Pisano, etc., SE of Trieste. Towards SW, the hydrogeologic units boundary continue in a straight line from Trieste to Aurisina and corresponds to the front of the "Comeno Platform" limestone overthrusting the complex structure of the Ćićarija (Placer, 1981), which comprises the impermeable terrigenous horizons extensively outcropping along the coast of the Trieste Gulf. Such a schematic outline is based on a lot of survey, gauging and tracer tests confirming the connection between the main surficial streams and springs.

The identified system (Fig. 2) appears to possess an area of 736 km^2 and the hydrogeologic structure is defined by several interacting rock complexes. The *alluvial complex*, formed by recent and present alluvial terrains (north-west sector, including the middle Isonzo flats), does not influence the dynamics of ground water. The *terrigenous complex* comprises Eocene low permeable marls and sandstones. It behaves as a relative aquiclude in relation to the carbonate complex and gives a permeability sill (Civita, 1973), superimposed northward and underlain in the SE and SW side of the structure.

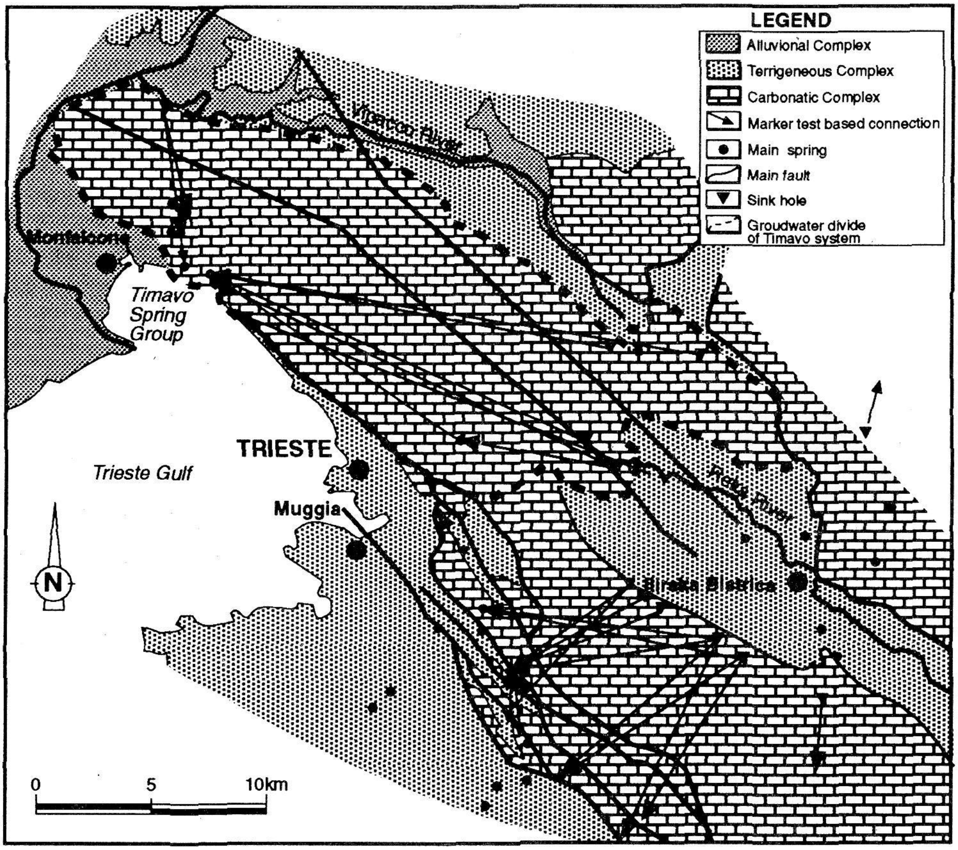


Fig. 2 Hydrogeological scheme of karst area

The *carbonate complex* is composed of several sub-complexes which exhibit a similar behaviour and a different degree but the same type of relative permeability. From the top, the sequence comprises stratified limestone (sometimes marly), thinly bedded limestones, fractured and partly karstified, of lower Palaeocene-Eocene age (40 to 450 m thickness). A thick sequence (300-1000 m) of Upper Cretaceous massively stratified limestone follows representing the most important sub complex of the hydrogeologic system. They are compact but fractured in great blocks and pervasively karstified both in depth and on the surface. They are underlain by a dolomite sub-complex of Middle Cretaceous age with a 300 to 600 m thickness.

The dolostone are poorly stratified, little karstified and have a relative permeability degree lower than that of the overlying limestones. They crop out in two main sub parallel bands along the Italo-Slovenian border, cut northward by the "Raša fault" (Cucchi & Forti, 1981). As the dolomite complex constitutes, particularly in the eastern section, an indefinite permeability limit for the overlying karstic limestone, where the saturated zones of the deepest active caves are located, it creates variable of conditions for the ground water flow. Furthermore, the dolomites, being wedged between the two main calcareous terms, behave as if they were the boundary between two semi-independent reservoirs, and influence flow directions and velocities in the highly permeable media.

The series, then, ends, with Middle-Lower Cretaceous limestone (about 300 m thickness) thinly bedded with a medium-high karstification level and high degree of permeability. Although differentiated, the entire carbonate complex contain an intense ground water circulation, which is based on a high ingestion index as well as on a high seepage index.

OUTPUT POINTS OF THE SYSTEM

The hydrogeologic system has a certain number of output points (Fig. 3), some quite evident other much less or even hidden or not directly observable. Among those are:

The Timavo spring group, at 2.40 m a.m.s.l., near S. Giovanni di Duino comprise several resurgences distributed in a wide area but interconnected underground, taking the period 1972-83, the overall average discharge 30.2 m^3/s (Q_{min} 9.1 m^3/s; Q_{max} 127 m^3/s).

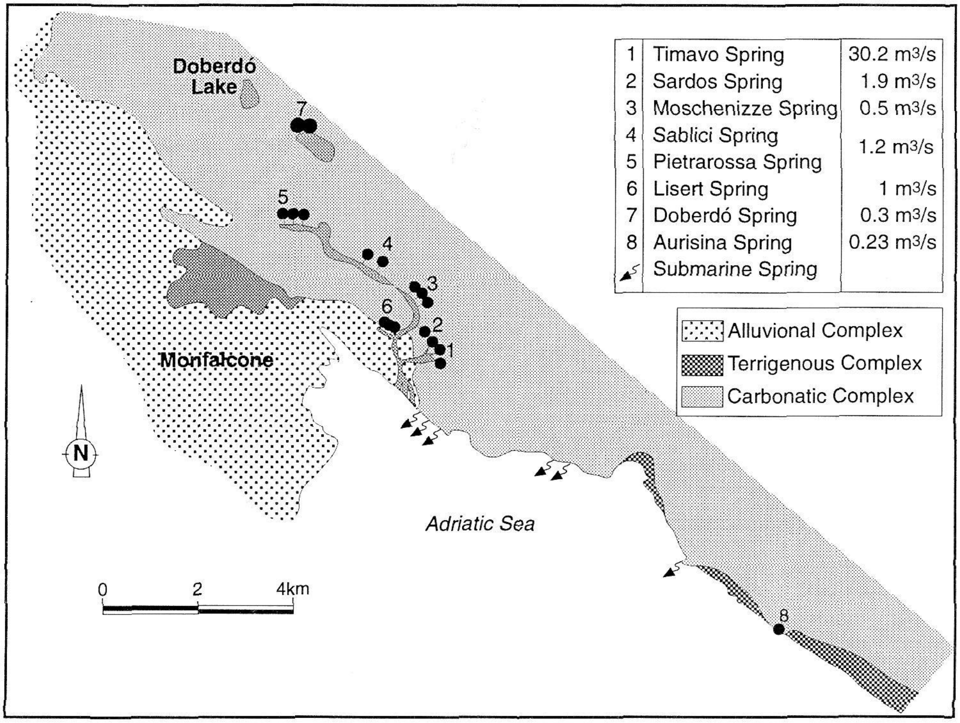
Daily discharge variations can be very sudden (Fig. 4), with rapid growths reaching 60 m^3/s in two days or 15 m^3/s in less than five days. There are three main springs (Timavo I-II-III) closed by regulations bulkheads. Near springs (Randaccio and Moschenizze) as well as some further ones (Aurisina spring group) are affected by regulating the Timavo discharge.

At about 500 m northward from the Timavo resurgences is located the Sardos-Randaccio spring group, at 2.30 m a.m.s.l. with average discharge 1.9

m^3/s ($Q_{min.}$ $1.5 m^3/s$ - Gemiti, 1984).

Further northward again are located the Moschenizze spring group, along the narrow valley of the same name, at 1.3 m a.m.s.l., with an average flow of 0.5 m^3/s. There is a cluster of 12 springs the main of which is the Molino spring (average discharge 0.23 m^3/s - Mosetti, 1966).

The Doberdò springs are NW of the same lake, at 6 to 12 m a.m.s.l. The average discharge of the main spring is 0.3 m^3/s, to which the value of the other numerous springs should be added, all having high variability index. Southward of the Daberdò lake a series of sinkholes drains the water toward Pietrarossa lake (about 1 km southward, 5 m a.m.s.l.). In case of exceptional flood, the level rises to 5.7 m a.m.s.l. not lining with the Sablici lake, located about 1 km to SE. Presently, a reclamation canal drains the waters of Pietrarossa lake and of Sablici springs, with a total discharge of 1.2 m^3/s. Along a front of 490 m, 8 springs constitute the Lisert spring group, located southward of the lake, at 0.4 m a.m.s.l. with an average yearly discharge 1.0 m^3/s (Gemiti, 1984). The dye tracing performed by Boegan in 1938 showed that the tracers, introduced at Sablici lake sinkholes took five hours to reach the Lisert springs still in high concentration.



1	Timavo Spring	30.2 m3/s
2	Sardos Spring	1.9 m3/s
3	Moschenizze Spring	0.5 m3/s
4	Sablici Spring	1.2 m3/s
5	Pietrarossa Spring	
6	Lisert Spring	1 m3/s
7	Doberdó Spring	0.3 m3/s
8	Aurisina Spring	0.23 m3/s
↙	Submarine Spring	

Fig. 3 Emergence zone of Timavo System

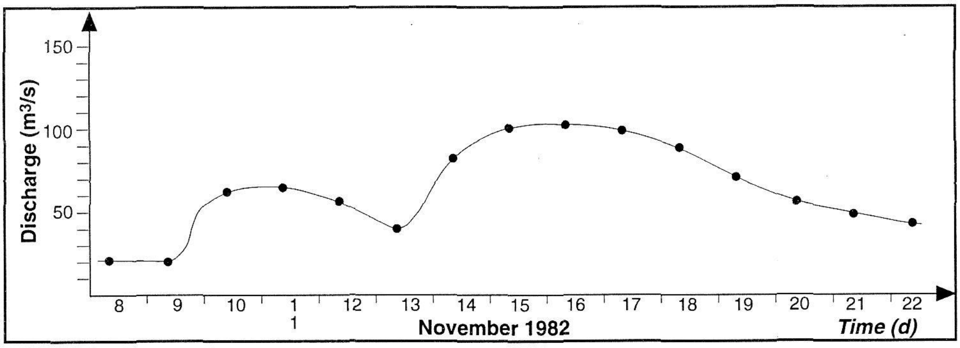


Fig. 4 Discharge of Timavo Springs in November 1982 (After: Gemiti, 1984, modif.)

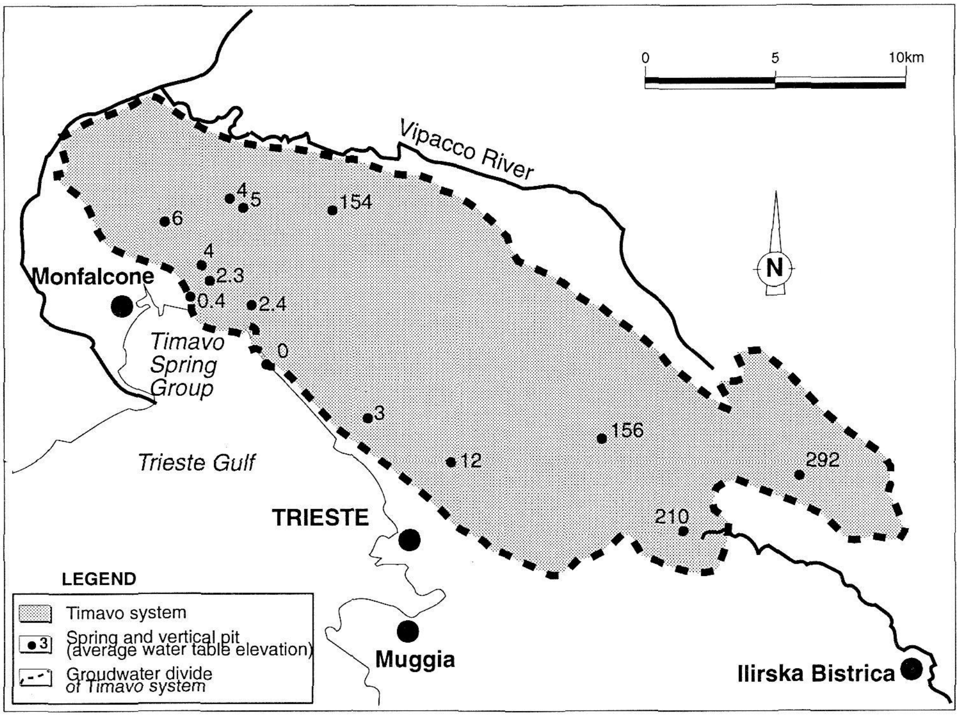


Fig. 5 Groundwater elevation of Timavo System

The Aurisina spring group is located at sea level, 13 km NW of Trieste, along a front of 350 m, where a cluster of 9 springs gives a discharge of 0.23 m^3/s. Impermeable flyschoid deposits at 3 m below sea level, constitute the underlying sill. In 1910, a tapping tunnel 263 m long was dug reaching a level of 0.61 m a.m.s.l. connecting only minor springs but not the main ones. Other submarine springs within the Gulf of Trieste (Villaggio dei Pescatori, Cerniza, Duino) were surveyed and LANDSAT thermographic imagery shown submarine discharges along the coast between Sistiana and Aurisina. Several authors have advanced the hypothesis of subsurficial linkages between the karstic structure and the Isonzo plain, taking into consideration both the piezometric level of the limestone and alluvial aquifers and the presence of *Proteus* in some wells located in the Isonzo flats (Mosetti, 1966).

PIEZOMETRIC DATA

Piezometric data of the karstic aquifer are scarce (Fig. 5). In the eastern part of the system an effective saturated zone seems to be lacking, while siphoning conduits are mainly present as submerged sectors of the draining network. In this sector the Gabranca cave behaves as inversac with low-water level at 292 m elevation.

Some km further west, low piezometric levels in the S. Canziano cave are at 210 m lifting at maximum flood level to 346 m a.m.s.l. (Boegan, 1938). Only 1500 m NW, in the Serpenti cave (Kačna jama), runoff water from the surficial Reka river flows along galleries fed by a siphon at 182 m and disappears again at 156 m elevation. During floods, the piezometric levels rise of about 90 m. In the Trebiciano cave, the ground water appears at 12 m reaching during floods the elevation of 115 m. Near Prosecco at the Massimo aven, the low-water level is 3 - 4 m a.m.s.l. Further downstream, at 12 and 7 km respectively from the resurgences, two caves (Cristalli cave and Lindner cave) which descend to 20 and 5 m elevation a.m.s.l. are generally dry,

Maker test	Year	Place		Velocity (m/h)	References
		Intput	Output		
Lithium chlorlde	1907	S. Canziano	Timavo springs	164	Timeus, 1928
Uranine	1908	Trebiciano	Timavo springs	102	Timeus, 1928
Pechblenda	1909	S. Canziano	Timavo springs	177	Timeus, 1928
Lithium chloride	1910	Vipacco River	Doberdò springs	104	Timeus 1928
Uranine	1911	Sablici lake	Lisert springs	108	Boegan, 1938
Tritium	1962	S. Canziano	Timavo springs	88	Mosetti, 1965
Tritium	1962	S. Canziano	Aurisina springs	52	Mosetti, 1965
Carbon tetrachlonde	1982	Trebiciano	Timavo springs	306	Gemiti, 1984
Carbon tetrachloride	1982	Trebiciano	Timavo springs	83	Gemiti, 1984
Carbon tetrachlonde	1982	Trebiciano	Sardos springs	306	Gemiti, 1984
Uranine	1987	Sajeviski potok	Sardos springs	83	Habic, 1989
Uranine	1987	Sajeviski potok	Timavo springs	25	Habic, 1989
Rodamine	1987	Rasa Lakovnik	Timavo springs	86	Habic, 1989
Rodamine	1987	Rasa Lakovnik	Sablici springs	64	Habic, 1989
Rodamine	1987	Rasa Lakovnik	Sardos springs	136	Habic, 1989

Table 1

whereas floods reach piezometric levels of 10 and 30 m a.m.s.l. respectively (Cucchi & Forti, 1981).

In the Slovenian karst, the Preserska cave, located 13 m from Timavo springs, present a siphoning zone at 154 m (low-water) reaching 210 m (high-water). Further west (5 km from the springs) the caves Dolenjca and Drča reach the piezometric level at 4 and 5 m elevation respectively. High level fluctuations are gauged in these caves due to consistent recharge rates. In the Timavo spring area, several caves reach the saturated zone at the same elevation of the springs, while in the Doberdò sector, the only reliable piezometric data are the same elevation as the springs (6 - 1.5 m a.m.s.l.).

GROUND WATER FLOW VELOCITY

The ground water apparent velocities, which are calculated by tracing techniques (Table 1), are generally high (over 100 m/h). Tracing tests from S. Canziano and Trebiciano have determined during floods flow velocity exceeding 300 m/h in relation to discharge rate about 90 m^3/s (Gemiti, 1984). At mean-water (32 - 37 m^3/s) the velocity is reduced to 109 m/h (Mosetti, 1965) and 164 m/h (Timeus, 1910). During low waters velocities about 90 m/h have been assessed, while tests performed by Habič (1989) from the north-eastern limit of the system gave about 80 m/h.

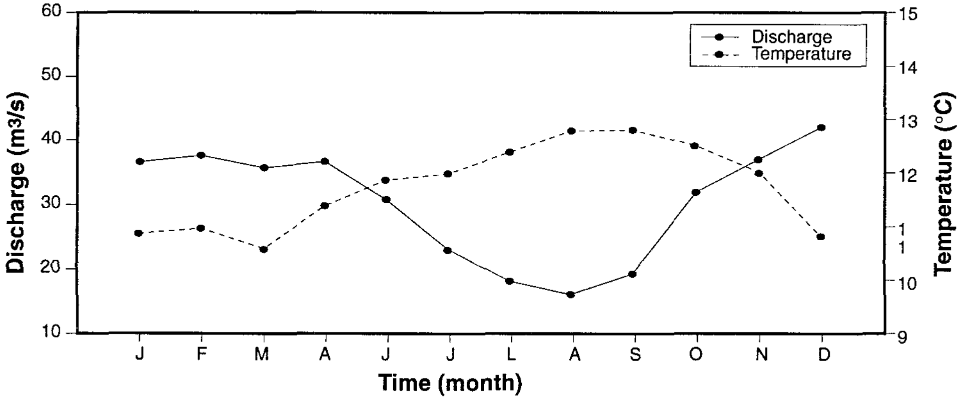


Fig. 6 Discharge-Temperature plotting of Timavo Springs

The velocities between the losses of Vipava at Vrtoče and the Doberdò, Pietrarossa and Sablici springs are, according to Timeus (1910), within 88 and 91 m/h. The few reliable tracer restitution curves (Gemiti, 1984) show a high peak over a short time with a single restitution pulse characteristic of a ground water flow mainly based on a main dominant conduit model (Civita et al. 1991).

CHEMICAL AND PHYSICAL CHARACTERISTICS OF GROUND WATER

Water temperatures of the Timavo springs (Fig. 6) show sharp variations (Tommasini, 1968; 1969; Flora et al., 1990) with cyclical fluctuation around 10°C in winter and a maximum of 13°C in summer. Lower values coincide with winter floods, while higher temperatures are related to secondary infiltration, when primary and secondary recharge are at their lowest.

The springs of north Moschenizze (11.8 - 13.8°C, Tommasini, 1969) and of Sardos (11.2 - 13.1°C, Gemiti & Licciardello, 1977), present a behaviour similar to the isochronous one of Timavo (Fig. 7). There are, however, no rapid variations thus confirming a fractures network flow type rather than a wide conduits flow. Similar data are shown in the Doberdò, Pietrarossa and Lisert (low of 9.5° in March and 15° in summertime) while for the Timavo springs the lowest temperature is recorded in February and a summer high of 13°.

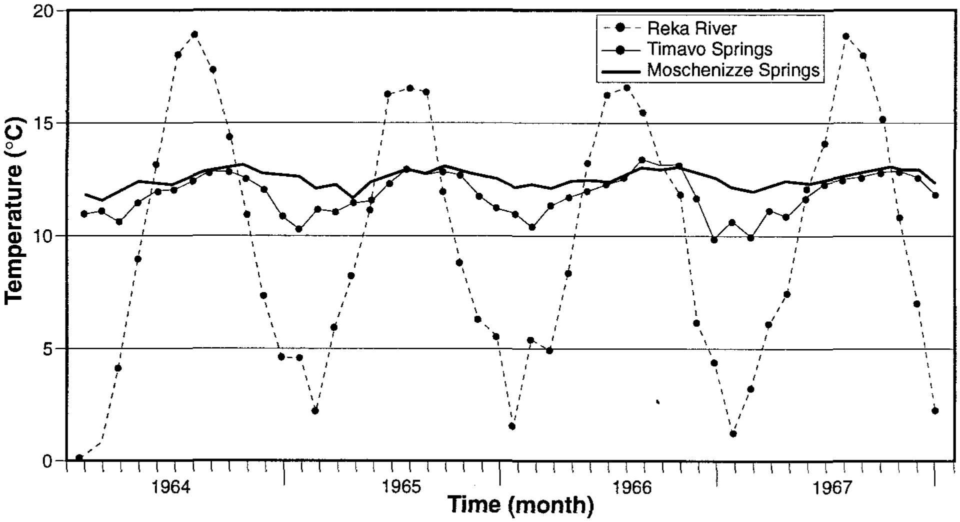


Fig. 7 Average monthly temperature (1964-1967)

The hydrochemical data so far available show marked differences in water composition at different springs. While the Timavo springs exhibit a rather particular chemical imprint, different from the others, the water of the Doberdò, Pietrarossa, Sablici and Lisert springs are similar to but at the same time different from those of Moschenizze, Sardos, Aurisina, where the chemistry indicate the presence of local circuits fed by a complex fracture and small conduits network, more or less independent from the main system.

It is impossible to verify and quantify the recharge from the Vipava and

Isonzo rivers to the subsystem of the Doberdò springs. This opinion is also shared by Flora et al. (1990) taking into consideration isotopic analyses (limited to the determination of 180 in period Nov. 84 - July 88), enhancing the importance of mixing of different waters.

GROUND WATER RECHARGE AND REGULATING RESERVES OF THE SYSTEM

The system's hydrodynamic is highly, but not widely, based on circulation through large conduits, while ground water reserves are being formed in various ways and not only by surficial watercourse losses. There exists in fact a strong *secondary infiltration*, which is well identified by waters of the Reka river, penetrating in the S. Canziano cave, as well as in other surficial points further up stream (assessed average discharge = 9.6 m^3/s), by losses from other rivers (Vipava being the most important with an estimated loss of 1 m^3/s) and from runoff inflow from no-karstic terrains outside the basin. A *primary infiltration* derives from rains (1633 mm/year) over a mature karstic morphology with a high index of surficial karstification.

The average recharge through primary infiltration was calculated through a numerical model HYDRAC (Civita et al., 1984) assembled in raster mode by a GIS.

Average rainfall were taken by historical records of 14 rain gauges well distributed in Italy and Slovenia, with elevation's corrections. The weight of the average yearly temperature to each cell of the model was also calculated on the base of two recording gauges, with corrections for elevation and average monthly rainfall.

The average hydrogeologic balance was competed (Table 2) knowing

INPUT			OUTPUT		
	m^3/s	Mm^3/y	Mm^3/y	m^3/s	
Surface contribution of Reka River	9.6	302.7	952.4	30.2	Timavo Springs
Surface contribution of Vipacco River	1.0?	31.5?	37.8	1.2	Sablici Springs
			31.5	1.0	Lisert Springs
Recharge of Karst Area (Infiltration)	20.7	652.2	15.8	0.5	Moschenizze S.
Surface contribution of Rasa River	?	?	60.0	1.9	Sardos Springs
			6.3	0.2	Aurisina Springs
			?	?	Submarine S.
INPUT	31.3	986.4	1103.8	35.8	**OUTPUT**

Table 2 Hydrogeologic Balance of Timavo System

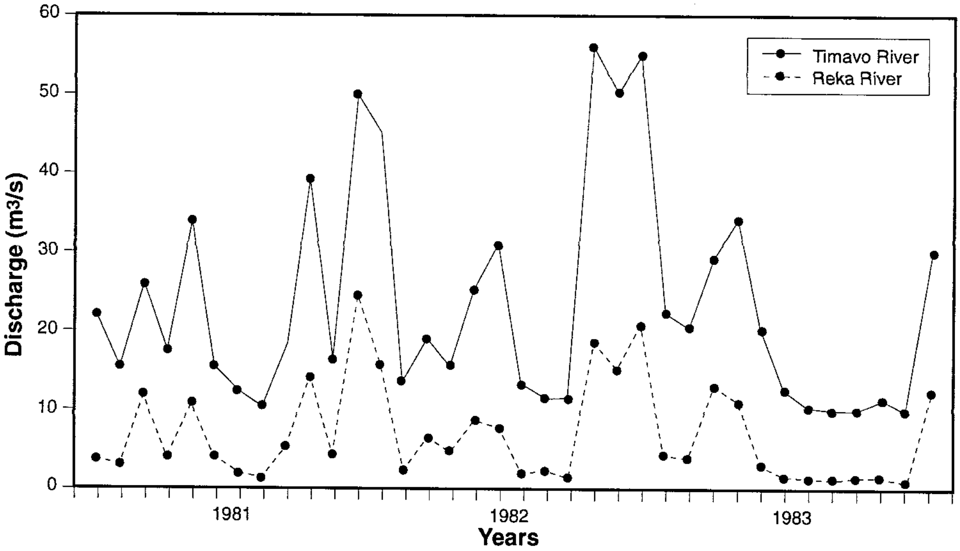
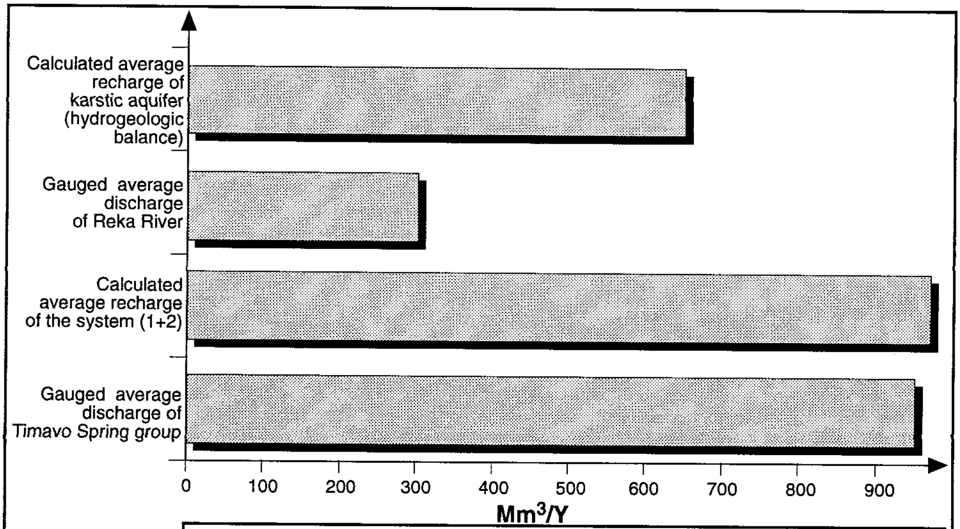


Fig. 8 Average monthly discharge (1981-1983)



Calculated average recharge of karstic aquifer (hydrog. balance)	652.2
Gauged average discharge of Reka River	302.7
Calculated average recharge of the system (1+2)	954.9
Gauged average discharge of Timavo Spring group	952.4

Fig. 9 Hydrogeological balance results comperend with average discharge gauged data.

however that such a balance represents more than anything a technical mean to evaluate the identification of boundaries and of the geometry of the system. In this case, the difference between recharge and discharge amount to 10%, a well acceptable value in view of the quality of data and of the often inconsistent historical records. Such differences in balance can also be explained by the underestimated losses from Vipava; by the interflow to the Goritian aquifer in the north-western sector of the structure; by the lack of gaugings of other losses from small impermeable basins, branching the structures; by and overestimation of the runoff probably all seeping into high karstified limestone. The dimensions and geometry of the hydrogeologic system so identified, can therefore be assured as sufficiently verified.

THE REKA - TIMAVO SYSTEM WORKING

As was said earlier, the Reka-Timavo hydrogeologic system l.s., which embraces a territory of over 1000 km^2 is made up of a surficial part corresponding to the Reka and minor drainage basins (Vipava basin p.p., Upper Raša basin p.p., minor drainage basins); and of an extensive hydrogeologic basin, covering 736 km^2, for the most part within Slovene territory (534 km^2), whereas the remaining 202 km^2 lie within the Italian karst.

By integrating the hydrodynamic data obtained from tracer tests with hydrochemical and thermal data, it is possible to hypothesise the presence of more or less interconnected subsystems within the general hydrogeologic system.

The main subsystem is the Reka - Timavo springs one. This is undoubtedly a complex system in which ground water flows along the main *dominant drain* (conduit) during floods and preferrentially along a number of *interdependent drains* (conduits) (Civita et al. 1991) during normal and low-water. The dominant drain is made up of a series of cavities and conduits which link the losses from the Reka to Timavo emergences. It runs predominantly through the undifferentiated carbonate complex and is probably conditioned by the presence, on the bed, in the eastern sectors, of the predominantly dolomite sub complex characterised by a lower relative permeability. The existence of a main dominant conduit is demonstrated by speleological explorations, flood velocity (over 300 m/h) and the tracer restitution curve type characterised by a single very sharp peak. A further control is provided by the abrupt variations in the physical and chemical parameters of waters and the striking changes of flow well correlated to the condition of the Reka and the propagation times of its flood waves. By subtracting the average isochronous monthly discharge rates of the Reka from the perfectly correlated rates of the Timavo springs (Fig. 8), it can also be seen that there is a massive component of ground water flow which cannot be provided by anything other than the massive and virtually immediate primary infiltration of congruent rainfall in the highly permeable rocks of the karst (Fig. 9). A second dominant drain, of lesser importance, could be located in correspondence with the Vallone di Doberdò. It may link the losses from the Vipava with the spring groups of the Doberdò, Pietrarossa and Sablici lakes, as well as with the Lisert springs themselves. This hypothesis is confirmed by tracer tests which have provided relatively high flow velocity, and by chemical and thermal changes in the waters. Even the limited piezometric measurements confirm the existence of a gradient (1.3 %) from NNW, with a flow whose direction and velocity are completely different from that of Timavo, but with distinctly lower discharge.

Within the system, therefore, part of the deep circulation runs through the dominant drains, in particular at times of high recharge rates, whereas at low water an incomparably slower circulation becomes preponderant running through the complex network of interdependent drains. The former interfere in the said circulation both by powerfully draining the network during periods of medium water, and by inducing, during flooding, piston-like and retroflexion actions of the ground water flow which are restricted in time but are important in quantitative terms when levels within the dominant drains increase by as much as several dozen metres. It is worth underlining that, at times of heavy rainfall, the subterranean system becomes enormously overloaded, raising the piezometric level from approximately 30 m in western sectors (Cristalli cave, Lindner cave) to over 100 m in the Trebiciano cave and in cavities near the sinks of the Reka river. A similar phenomenon exerts a powerful effect on the overall hydrodynamics of the system, since it slows down the ordinary flow in the fracture and small-sized conduit network when it does not even succeed in annulling the ground water velocity and inverting, even if partially and briefly, the flow directions.

Even if apparently discontinuous, the dolomite sub complex seems to represent an important element of hydrogeologic separation between the southern (site of the Timavo subterranean river) and northern zone of the karst system. This sector should contain better quality ground water originating from the substantial contributions of primary infiltration, which are well distributed across the wide karst area. Before reaching the risings, these were mixed with the poorer quality waters circulating in the dominant drain, thus improving the characteristics above all during low-water periods.

The south Moschenizze and Sardos springs are fed by the slower circulation originating from the body of the main aquifer itself (interdependent drains circulation) as is shown by the relative constancy of chemical and thermal parameters which are distinctly higher than those of nearby springs. They are only very marginally influenced by the contribution of main drains, generally only during periods of considerable discharge when partial mixing between the various waters take place.

The Aurisina springs, partially linked to the main system as is shown by numerous tracer tests, are strongly fed by the local flow in fractures and small conduits, as shown by the chemical and thermal load which is the highest of all the system's outputs (Gemiti & Licciardello, 1977).

The proposed model justifies the existence of mixed conditions, with the main springs being characterised by accentuated flood peaks (main drains contribution) but with a high and relatively constant basal flow in the absence of direct recharge. It also justifies the many reports regarding periodical turbidity and the hydrochemical differences between the various spring waters. These differences are small but important to attain an adequate understanding of the numerous processes that take place in the system.

CONCLUSIONS

To summarise, it is possible to draw a series of conclusions and make a series of useful suggestions for the full exploitation of the identified resources and their protection from contamination. For this purpose, it therefore appears vital:

- to ascertain the existence of good quality ground water resources which differ from those flowing in the main dominant drain;
- to quantify the contamination induced in the system and identify its type and origin;
- to locate the precise and widespread sources of direct and indirect contamination (brought by surficial contributors);
- to make an analytical assessment and zoning of the vulnerability of the aquifer system.

On the basis of these necessary studies, it will be possible:

- to plan the adequate actions to restore and reclaim the water bodies;
- to plan the rational fractionated exploitation of the resource in relation to its varying levels of quality;
- to design the contamination elimination systems and ways to protect the different parts of the aquifer;
- to study the necessary limitation severity to be set on the dominant territorial system and their graduation over space and time.

In this way it will be possible to achieve the complete recovery of a major water resource which, if well tapped, exploited and protected, may represent an outstanding strategic reserve in the immediate future for replacing or integrating traditional resources in all adjacent areas, in particular those exposed to a strong depletion or contamination hazard and making possible to develop new socio-economic opportunity in the border areas.

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HIDROGEOLOŠKI SISTEM TIMAVE: POMEMBEN DODATNI VODNI VIR, KI MORA BITI UPORABLJEN IN ZAŠČITEN

Povzetek

Hidrogeološki sistem Reka-Timava sestavljata površinski (porečje Reke - 407 km^2) in podzemeljski del (Timava, 41 km razdalje med ponorom v Škocjanske jame in izviri pri Devinu). Tako velik sistem je pomemben vodni vir, ki ga ne predstavljajo le vode ponikalnic ampak tudi padavine, ki padajo na Kras. Zato so izredno pomembne poglobljene raziskave, ki bodo omogočile vzpostaviti okoljevarstveni program za varovanje teh vodnih virov. Prispevek končuje z vrsto sklepov in napotkov za polno izkoriščanje znanih virov ter za njihovo varovanje pred onesnaževanjem. Prispevek je predhodna sinteza znanih podatkov s posebnim poudarkom na geometriji sistema, dinamiki procesov in kvalitativni obremenitvi, zaradi katerih je danes sistem tako malo izkoriščan.