WATER–BUDGET AS A TOOL TO EVALUATE THE SUSTAINABLE USE OF GROUNDWATER RESOURCES (ISONZO PLAIN, NE ITALY)

Calligaris C. (a), Casagrande G. (b), Iervolino D. (c), Lippi F. (c), Olivo P. (c), Ramani M. (c), Treu F. (a), Zini L. (a)

(a) Department of Mathematics and Geosciences, Trieste University, Via Weiss, 2, 34128, Trieste, Italy. E-mail: calligar@units.it
(b) Servizio gestione risorse idriche, Regione Friuli Venezia Giulia, Via Longarone 38 – Udine (Italy)
(c) Servizio gestione risorse idriche, Regione Friuli Venezia Giulia, Via Giulia 75/1 – Trieste (Italy)

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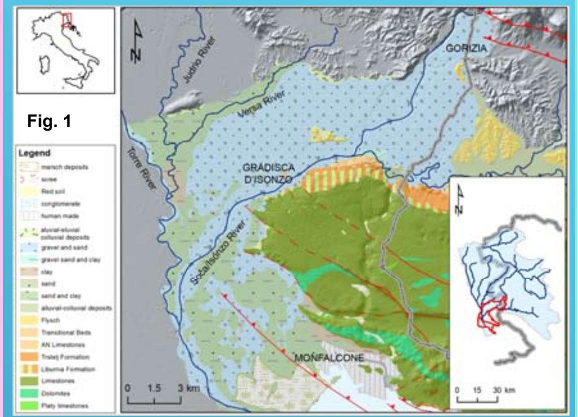
ABSTRACT

Climate change and the necessity to preserve and provide good quality freshwater for human consumption has led researchers to study the aquifers of the Friuli Venezia Giulia Region (NE Italy) in more detail. Of particular interest is the cross-border Soča/Isonzo River, which contributed to the creation of a remarkable alluvial aquifer. Today more than 300.000 inhabitants are supplied by water withdrawals from AcegasApsAmga Hera Group and the IrisAcqua water companies, the water wells of which are located in the southern part of the afore mentioned aquifer. Taking into consideration the importance of this area for the inhabitants, in order to guarantee the sustainability of the actual use of the water resource, the necessity has arisen to compute a groundwater balance.

The leakages of the Soča/Isonzo River and the effective infiltrations constitute the water balance input parameters. Outflow, evapotranspiration, spring discharges and groundwater withdrawals estimated for each type of use and for each aquifer system have been evaluated.

Withdrawal entity, resurgence belt discharge, phreatic levels and confined aquifer pressure are closely interdependent and in dynamic equilibrium. The sustainability of the actual use of the resource comes from the consistency and ratio between recharge and withdrawals. The more detailed and precise the input values in the water balance are, the more conscious is the management and safeguarding of this precious resource, avoiding pauperization in terms of quantity but especially quality.

Within the framework where trends in rising temperature are clear, (2014 and 2015 were the hottest years of the last century), trends in precipitation are not clearly indicated, groundwater balance can be understood as a starting point for any future planning.



INTRODUCTION

The Friuli Venezia Giulia Region (NE Italy) is a small territory (7.845 km²) where surface fresh waters, springs and groundwaters are abundant, in fact the area is reported as the most rainy in Italy. They are an important natural wealth in terms of quantity, quality and ease of supply. This optimal condition, however, has long believed that it allowed an irrational and poorly controlled exploitation. This inevitably produced tangible consequences on the water resources availability. Since twenty years ago, has been noted a lowering in the phreatic groundwater levels of the High Plain and a lowering of pressure in the confined aquifers of the Low Plain (Cucchi et al., 1999; Calligaris et al., 2016). These phenomena are accompanied by the gradual amplitude range reduction of the resurgence belt, resulting in a decrease of the amount of available water to the naturalness of the lowlands, its impact on ecosystems and related loss of traditional habitats such as wet meadows.

In light of this, it is easy to predict that, unless appropriate measures will be taken at a regional level, the intense human pressure will cause the persistence, if not the increase, of the just described phenomena.

The recharge, the natural runoff and groundwater exploitation rates have also to be known in light of a sustainable groundwater management.

GEOLOGICAL AND HYDROGEOLOGICAL SETTING

The Soča/Isonzo Plain is located in the north-eastern corner of Italy, in the eastern side of the Friuli Venezia Giulia Region bordering Slovenia (Fig. 1).

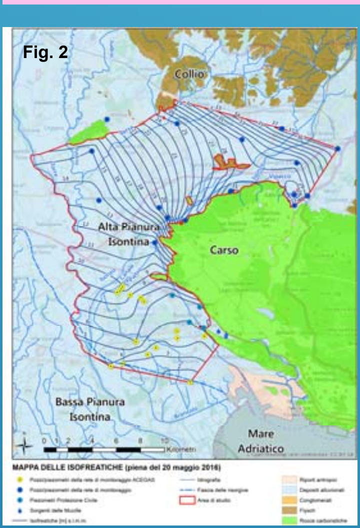
The karst spring of the Soča/Isonzo River originates under the glaciated Julian Alps in Slovenia. It crosses the Italian border after a course long about 100 km flowing into the Adriatic Sea. It is the second largest river of the Region. Its average discharge, measured 5 km inland from the Adriatic Sea, is 134 m3/s (Zini et al., 2011).

The plain area, subject of the present study, is the result of an important sediment transport occurred during the Quaternary. It is enough to consider the period after the Würmian glacial age when from the frontal side of the alpine glacier, the glacial outlets were flowing modifying the environment and building up the actual morphology (Venturini, 2003). With these preconditions, it is easy to understand how the Friuli plain, as we can observe it today, is due to the fluvial redistribution of several hundred cubic meters of rocks subtracted to the Alpine ridge and reduced into small fragments as sand and pebbles. Is known that during the Roman age, the Soča/Isonzo River was flowing bordering the Karst hydrostructure in correspondence of Ronchi dei Legionari small town. Within the Middle Ages, that river branch was abandoned and the river started to flow into the actual riverbed (Venturini, 2003).

Quaternary deposits which form the Plain are characterised to have a variable thickness: from 100 m in a depression sited S to Gorizia, up to 350 m in the Villesse area. The thickness gradually decrease towards NE at the border with Slovenia where it is between 20 - 30 m (Zini et al., 2011).

With this in mind, it is easy to understand that the area is characterised by the presence of an extensive alluvial unconfined aquifer, which evolve southward into a multi-layered confined/semiconfined aquifer before outflowing into the Adriatic Sea. The aquifers greatly differ from a textural viewpoint: the northern part of the plain, the so-called High Plain (Fig.1), is more gravelly, while the Low Plain (Fig. 1) in the southern part, mainly consists of finer deposits sizing from gravel to sand and silty-sand.

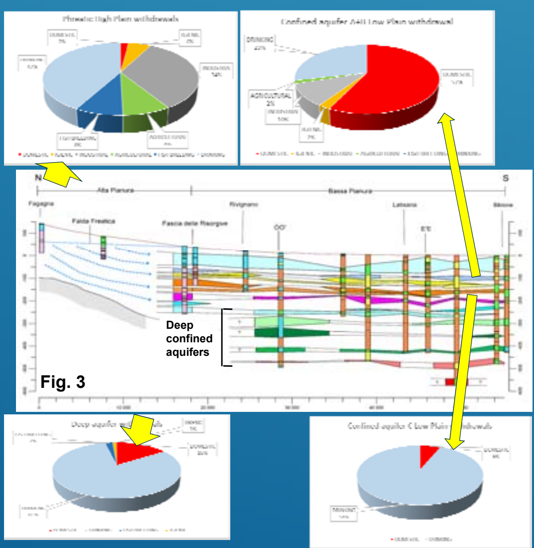
The Soča/Isonzo River is powered by the Slovene waters flowing in its mountain basin. Prior that its course reaches the Italian border, the Salcano dam intercepts its flow, regulated by the Slovene. Once in Italy, Soča/Isonzo waters freely flow on and in the alluvial deposits where their influent character contribute to the aquifer recharge which partially also contribute to the recharge of the Classical Karst hydrostructure with about 10 m3/s (Zini et al., 2013).



From the hydrogeological viewpoint, the High Plain is characterised by a phreatic aquifer which, during high flow conditions, is well represented by the **Fig.2.** To realise this map, several field surveys were done and the presented map is realted to the one of 20th May 2016 (AAVV, DMG Internal Report, 2017).

The general groundwater flow goes from NE towards SW in the northern part of the area, mainly guided by the flow direction of the main rivers. After the junction between Isonzo and Torre rivers, the main flow direction changes and the flow is toward S and SE.

Well withdrawals



To obtain the budget in non-natural conditions, the groundwater withdrawals were evaluated for each type of use and for each aquifer system. Data were analysed starting from 2 Geodatabase: one for the domestic use, not subject to withdrawn license named as "domestic withdrawals" (1077 wells and 4244 estimated users in the High Plain, and 2068 wells and 7345 estimated users in the confined aquifers of the Low Plain) and one concerning industrial, agricultural, fish breeding, hygienic, geothermal and other minor uses, named "licensed withdrawals", instead subjected to a required license for withdrawing. The well withdrawals amount were evaluated, on annual base and expressed as m3/s. The withdrawal quantity is calculated on the year 2016 which has been considered to be a mean year.

In the High Plain, considering to use 290 l/d for a single person, from the phreatic aquifer there is a withdrawal of 0.01 m3/s for the domestic uses. The total licensed withdrawals amount has been calculated to be 0.70 m3/s with a prevalence of the drinking use (42%) on the industrial (34%) and the agricultural (8%).

In the Low Plain, downstream the spring belt, most part of the withdrawals are related to shallow aquifer system (A+B) with a withdrawal volume of about 2.60 m3/s (1.11 m3/s licensed and 1.49 m3/s domestic) due mainly to domestic (57%) and drinking (29%) uses over the others.

In the C aquifer system, the domestic withdrawals are really few, only 0.02 m3/s, 6% of the total amount in that aquifer system compared to the drinking ones which reaches 0.49 m3/s, the 94%. The situation is similar if we go more in depth, from D to F. In these deep aquifers, 81% of the waters are used for drinking, and the rest is used for other purposes. These numbers are linked to the good quality waters present in these aquifers and to the withdrawn due to the water supply systems for drinking purposes.

If we analyse the quantities and not the percentages, from the phreatic aquifer of the High Plain there is a total withdrawn volume of water of 0.71 m3/s. From the systems of aquifer in the Low Plain, the amount of withdrawn water is instead of 3.95 m3/s.

The groundwater budget

The considerable water withdrawals and the rapid deterioration of the groundwaters highlighted the necessity of the assessment of its sustainable consumption and its future use. To reach the goal, the hydrogeological balance can be considered a useful tool in the evaluation of the resources.

The budget was computed solving the equation P=ET+R+I on a 500 m regular grid and daily temporal resolution. P is the daily rainfall; the process of snow accumulation and snow melting was taken into account in computation. The evapotranspiration (ET) was quantified as "crop evapotranspiration" and calculated with the two step approach as product between reference evapotranspiration, computed with the Hargreaves Samani formula (FAO Irrigation and drainage paper 56, FAO; Allen at al., 1998) and crop coefficient (Kc). The run – off component (R) was calculated using the curve number methodology modified by Williams et al. (2008) for continuous analysis.

For the Judrio and Versa rivers, using R and I, the mountain basin discharge was calculated as 7,6 m3/s. Of this amount during the wet months, 90% is the part which infiltrates, during the dry season instead all the discharges infiltrate. With this in mind the obtained infiltration value was of 7,4 m3/s.

For the Soča/Isonzo River basin, seen that run-off (R) and infiltration (I) were not available, we used the river discharge. Thanks to the results obtained in the framework of the ITA-SLO 2007-2013 Camis Project (www.camisproject.eu), several field surveys allowed to measure the missing data (Casagrande and Avon, 2016). Despite the difficulties caused by the hydropicking at Salcano dam (SLO), for the 2016, an average discharge has been calculated: 101,0 m3/s. The grain size characteristics of the alluvial deposits of the High Plain represent the perfect environment were developed the influent character of the river. The latter was measured defining the river leakages in close cross-sections and using 6 piezometers. The leakages have been evaluated to be 15% of the river discharge.

For the Vipacco river, as for the Soča/Isonzo, the available discharges measured at Miren, close to the ITA-SLO border, were used in order to estimate the value of the leakages which were considered to be 10% of the measured discharge.

For the Torre river, discharge value was available in the regional archives and an infiltration value of 1,3 m3/s was given.

For the High Plain area, the effective infiltration (I) was 3,6 m3/s, to which, in order not to neglect a single component, the contribution to the irrigation (0,5 m3/s) was added.

From all the input which contribute to the recharge of the High Plain, to obtain the groundwater balance, it is necessary to subtract the waters which contribute to the recharge of the karst hydrostructure and which were estimated to be 10,0 m3/s. From the High Plain, also another component flows away, and this is the discharge in correspondence of the spring belt. This amount was estimated to be 16,0 m3/s.

Subtracted all the withdrawals, to recharge the systems of aquifers of the Low Plain, only a modest amount of water remains, 3,4 m3/s to which we have to add the contribution to the recharge coming from the karst aquifer (1,0 m3/s), witnessed by the presence of springs bordering the karst hydrostructure at the contact with the alluvial plain. With these numbers, the balance is positive, with a surplus of water of 0,4 m3/s, value that make us conscious that we can not waste the resource that we have. All the groundwater balance component are in fact affected by an uncertainty and some of them have to be better refined. So it is easy in this situation to reach a deficit in the availability amount of water.

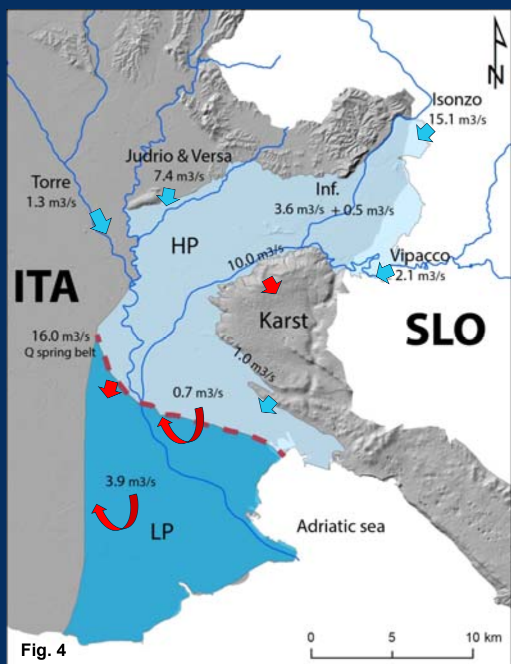


Fig. 4

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