Groundwater as a renewable source; groundwater protection

QUALFALDA PROJECT: QUALI/QUANTITATIVE STATE OF AQUIFERS IN THE MILAN PROVINCE

Licia Guzzella, Franco Salerno, Stefano Ravelli, CNR-IRSA, via della Mornera 25, 20047 Brugherio (MI)
guzzella@irsa.cnr.it
Fiammetta Di Palma Cristina Arduini, Andrea Zelioli, Servizio Gestione Acque Sotterranee, Provincia di Milano, Corso di Porta Vittoria 27, 20122 Milano

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Summary

In agreement with the Water Frame Directive 2000/60/CE and with the Daughter Directive 2006/118/CE, the Water Research Institute of National Research Council and the Groundwater Department of the Milan Province were undertaken an investigation, called QUALFALDA Project, regarding the environmental state of the different aquifers in the Milan Province. The study was carried out in 2006 with the aim of evaluating the basic hydrochemical characteristics of the three main aquifers: the surface one, the middle one and the confined aquifer. The three aquifers showed different mean value of conductivity and chlorine content, depending on the different capacity of ions to be transported from topsoil to groundwater. Some additional parameters as total organochlorine compounds, total pesticides, lead and cadmium concentrations were also considered because they were considered as the main pollutants of anthropogenic origin.
In the present study the quantitative status of the different aquifers was classified according to the published Regional Plan that based the evaluation by considering the mass balance between the use of the water resources for drinking consumption and the natural or artificial recharge and the piezometric level trend in respect to a reference year.
All the maps were GIS (Geographical Information System) referred with the use of ArcView 3.2 ver. software and they allowed the description of the environmental state of the different aquifers, underlining critical aspects of Water Frame Directive application.

Introduction

In agreement with the convention between IRSA-CNR Institute and Milan Province to study the quali/quantitative state of aquifers in the Milan Province, a first classification of the Chemical State (SCAS) and of Quantitative State (SQAS) was undertaken for the main aquifers: the surface one, the second one and the third aquifer. According to our national law (D.Lgs. 152/99) and to the Daughter Directive 2006/118/CE, the conducted study was undertaken with the aim of both evaluating the problems associated to the law application for the aquifer classification and supporting the Milan Province in the management of authoritative procedure for allowing the use of wells for civil or industrial uses.
In order to define the Chemical State of underground waters, the chemical analyses of the wells located in the Province for the different aquifers were considered, producing GIS maps specific for each basic (chlorine, conductivity, sulphate, ammonia, iron, manganese and nitrate) and additional (total organochlorine compounds, total pesticides, lead and cadmium) parameters, while the Quantitative State was not defined ex-novo for this study. A previously defined SQAS State was reported in Piano di Tutela delle Acque of the Lombardy Region (2006), showing a quantitative classification of the surface and the second aquifers referring to 2003 year. The integration of

Qualitative and Quantitative State classifications allowed the establishment of the Environmental State of the different aquifers in 2000-2004 period as requested by the national law D.Lgs. 152/99. At the end, a different Environmental State of the aquifers was evaluated, considering the new law D.Lgs.152/06 and showing the differences between the two obtained maps.

Material and methods

The first phase of the project was focused on the identification of the aquifer attribution for each well: the *surface* one (first), the *traditional* one (first and second), both of them unconfined and the *deep* aquifers (second and third) that contrarily are confined. The Underground Department of the Milan Province assigned to each well the relevant aquifer, considering the depth of the well, the depth of the fenestrations and the stratigraphy. Exclusively the wells with a well-known attribution of the relevant aquifer and with at least ten chemical analyses for the considered period (2000-2004) were selected in this project for the evaluation.
Following these criteria, 599 well/piezometers were selected: 55 wells for the first aquifer, 268 for the traditional one, 138 for the second one and 138 for the third aquifer. These wells were located in 164 municipalities, while no wells were available for 24 municipalities, because of the scarcity of the chemical results.
In order to process the data, a Microsoft Access® Database was used with the aim of evidencing possible mistakes (aquifer attribution, anomalous chemical analysis, ect…). For each well, the average, the standard deviation and the percentage standard deviation of each chemical parameter for the considered period was computed according to the D.Lgs. 152/99 (7 basic parameters more the additional ones). Following this procedure, possible anomalies or point pollutant sources were detected (*hot spots*). Using ArcView GIS ® 3.2 and the kriging as geostatistical method, a map was performed for each parameter and for each aquifer. For the municipalities with almost one well, a full colour was assigned (*direct interpolatio*n) in the map; contrarily for the municipalities with no field data available, a broken colour was used (*indirect interpolation*). In order to evaluate the goodness of the interpolation, considering that an independent series of data was not available, the comparison was made using the interpolated data versus the relevant observed ones. For each parameter the determinated coefficients on the average were very high (R^2=0,97). Moreover a slight underestimation of the interpolated values versus the observed ones was observed. To evaluate how much this underestimation affected the result evaluation, for each parameter, the number of wells that after the interpolation process changed class was computed. This analysis underlined that a lower class was assigned only to 2,8% of the total considered wells (4 on 138). Therefore the low error level pointed out the high reliability of the results.
At last, because of the few available data for the first aquifer (55 wells, for which only 38 of them with 5 parameters on 7), we preferred not interpolating in any way the data, limiting the results to a point representation on the map.

RISULTS AND DISCUSSION

SCAS for the traditional aquifer

The map of the Chemical State (SCAS) for the traditional aquifer, considering the basis parameters, is reported in figure 1. In the case of 11 municipaliteis (4% of the total Province surface) it was impossible to define a SCAS State both undertaking a direct or/and an undirect interpolation (table 1), because the chemical analyses for more than two basic parameters were missing.
The class attribution was defined on the basis of the worst chemical class according to our national law D.Lgs. 152/99. The results (table 1) showed that only 1% of the total surface, located in the Southern part of the Milan Province, was in class 1, then very good; the 43% in the class 2, than good, and 52% in the classes sufficient or scarce. Nitrate (figure 2) was the chemical parameter responsible of the class attribution with a diffuse contamination located in the Milan municipality and in the Northern part of the Province.
The additional considered parameters (total organochlorine compounds, total pesticides, lead and cadmium) were selected in the present investigation on the basis of the main human activities relevant for the territory and of the availability of chemical analyses in the 2000-2004 period. In this case the limit fixed by the national law was considered for the chemical classification: 5 µg L^{-1} for cadmium, 10 µg L^{-1} for lead and organohalogen compounds, 0,5 µg L^{-1} for total pesticides. The geographical areas that exceed the limit values were attributed to the scarce chemical quality (red colour)
The limit value was exceed mainly for organohalogen compounds that showed a diffuse contamination in the Northern and Central part of the Province with a tounge-shape coming from the North (figure 3).
Cadmium and lead never exceed limit values and the total pesticide only in a limited number of cases.

By considering additional parameters, 23% of the surface of the traditional aquifer in the Milan Province was in a scarce state (figure 4), 21% mainly due to the total organohalogen content and 2% to the total pesticide content, while 32% of the surface aquifer was in a sufficient class and the remaining 45% in good or very good quality.

SCAS for the surface and second aquifers

The chemical classification of the wells located in the first aquifer was possible only for 38 wells/piezometers distributed in 17 municipalities; for these wells six basic parameters were considered: no data for ammonia was in fact available. According to this classification, no well was in a very good quality state, 16% of the wells was in a good quality and 84% in a sufficient or scarce
As regard the second confined aquifer, the SCAS State was very good for 1% of the Milan surface (table 1), mainly in the Southern area; 41% of the total surface was good and 21% was sufficient.
It was impossible to define the presence of a confined second aquifer in a 36% of the considered provincial surface, mainly in the Northern-Western and Northern-Eastern part of the Province.
Nitrate average concentration was the main cause of class attribution of wells and a diffuse nitrate contamination was observed in the Northern-Central part of the Province and in the Milan municipality.
The chemical state of the second aquifer was generally better in respect to that of the traditional aquifer (table 1), both because of a real improvement of the aquifer chemical state and because the second aquifer was present in a limited part of the Province and the high contaminated Northern-Eastern part of the Province was excluded.

SCAS for the third aquifer

The map for the SCAS State for the third aquifer considering the basic parameters is reported in figure 5, showing that 11% of the total surface located in the Southern part of the Milan Province, was in a very good condition; 70% of the surface was in a good chemical quality and only a limited 12% had a sufficient or scarce water quality (table 1).
Nitrate was the dominant parameter in the chemical classification; however some contaminated hot spot situations of manganese were also present in the municipalities of Aicurzio, Arcore, Biassono, Cernusco S/N. In conclusion, the 80% of the Milan Province was in almost in a good quality condition as regard the third aquifer.

SCAS according to the law D.Lgs. 152/06

In the new law D.Lgs.152/06 some chemical parameters were listed for monitoring underground water resources: oxygen content, pH, conductivity, nitrate and ammonia. By comparing the two laws edited in 1999 and 2006, oxygen content and pH parameters were considered only in the new one. No available chemical analyses for oxygen content allowed a map description of the chemical state, while for pH a map for the traditional and the third aquifer was undertaken. Because the law did not indicate a specific range of classification for pH, the authors consider as not alterated or degradated state a pH range of 6-8 units, while pH < 6 or pH > 8 were considered as acid or basic chemical state of aquifers.Therefore a scarce water quality was attributed to wells characterized by pH values out of 6-9 range of values.
The obtained results showed a 100% good chemical state as regard to pH for the traditional aquifer and a 98,5% of the Milan provincial surface for the third aquifer. Some limited alteration of pH (pH$>$8) was measured in the municipalities of Rozzano, Lainate and Desio

Quantitative State of the traditional aquifer according to D.Lgs. 152/99 and D.Lgs. 152/06

The law D.Lgs.152/99 established that the parameters to be considered for quantitative state were defined by the Regions on the basis of the main morfological characteristics of aquifers and of the considered uses. Besides, this law defines that the Regional Water Master plan contain indication of the human pressures due to water different uses.
In this study the quantitative classification reported in the Regional Water Master plan (D.G.R., 2006). for year 2003 was used and a new ex-novo definition was not undertaken. The Regional estimation was conducted by considering the piezometric trends of the traditional aquifer and the ratio between the use of the water resources for drinking consumption and the natural or artificial recharges. The proposed classification was considered representative of surface and traditional aquifers.
The Quantitative State of the Milan Province is reported in figure 6, using a classification undertaken on the basis of municipal surface. As showed, only Milan municipality (9% of the surface) had a

consistent squilibrium (class C of the law), while the Northern-Eastern municipalities (22% of the surface) located in the future Monza Province had a reduced squilibrium (class B of the law).
Only two main classes (good or scarce) of the Quantitative State were reported in the new law D.Lgs. 152/06,but a conversion table between the two classification, the previous one and the new one, was not reported.
Therefore, considering the reduced squilibrium class (class B) as correspondent to a good or a scarce state, the Milan provincial surface in a scarce state can varies between a 9% or a 31% of the total surface.

Environmental State for the traditional aquifer

The law D.Lgs 152/99 established five different Environmental States, overlapping the SCAS values (classes 1, 2, 3, 4, 0 in figure 4) with the Quantitative State (classes A, B, C, D in figure 6).
The map of the Environmental State of the traditional aquifer is reported in figure 7: 43% of the Milan provincial surface was in a good or very good state. In respect to the SCAS classification, the Environmental State showed a reduced surface of the good state, because of the quantitative squilibrium of the Milan municipality.
As regard the new D.Lgs. 152/06, the Environmental State reported both the SCAS classification and the Quantitative State in one map (figure 8), using a full colour for SCAS values and a dashed colour for the Quantitative State. By converting the reduce squilibrium (class B) of the D.Lgs. 152/99 with the good state of the D.Lgs. 152/06, the 43% of the total Milan provincial surface is in a good Environmental State, according to the new law.

CONCLUSIONS

The first data elaborated for the quantification of the aquifer Chemical State in the Milan Province in the 2000-2004 period showed that the aquifer used for drinking water production (the traditional aquifer) is for almost 44% in a good state and that the confined aquifer (the third aquifer) has a good state for 81% of its surface. Nitrate and organochlorine compounds are the main contaminants. As regard Quantitative State, only Milan area can be considered affected by a significative human impact.

References

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Table 1 – Percentage distribution of the SCAS State for the different aquifers

I+II aquifer	**Parameters**							**SCAS**
	Conductivity	Chlorine	Iron	Manganese	Sulphate	Nitrate	Ammonia	
I Class	5 %	86 %	93 %	94,5 %	18 %	2 %	86 %	1 %
II Class	91 %	10 %	3 %	1 %	78 %	42 %	6 %	43 %
III Class	-	-	-	-	-	51 %	-	51 %
IV Class	-	-	-	-	-	1 %	-	1 %
Not interpolated area	4 %	4 %	4 %	4,5 %	4 %	4 %	8 %	4 %

II aquifer	Parameters							SCAS
	Conductivity	Chlorine	Iron	Manganese	Sulphate	Nitrate	Ammonia	
I Class	11 %	60 %	62 %	63 %	18 %	3 %	63,5 %	2 %
II Class	53 %	4 %	2 %	-	46 %	40 %	0,5 %	41 %
III Class	-	-	-	-	-	21 %	-	21 %
IV Class	-	-	-	-	-	-	-	-
Not interpolated area	36 %	36 %	36 %	37 %	36 %	36 %	36 %	36 %
III aquifer	**Parameters**							**SCAS**
	Conductivity	Chlorine	Iron	Manganese	Sulphate	Nitrate	Ammonia	
I Class	71 %	92 %	90 %	87 %	82 %	13 %	76 %	11 %
II Class	22 %	1 %	3 %	4 %	11 %	69 %	14 %	70 %
III Class	-	-	-	-	-	10 %	-	10 %
IV Class	-	-	-	1 %	-	1 %	-	2 %
Not interpolated area	7 %	7 %	7 %	8 %	7 %	7 %	10 %	7 %

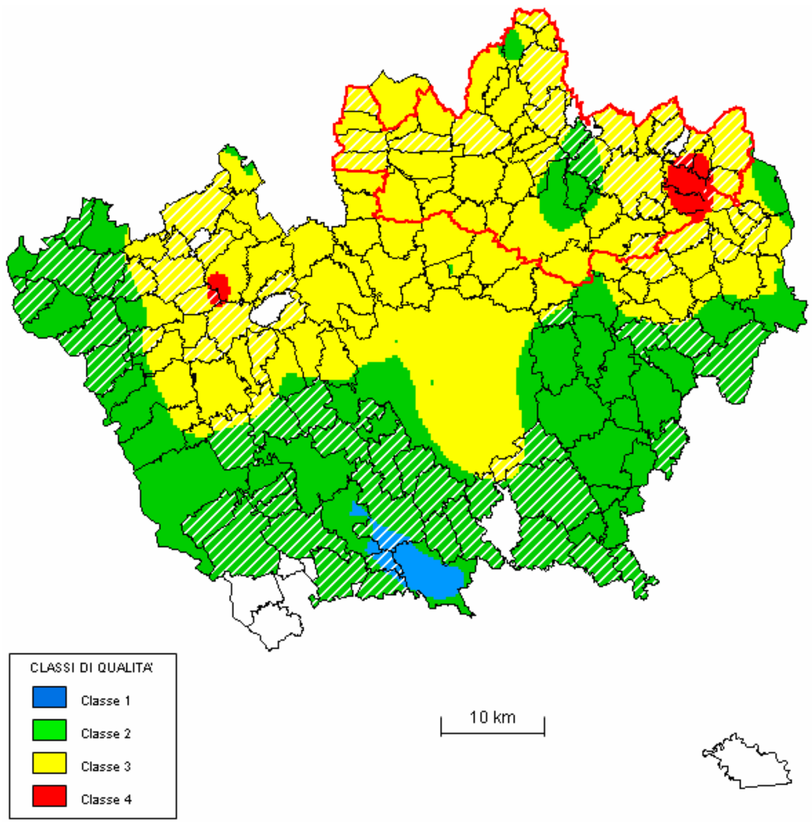

Figure 1 - SCAS of the first and second aquifers with basic parameters

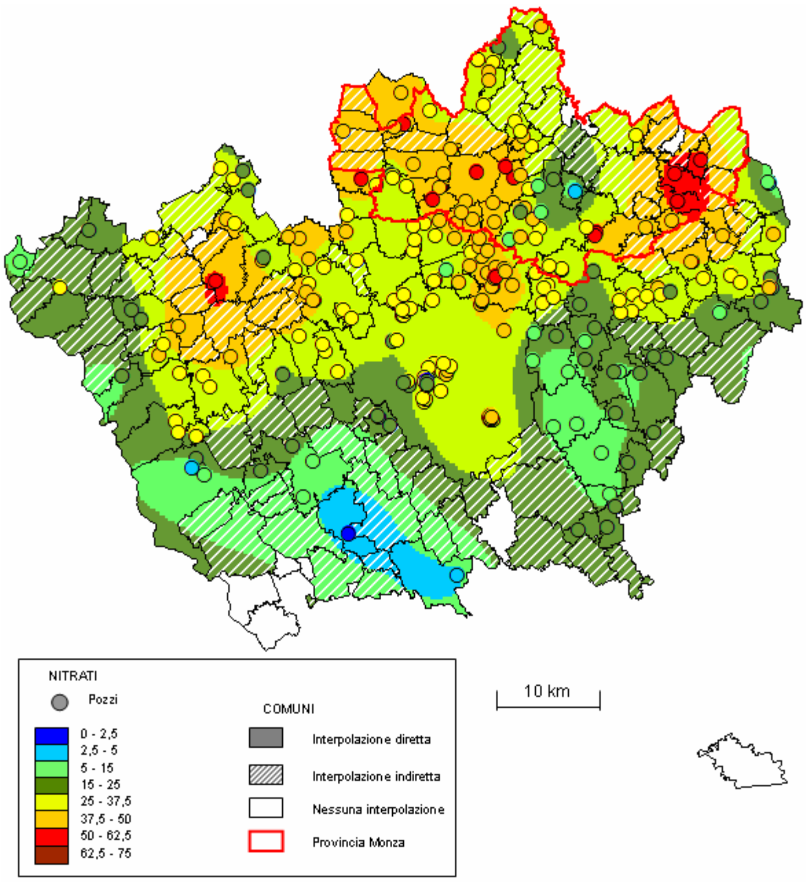

Figure 2 - Nitrate concentrations (mg L^{-1}) for the first and second aquifers

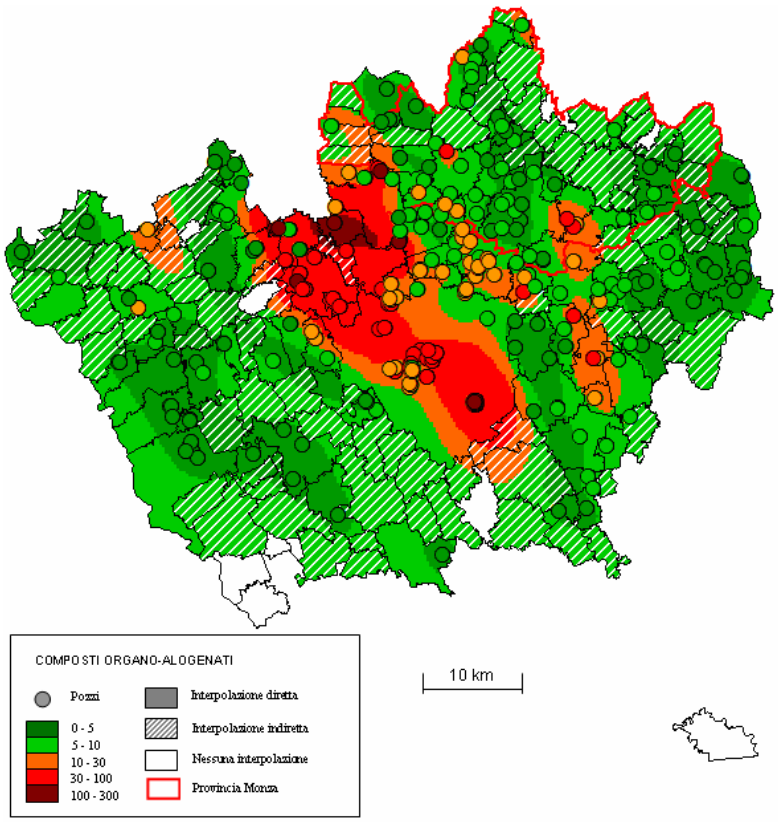

Figure 3 - Concentrations (µg L^{-1}) of total organochlorine compounds for the first and second

aquifers

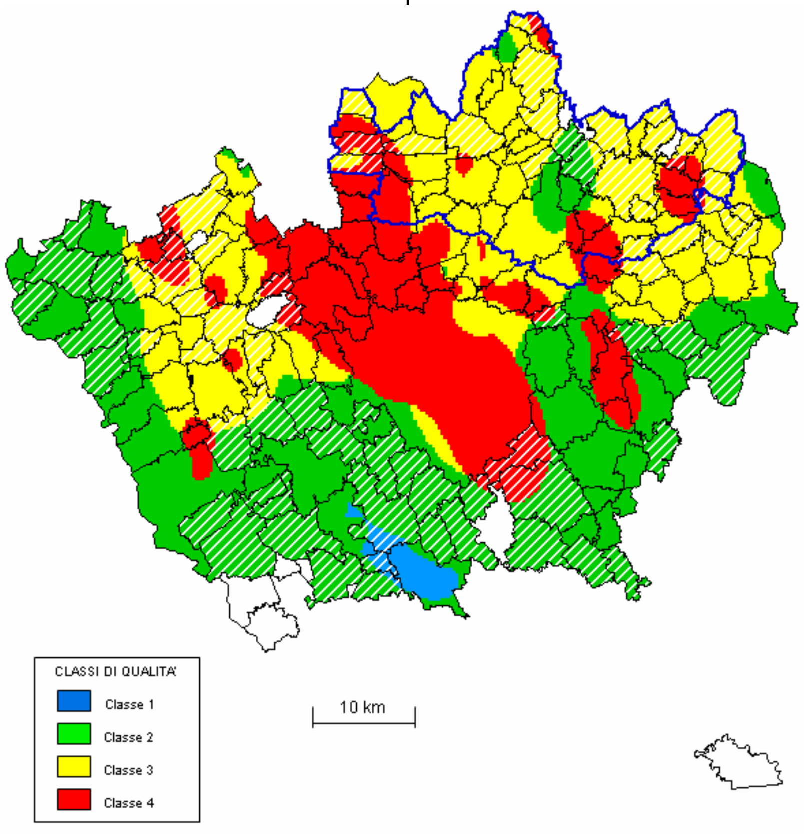

Figure 4 - SCAS for the first and second aquifers with basic and additional parameters

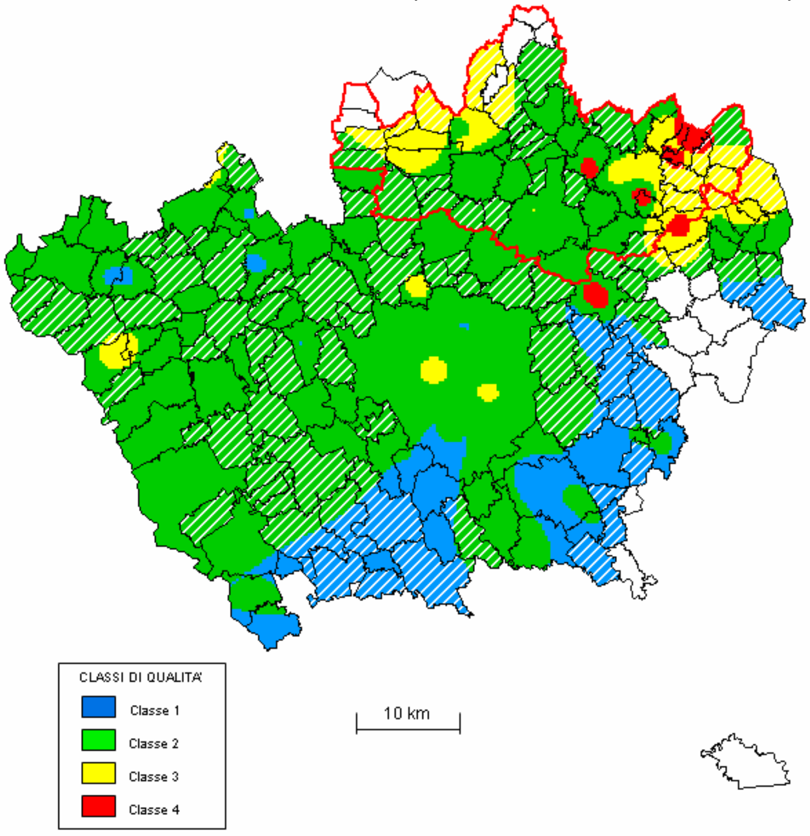

Figure 5 - SCAS of the third aquifer with basic parameters

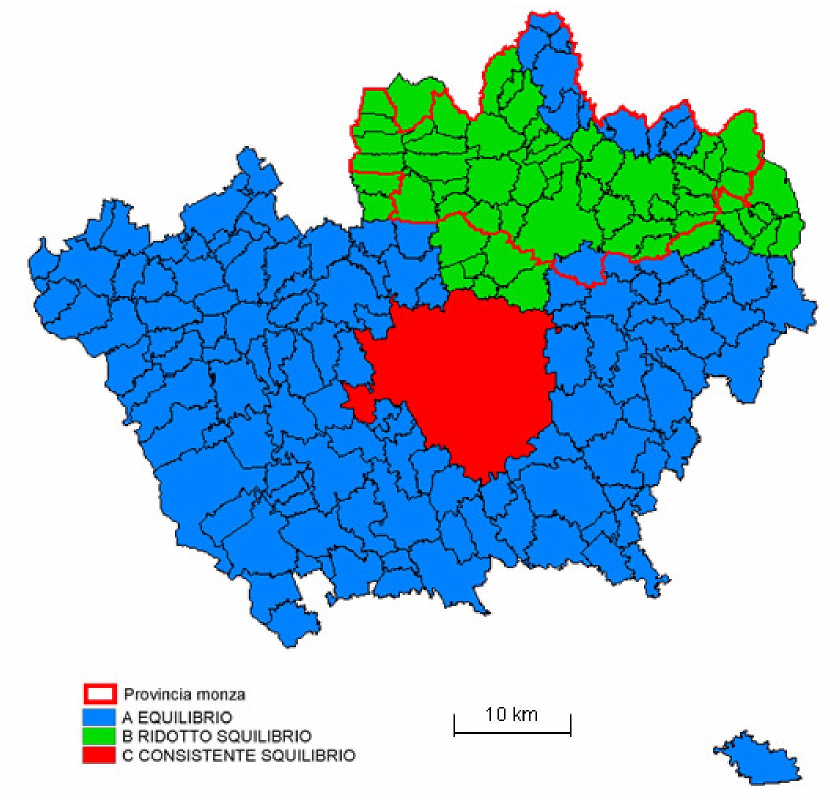

Figure 6 – Quantitative State of traditional aquifer according to D.Lgs. 152/99

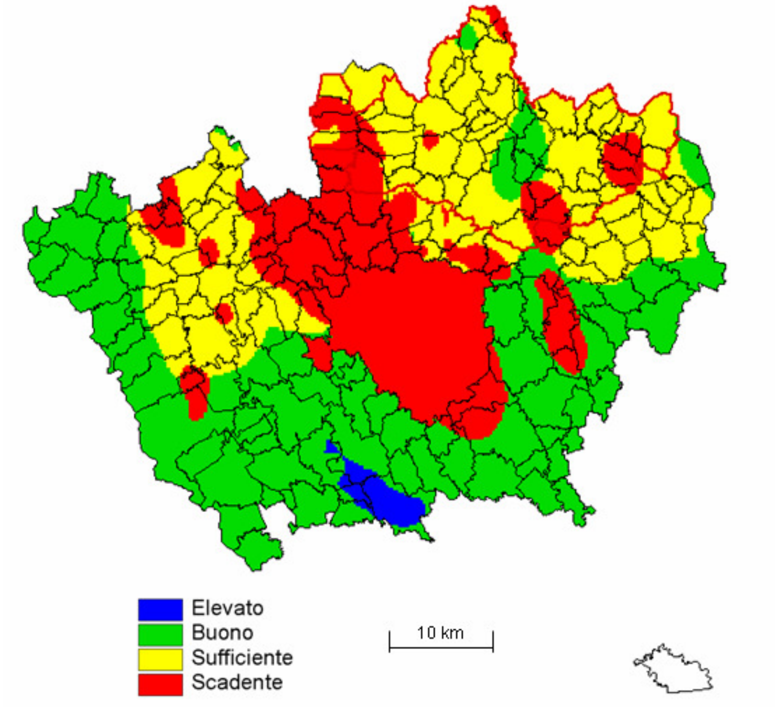

Figure 7 – Environmental State of traditional aquifer according to D.Lgs. 152/99

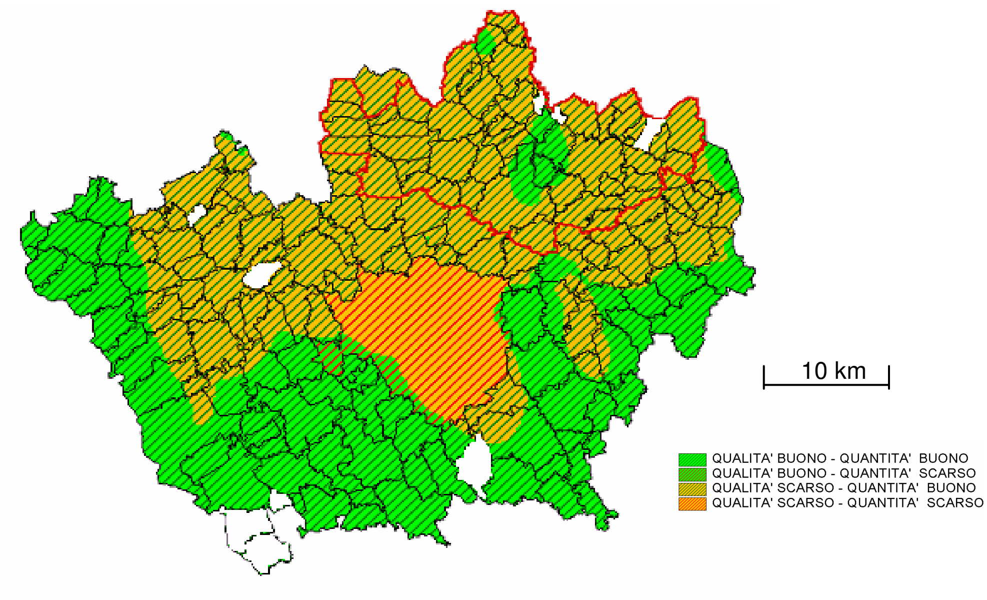

Figure 8 – Environmental State of traditional aquifer according to D.Lgs. 152/06