The integration of the water cycle with other natural resources: new measures for soil conservation

Extract from the "Report on the State of the Environment in Italy" by the Ministry of the Environment published in 1993.

Contents:

The Water resources and soil conservation

The law on soil conservation in Italy was approved by Parliament in 1989. This law (183/89) is designed to secure coordination of the different sectoral policies for the water cycle, soil conservation, water pollution abatement and protection operations, use and management of water resources for the purposes of rational economic and social development, and protection of the associated environmental aspects. To achieve these objectives, the law assigns duties to all the competent authorities dealing with land use and water management, namely central government, the regional, provincial and municipal administrations, the mountain community administration, the reclamation and irrigation consortia, including the mountain watershed consortia.

The real institutional innovation is represented by the formation of the watershed authorities, which have as their geographical reference framework the river basin or watershed, a division that supersedes the earlier regional and sub-regional administration boundaries. The authorities can be separated into three different levels of representation: watershed of national, interregional and regional concern.

The operative instrument for attaining the objectives identified by the law is the watershed plan, which serves as an area plan for the sector. It represents the means of collecting information, and defining the legislative and technical-operational aspects to be used in the preparation of the programmes and regulations for the conservation, protection and improvement of the soil and for correct water use, according to the physical and environmental features of the geographical area concerned.

At the second session of the Preparatory Committee for the United Nations Conference on Environment and Development, held in in Geneva from 18 March to 5 April 1991, it became clear that the most suitable scale for correct water management is the watershed level. This approach is adopted both for small scale and medium-size watershed and for the larger watersheds (Rhine, Danube) which concern several countries.

Under the new laws on soil conservation Italy has been divided into:
- six watersheds of national significance;
- eighteen watersheds of interregional significance;
- watersheds of regional significance;
- the experimental watershed of the River Serchio.

Implementing Law 183/1989 on soil conservation

The work of the watershed authorities is proceeding with some difficulty: practical and organisational problems on the one hand and staffing problems on the other have stalled efforts to deal with the burdensome task deriving from the implementation of the law. The same setbacks are being faced for the interregional and regional watersheds, where delays in organisation are considerable. These problems, coupled with the institutional innovations introduced, have resulted in the implementation of the different provisions being held up by almost two years, These provisions include the preparation of the forecast and planning outlines described in the law, which, among other things, should set the priorities for urgent action to safeguard the land, and for the protection and rational use and management of the water. However, the definition of these plans has provided an initial general outline of the matters needing attention, as well as a brief inventory of the more widespread cases of deterioration in our country. Given the size of funds set aside for study and planning activities (about 200 billion lire for all the national, interregional and regional watersheds, i.e., 10% of the overall resources allocated for the five years 1989-1993), the attainment of the more general planning targets of the watershed plans ought to be facilitated.

Moreover, it was precisely in recognition of the inevitable problems associated with the early stages of implementing the law that the legislator choose to operate in stages, in other words by establishing that watersheds plans should be drawn up initially as forecast and planning outlines that would be temporary in nature and provide the basis for the final planning process.

Watershed classified as being of national concern by Law 183

The River Po watershed

The River Po watershed is by far the largest and the most complex of the watersheds of national significance identified by the law on soil conservation. The main stretch of the river is 652 long, of which 510 are embanked, and it is fed by 141 tributaries. The watershed extends for 71,057 square kilometres (23.6% of the total area of Italy) into six regions (Piedmont, Valle d'Aosta, Lombardy, Veneto, Liguria, Emilia Romagna), the autonomous province of Trento, twenty-six provinces and 3,188 municipalities.
The watershed's economic, productive and environmental importance is second to none, in that it contributes as much as 40% to the formation of Gross Domestic Product. As regards residential and productive settlements in the watershed, there are approximately 15,764,600 inhabitants, 3,171,000 employed by industries and 2,791,000 by services; there are 4,188,000 heads of cattle, 5,232,000 swine. Livestock farming, which in the case of swine is concentrated in the provinces of Parma, Reggio Emilia, Modena, Cremona and Mantova, accounts for 55% of the national total and, in the case of cattle, for 48%.
The highest density of settlements is found in the Lambro-Seveso-Olona catchment basin, with 1,478 inhabitants/square kilometre, while the minimun levels are in the upper part of the Trebbia and Parma sub-watersheds with 26 and 24 inhabitants/square kilometres. The two main agglomerations are the municipalities of Milan and Turin. Some 37% of Italy's industry is located in the watershed, employing 47% of the workforce and accounting for 48% of the total national electric consumption. There are 280 power plants (269 hydroelectric, 11 thermal power) with a total power rating in the region of 17,000 MW.

Agricultural activities are conducted on more than 31,000 square kilometres of cropland, 50% of which is irrigated and yields 35% of the gross national output. Each year about 7.9 billion cubic metres of water are withdrawn, of which 5.1 billion for industry, 0.6 billion for agriculture and 2.2 billion mainly from wells (about 90%)
for domestic and commercial use, Annual consumption for agricultural use is estimated at 20 billion cubic metres.

The Water System

The main physical-geographical system of the watershed are represented by the Alps and Apennines, with the Po Delta lying between the two. Each of these system has a specific hydrological significance. The aquifers of the Alps reflect a variety of lithomorphological conditions which essentially can be linked up with plutonic and metamorphic rocks mainly in the central and western Alps, and carbonatic and dolomitic rocks in the notably karst-like eastern Pre-Alps and the Alps, which are sites of considerably active underground infiltration and circulation.

The presence of glaciers is a factor of major importance for the volume of water yielded to feed the watercourses in the summer months. The largest lakes in the Pre-Alpine area function as hydroregulatory reservoirs for the flows of water from the Alps toward the lowlands.

In the pediment section of the lowlands predominantly sandy deposits occupying the Piedmont plains are the site of limited underground circulation. Terraces and alluvial fan skirting the rest of the Alpine and Apennine ranges are the broad recharge areas which feed the aquifers where underground circulation is extensive, as well as the belt of blowouts to the left of the River Po.

The Po Delta, which covers 46,000 square kilometres, is a drainage area for the whole watershed and is the most active hydrogeological section in terms of the distribution and abundance of groundwater. The aquifers nearest the surface are also feed by the principal watercourses. The most significant areas feeding the deep aquifers are instead, as we have said, above the medial and apical portions of the large alluvial fans.

The main aquifers in the Apennine area are situated at outcrops of predominantly lithoid materials with fissures that results in their being permeable; the principal groundwater flow routes and their outlets are conditioned both by the main tectonic lines and by contact with the impermeable argillaceous rocks.

The lowlands of the Po Delta have a unitary aquifer system in which there are two different types of aquifer:
- free or semi-free surface aquifer, with possible intercommunication between soil and deep-set layers;
- pressure or confined aquifer, where continuous or semi-continuous barely permeable layers isolate the deeper aquifers from the surface.

This produces a system which has a surface layer, namely the groundwater table which communicates with the surface hydrographic system and with the sea, and deeper layers representing the confined aquifers.

The chemism of the groundwater, and hence its quality characteristics, differs notably in the two systems described above. In fact, where present, the propagation of any diffuse dispersion pollutants (nitrates, pesticides, fertilizers, etc.) is generally found in the case of the free aquifer; the confined aquifer is instead better protected from pollution of this kind.

It can be seen from the analysis of the exploitation coefficients (empirically indicating the exploitation of the aquifers) in this table that:
- the watersheds in the most critical conditions are those of the Lambro-Seveso-Olona, Sangone, Trebbia-Nure, Parma, Enza-Crostolo and Panaro rivers (exploitation coefficients above 1);
- the watersheds with exploitation coefficients fluctuating between 0.6 and 0.8, in what is considered to be the optimum range, are those of the Mincio, Oglio, Adda and Ticino rivers.
- the overall exploitation coefficient for the Po Delta is 0.8, intensive use is therefore made of the ground water and the potential residual percentage (20%) must be considered to be the margin needed to guarantee minimum efficiency of the hydro-dynamic packing of the aquifer.

Geophysical and geomorphological aspects

The landslides and erosive phenomena manifested in the mountainous areas at the edge of the watershed vary widely in terms of their different lithological and structural conditions, and also because of the different climatic conditions.

In the southern calcareous Alps, landslides are infrequent but potentially of large dimensions. Rockfalls are frequent, generally involving limited volumes but, because of their speed and unpredictability, they represent a serious threat to the inhabited centres and to road conditions.

The metamorphic and crystalline Alps are more prone to landslides, with rapid and sudden detachments. In the Po Delta proneness to landslides is particularly severe and extensive in the areas with widespread, especially_scaly, clay rocks, and a predominance of generally slow-moving landslides; this type of landslides represent a moderate risk to the safety of the population, but can cause severe damage to infrastructures and the economy.

Subsidence, which is particularly widespread, concerns several inhabited areas and the basic profile of the watercourses. For the most part, it can be said to be caused by over-exploitation of the aquifers and the extraction of methane. The phenomenon is to be found mainly along the embanked stretch of the Po and in the delta. One of the causes of subsidence is represented by the embankments which tends to retain water and prevent the spontaneous flow of the rivers from the plains towards the more depressed areas.

Hydrological Instability Particularly Relevant to Human Safety

Throughout the watershed hydrogeological instability is severe; the most critical aspects can be summarized as follows:

- the flood risk (5) is particularly high in areas where the adverse geometry of the river beds is level with major settlements; this helps to cause flooding which affects densely populated areas, infrastructures of primary importance, as well as valuable cropland. The flood risk is demanding more and more attention due to many often interrelated factors, such as: the reduction in the vegetation cover of the slopes, which results in a more abundant water run-off; the numerous interventions, particularly along the mountain reaches, to level out stretches of the instable river bed, which result in an increased flow rate; the considerable increase in the impermeable areas of the watershed also extended to areas of natural flooding;

- lowering the river floor as a result of the extraction of the inert materials, which undermines the stability of hydraulic works and brings about a systematic decrease in low water levels, with numerous withdrawal points, used particularly for irrigation, becoming unworkable. Furthermore, the extraction of inert material and the decrease in solid transported which results from the numerous wiers present in the watershed, is one of the primary causes of coastal erosion;

- the landslides and erosion which have always been present in the watershed are now increasing as human activities are intensified (deforestation, crop-growing, infrastructure building), and also due to the more general problem of improper soil use.

The Main Critical Areas in the Po Watershed

This section summarizes the main features of the areas in the watershed that are affected by environmental deterioration either of a geomorphological nature or caused by exceptional pollutant loads deriving from human activities.

Lambro, Seveso, Olona: covering an area of 3,336 square kilometres, with a population of 4.7 million and including the whole of province of Milan, part of the province of Como and Varese and a small part of the province of Pavia.
From the hydrographical point of view, the highwater flow channels are inadequate. The serious pollution situation is linked is linked to the heavy anthropogenic pressures on the area, which supports 22.6 million total inhabitants equivalents. Water quality is affected by the presence in the groundwater of concentrations of chlorinated organic solvents, hexavalent chromium, nitrates, fertilizers and pesticides, which generally exceed acceptable quality standards.

The generation of urban waste, waste disposal as urban, and waste of industrial origin, is one of major problems in the area, declared by Council of Ministers as high risk area because of its critical environmental conditions, in accordance of Law 349/1986.

Bormida: the Bormida watershed covers about 2,600 square kilometres, and includes the watershed of the Bormida di Millesimo, the Bormida di Spigno and the main stretch of the Bormida as far as its convergence with Tanaro. It concerns 69 municipalities (51 in Piedmont, 18 in Liguria) with a total resident population of about 210,000. The watershed includes the area declared to be a high risk area (under DCPM, 27 November 1987) wich covers 2,562 square kilometres and hosts the Acna chemical plant at Cengio.
This is an area which has been the focus of many studies to explore its hydrological and environmental features. With funds disbursed by Ministry of the Environment, the region of Piedmont is conducting a systematic water quality monitoring programme here to measure the extent of the damage to water resources caused by chemical and industrial plants.

The chemical quality parameters introduced by current legislation are measured, together with the special parameters attributable to the industrial processing carried out downstream. Specific detailed studies are also being made of the river ecosystem using biological indicators based on ichthyofauna and the macro invertebrates.

A method has been devised for producing a concise representation of the water quality level on the basis of chemical parameters.

The classification criteria adopted are based on four quality classes (A, B, C, D, in declining order of quality) according to the adequacy of water for drinking supply, bathing, fish life, irrigation of tolerant and sensitive crops. These classes are supplemented by class E for water suitable for industiral use only.

Water to be used as drinking supply is divided into the classes proposed by DPR 515/82, namely:

- A1: adequate for drinking water after simple treatment operations such as filtration;
- A2: adequate for drinking water after normal treatments processes such as sedimentation and filtration;
- A3: requiring sophisticated treatment operations.

The definition of water adequate to support Salmonidae and Cyprinidae is based on EC directive n° 78/659.

It can be seen from the figure that the situation throughout the Bormida area is serious, with almost all water being placed in class E and in class B at two sites only.
The treatment infrastructures already built fails to meet the overall requirements. The urban solid and special waste disposal system is precarious and unauthorized dumps are widespread.

ALLUVIAL FANS IN EMILIA ROMAGNA: the area concerns 74 municipalities in the alluvial fan and lowland belt between the watersheds of rivers Taro and Panaro, and extends for some 3,556 square kilometres, with a population of 1.2 million.
The main problems affecting the drainage pattern concern flood risk, river channel erosion and subsidence brought about by over-exploitation of groundwater. The pollutant load in the area is estimated to be 13 million inhabitant equivalent.
The present capacity for water treatment is just under one-third of the demand; untreated or untreatable pollutants are responsible for the decline in the quality of both surface water and grounwater.
For the most part, the deterioration in groudwater quality is to be put down to the practice of spreading waste produced by livestock farming on the land. The area has been declared as a high risk area because of its critical environmental conditions.

BURANA – PO DI VOLANO: the area covers about 2,596 square kilometres and is bordered in the north by the Po and the Po di Goro tributary. In the east and south by the Goro inlet and the Bertuzzi and Comacchio valleys. A decline in natural resources is visible in all the valley and coastal areas of a high environmental value, which are, more specifically, the wetlands of the original Po Delta. Surface water quality in the whole system is jeopardized by the input of water originating from the western part of the area which used extensively for agricultural purposes.

POLESINE: the area includes the Fissero - Tartaro – Canal Biano – Po di Levante watershed, in other words most of the province of Rovigo and the southern part of the province pf Verona, covering some 1,962 square kilometres.
The main sources of pollution are the civil settlements, industries, agricultural and livestock farming. As a rule, it is found that a greater volume of water is affected in the end sections of the rivers than in others.
Disturbing eutrophication phenomena have appeared in the marine and brackish water. Because of all these factors of deterioration, this area has been included among those declared high risk areas.

OLTREPO PAVESE: the area is characterized by significant hydrogeological instability. Some 21% of the total area is landslide-prone, while 9% has been partially stabilized.

SUB-ALPINE LAKES AND MANTOVA LAKES: improved use, and particularly purification and protection of the natural resources provided by the lakes in the Po watershed,

represent key factors in the strategy pursued in this area (and, moreover, established by three-year plan for environmental protection).
In addition, they represent an exceptional driving force for all the socio-economic and tourist activities in the respective watersheds which altogether have just 3 million inhabitants. In any event, it is important not to overlook the strategic importance these lakes may have in the future in resolving major problems associated with drinking water supply.

The Water Quality

The information available on surface water refers to a period of about 20 years and to the entire drainage pattern of the Po watershed. The most recent data on groundwater enables the areas affected by pollution to be identified in each watershed, together with the different pollutants present (heavy metals, chlorinated solvents, nitrates, pesticides) and to what extent any possible uses may be endangered. All the watershed's water resources, however, are subjected to considerable anthropogenic pressure, which generates an estimated load of 138 million inhabitant equivalents (IE). 13% of this load can be attributed to civil effluents, 42% to industrial, 45% to agricultural and livestock farming. These estimated are being updated.

Rivers

Much of the data on the quality of watercourses is derived from the surveys conducted under law 319/1976 as part of the regional plans for water pollution abatement. The surveys aim to systematically measure the hydrological, physical, chemical and biological features of the water sources and their development over time, on the basis of provisions made (February 1977) by the Interministerial Committee for the protection of water from pollution, the duties of which have been transferred to the Ministry of the Environment. Because the surveys were conducted by so many different bodies, the data are not uniform in quality and the elaboration procedure has been complicated. In addition, since there is a shortage of data on water flows that can be associated with quality data, efforts to obtain comparable and uniform figures for the different situations in the various area of the watershed have encountered problems. The elaboration of analytical data for the period 1987-91 are based on a classification system devised by the for Scientific Water Research Institute (IRSA) of the National Research Council (CNR) in which there are 4 classes: class 1, unpolluted; class 2, moderately polluted; class 3, polluted; class 4, highly polluted. This methodology, which uses basic water quality parameters, does not classify the water in relation to its possible uses, nor does it take into account pollution of industrial origin; it only allows an overall characterization of the quality of the watercourses in each watershed.

Turning to the tributaries, it is important to note that the different hydrogeological and geological characteristics of the watershed determine a moderate rate of solid transport in those to the left and more substantial transport in several watershed to the right, such as Adda, Ongina and taro. The tributaries responsible for most of the rising pollution levels in the Po can be grouped as follows:

- a first group, with high values for BOD, COD (8), ammonia, phosphates and coliforms, consists of the Doria Riparia, Cervo (tributary of the Sesia), Bormida of Millesimo, Lambro, Parma, Staffora and Crostolo rivers. The dissolved oxygen (DO) in these rivers normally is far below saturation; surfactant are also present in high concentrations. On the whole, the risk threshold, i.e. the concentration limits listed in DPR /25 January 1992 (implementing EC directive 78/659 on water quality for fish life), is considered to be permanently

- exceeded. Even the use of water after treatment as drinking supply is affected, since as a rule the quality requirements of class A3 (9) envisaged by DPR 515/1982 are not meet;
- a second group consists of the Rivers Sesia, Ticino, Nure, Trebbia and Adda. For these, the values for BOD, COD, ammonia, phosphates, surfactants are generally 5 – 10 times lower than those in the previous group. The DO remains at acceptable levels, namely around saturation, while the concentration of coliforms is 1 – 2 orders of magnitude lower than that for the rivers considered above;
- a third group consists of the Rivers Tanaro, Ongina, Taro, Oglio. For most of the parameters examined these rivers presents values mid-way between the other two groups.

The constant presence of faecal coliforms even in the affluents listed in the second and third groups indicates an equally steady input of untreated sewerage. Even more so than phosphorous, faecal coliforms which are typical of untreated urban waste represent one the reasons why the various sampling stations are placed in the fourth class (highly polluted), even in those cases in which DO concentrations remains at optimum values. The presence of heavy metals, not considered in the IRSA classification, is a means of identifying the input of pollution of industrial origin.
The input of heavy metals is low in the affluents on the right-hand side, and is instead quite high in those to the left, mainly because the density of industries is greater.

The highest average concentration of arsenic, lead and copper are found in the River Lambro, followed by the Oglio with significant peaks of arsenic, mercury, lead and zinc.

With regard to the overall state of water of the River Po, it should be stressed that the highest values of BOD, ammonia and coliforms, and the shortages of DO, generally are more often found downstream of the industrial conurbation of Turin and Milan and Casalmaggiore area situated between the provinces of Cremona and Mantua. In this last area, the high BOD values are accounted for mainly by runoff and percolation water from agricultural land extensively manured with effluents from livestock farming.

Pollution of industrial origin is well represented by the pattern of heavy metal concentration. Water flowing from the Lambro into the River Po results in a marked profile of heavy metal pollution, which is also evident in its end stretch leading to the outlet into the sea. In the upper stretch downstream of Turin the following average concentrations are detected (expressed in micrograms per litre, the number of measurements considered is shown in brackets): chromium 3.6 (36); copper 6.4 (28); nickel 11.0 (12); lead 3.4 (36); zinc 78.9 (30).

In the middle stretch of the River Po, downstream of the Lambro as far as Isola Serafini (province of Piacenza), the same metals are present in higher average concentrations: chromium 5.3 (263); copper 12.5 (238); nickel 13.1 (326); lead 6.6 (330); zinc 50.6 (335).

By referring to current statutory requirements for water quality adequate to support fish life, it can be noted that even though the heavy metal concentrations have not yet reached risk levels, there is a possibility, which certainly cannot be overlooked and in some cases is even documented, that they maybe accumulating elsewhere (e.g., in the food chain).

Industry therefore plays a specific role in modifying water quality in the Po; moreover, organic pollutants (organic solvents, PCBs, phenols, phthalates, pesticides in general), are detected systematically at Pontelagoscuro, the section which close the whole Po watershed.

The study of the distribution of bacteriological pollution indices in the Po reveals three areas of major contamination corresponding to the stretches downstream Turin, downstream of the confluence with the River Lambro and between Cremona and Boretto wher the Rivers Enza, Parma and Taro meet. The notable decrease in bacterial load found in the end stretch is an indicator of a residual but significant capacity of the river to self-purify.

In conclusion, it must be stressed that, even though in many stretches of the main river course and the tributaries different uses are possible, this should not encourage over-optimism for the following two reasons:
- phenomena of bioaccumulation and persistence of pollutants are nevertheless observed and may entail risks to the environment and health;
- the pollutant load, which in any event will be carried into the Adriatic Sea, heavily conditions the phenomena that occur in this sea with a high frequency and virulence;
- the increased content of nutrients, with the consequent rise in the trophic load discharged by the River Po, has practically doubled over the last twenty years.

Nevertheless, changes for the better have been seen, compared with the conditions of early seventies; the improvement is mainly due to the introduction onto the market of biodegradable detergents, the ban on the use of DDT and similar pesticides, the reduction of the phosphorous content in detergents to a maximum of 1%. Furthermore, it is important to note that before any significant environmental improvements became visible, a long period of time and huge investments are required.

Lakes

In the Po watershed there are 108 lakes covering an area of more than 0.2 kilometres. Most of these are situated at high altitude of more than 1,000 metres; they generally are of artificial or mixed origin (natural lakes extended with dams used mainly for hydraulic regime regulation and the production of electric energy).

The main sub-Alpine lakes (Orta, Maggiore, Lugano, Como; Iseo, Garda) and the morainal lakes of Viverone, Mergozzi, Varese, Monate, Pusiano, are the largest in volume.

Much of the data collected was originally produced to evaluate the water trophism; several situation in which the limnological and hydrochemical aspects have been studied in detail concern, for instance, Lakes Maggiore, Lugano, Orta, Garda, as well as the Brianza lakes.

From the analysis of the data available on lakes the following can be inferred:

- situations of severe pollution are present both in the well-known case of Lake Orta (water acidification) and only occasionally in several small, low altitude lakes, such as Annone, Pusiano, Trana, Avigliana.
- From the trophic point of view, there is a clear-cut difference between the high altitude lakes above 1,000 metres and low altitude lakes. In the first case the environments are almost always characterized by oligotrophic and ultra-oligotrophic conditions. There are a number of exceptions for which the analysis of the data reveals a state of natural mesotrophy due to the lithology of the watershed or the presence of particulate material of glacial origin. A typical example is Lake Dosazzo in Lombardy which is at an altitude of over 2,000 metres.

Few environments associated with the low altitude lakes are in a state approaching oligotrophy or natural conditions, and loads of potential eutrophizing substances far above the acceptable levels are widwspread, resulting in conditions far from those of natural trophy. In addition to the more eutrophic lakes of Italy (Varese, Avigliana, Trana, Comabbio, Alserio, Frassino), these include the cases of the altered conditions of Lake Como (meso-eutrophy, natural condition oligotrophy) and Lake Iseo (meso-eutrophy, natural condition oligotrophy).

Among the large sub-Alpine lakes only Lake Maggiore is showing signs of improvement following the purification interventions and is now approaching the lower mesotrophy limit, Lake Garda, on other hand remains in a state very near to the natural conditions of oligotrophy.

Groundwater

One of the main groundwater pollutants is nitrogen, which normally is carried by infiltration water into the aquifer in the form of very stable nitrates. There is no doubt that a significant correlation exists between groundwater nitrate pollution and intensive agricultural-livestock farming.

For the most part, the problem of nitrate pollution concerns aquifers in the alluvial fans of the upper plains; on the whole, in the middle and lower plain the problem has not yet reached warning levels, except for some local cases. Virtually all the alluvial fans in Emilia Romagna that are included in the boundaries of the provinces of Piacenza, Reggio Emilia, Modena, Bologna, Ravenna and Forlì (as well as Rimini) are affected by increasing nitrate pollution; the phenomenon seems to be equally as significant in the provinces of Alessandria, Vercelli, Brescia and Verona.

Many active formulations used in pesticides also behave in much the same way as nitrate and, depending on how soluble they are and how stable in the soil, they may also affect the aquifer, in recent years, contamination of groundwater by atrazine, simazine, bentazone, molinate, to mention just the most common herbicides, has affected, and to some extent continues to affect, several of the aquifers in the provinces of Turin, Vercelli, Novara, Milan, Varese, Pavia, Cremona and Mantua. The problems also exists in the region of Emilia Romagna, although on a smaller scale.

Turning to the other pollutants (heavy metals, chlorinated solvents) in the aquifers, even though knowledge is still fragmentary there seems not to be a problem in the watershed as a whole but only in specific areas with dense industrial settlements.

It is also worth mentioning another phenomenon that is often encountered where there is a need to exploit increasingly deeper aquifers, in some cases significant amounts have been registered (even though due to natural causes) of such substances as ammonia, iron, manganese, magnesium, sulphides and sulphates, in concentrations even above maximum allowable limits. This may result in inferior water quality, as well as the need to treat water before releasing it onto the distribution network.

Water cycle management infrastructure

The infrastructures for water resource management consist of a series of works which ensure:

- supply and distribution of potable water for civil and industrial uses;
- collection of waste water of civil and industrial origin;

treatment of waste water.

Supply and distribution of potable water

In the Po watershed the average capacity for potable water supply is the region of 70 cubic metres per second, equal to about 2.2 billion cubit metres per year. The sources of supply are:

- aquifers, which represent the only source for most of the plains and meet about 82% of the requirement;
- spring, mainly concentrated in the mountain channel nets, which contribute about 15%;
- surface water bodies (lakes and rivers), which contributes 3%.

Potable water is drawn from the aquifers through either individual or interconnected wells. It is estimated that the interconnected wells represent just under 50% of the total.

The municipal authorities, together with the municipal enterprises, are responsible for managing the infrastructures which distribute potable water to about 80% of the population served by networks. Of the remaining 20%, 18% are served through authorities managed by joint municipal associations or enterprises, while remaining 2% are served by private bodies.

The aqueduct networks have been subjected to the effects of progressive urban sprawl and often have been penalized by morphological conditions. Therefore their efficiency is extremely variable and diversified throughout the Po watershed.

One way to measure the efficiency of the aqueducts is to consider the losses, i.e., the volumes of water not recorded by the metres on consumption. In the Po watershed average losses are estimated at approximately 22% of the water drawn at sources; in the individual watersheds posses may vary from the 14% on the more recent aqueduct network and coastal areas up to as much as 30-35% in the oldest aqueducts or those penalized by the morphology of the area served.

Collection of waste water and sewage

The existing trunk sewer and sewerage networks are able to meet the requirements of more than 85% of the population.

Most of the uncollected urban waste water is concentrated in the area at the foot of the Alps and Apennines and, in far smaller proportion, in the isolated areas of the plains.

The sewer network in the Po watershed are mainly of the mixed type, suitable for collecting both waste water and rainwater. About 80% of the network in the watershed are of this type, and fewer than 20% are separate networks, all of which have been built during the last twenty years.

The efficiency of the individual systems depends not so much on the materials used as on the scale of the networks, the morphological conditions, especially when lifting wiers are required, and on the age.
On the basis of these criteria it has been possible to estimate the efficiency of the sewer network:
- acceptable for about 65% of the small to large scale sewer systems;
- good for 20% of the more recent and better scales sewer systems;
- poor or unsatisfactory for 15% of the oldest and badly functioning sewer systems.

Treatment infrastuctures

According to recent data acquired by the Ministry of the Environment (1991), in the Po watershed there are 3,112 public municipal waste water treatment plans altogether. Of these, 1,535 are primary plans, that is, able to achieve an average 30% reduction in BOD values. The remaining 1,577 are divided into:

The potential load treated by the plants above 10,000 IE is equal to approximately 17,000,000 IE.

The data on the overall number of plants and those with a capacity of less than 10,000 IE could be further updated since informations on the small plants of a capacity of less than 2,000 is uncertain.
In terms of the technological processes employed (referred to the volumes treated), it can be said that:
- about 50% (small plants) of the total 3,112 provide primary treatment only;
- 30% provide primary and secondary treatment (including sludge lines);
- 20% also provide tertiary treatment.

One can take as an example the area connected with Lambro-Olona-Seveso watershed, where plants of more than 10,000 IE in capacity have the highest treatment capacity (6.4 million IE). For the Lambro watershed, however, it is important to note that although the treatment capacity is high, it still falls short of demand, which is an estimated 17 million IE.

RIVER ADIGE WATERSHED

The River Adige watershed covers about 12,000 square kilometres in the autonomous provinces of and Trento and the Veneto region. The main river course is 409 km in length. The watershed supports a population of 1.5 million; the water resources are used for many purposes and are subjected to increasing pollution particularly in he areas where the density of urban and industrial settlements is higher, such the Bolzano and Vicenza valley floors. The orographic profile of the watershed is characterized by ample ridges.

The River Adige and its main tributaries, which stem from Alpine saddles and rims, are characterized by slight gradients; the secondary courses, on the other hand, begin at higher altitudes and flow down into the recipient courses after a short stretch. 185 glaciers are situated in the watershed, covering an overall surface area of 212 square kilometres, the main ones in the Venosta mountains, the Pusteresi Alps and the Ortles Cavedale.

The northernmost part of the Adige watershed is formed of crystalline and metamorphic rocks, the low permeability of which is reflected in the limited underground circulation. The water yeld becomes more significant level which the volcanites occupying the central portion of the mountainous area of the watershed, and particularly the calcareous-dolomitic rocks, which represent abundant water reservoirs.

Snow persists until late spring and represent a steady source of water supply. The higher part of the Adige valley interrupts the continuity of the belt of blowouts which runs along the foot of the Alps from Piemonte to Friuli.

The lower course of the Adige assumes the characteristic common to watercourses flowing into the upper Adriatic, which cross the plains with aquifers very near to the surface and terminate in marshy deltas. Substantial withdrawals for potable supply are made from the lower Adige by the provinces of Rovigo, Padua and Venice (total population about 500,000). Completion of the sewer networks and the construction of industrial and municipal waste water treatment facilities is becoming increasingly urgent. The smaller valleys are crossed by rapid torrential streams carrying large amounts of solid which exceed the receptive and disposal capacity of the watercourses and result in the formation of voluminous and ample alluvial fans: Substantial masses of debris thus block the channel of the Adige, cause the river bed to rise progressively and raise the flood stage.

Rainwater and the melting snow cover and glaciers in spring and summer, together with the heavier and sudden autumn precipitations, give rise to violent and extensive flooding which has been amply documented in the last two centuries. This situation makes it necessary to continually extract material from the channel to prevent its bed from rising, since much of the river is forced to run between artificial embankments.

THE UPPER ADRIATIC WATERSHED

The watersheds of the Rivers Isonzo, Tagliamento, Livenza, Piave, Brenta-Bacchiglione, together known as the Upper Adriatic Basin, cover a total of 17,000 sq km in the Regions of Trentino-Alto Adige, Veneto and Friuli Venezia Giulia, with a resident population of about 2,3 million. The extension of the individual watersheds is as follows: the Isonzo extends for about 1,100 square kilometres beyond the boundaries, the Tagliamento extends for 2,700 squre kilometres in Friuli Venezia Giulia, the Livenza for about 2,600 square kilometres in Friuli Venezia Giulia and Veneto, the Piave for 4,000 in the provinces of Veneto di (sic!) di Belluno, Treviso, and Venice; the Brenta-Bacchiglione for about 6,600 kilometres in the provinces of Vicenza, Padova, (cfr. supra "Padua"), Verona and Treviso in Veneto, and in the province of Trento.

Both the mountain and piedmont areas are characterized by numerous small inhabited centres; in the upper plain area there are a high number of large municipalities; the lower plain hosts the most important residential settlements: For the most part, the presence of industry is moderate, if we exclude Belluno valley in the

Piave watershed, the location of Belluno and Feltre which are centres with significant industrial settlements. In the upper plains industry is widespread; in the lower plains there are important industrial settlements and agriculture is intensive. Altogether the area included in the watersheds can be regarded as consisting of three homogeneous zones from the hydrological point of view:

- the mountain and mountain pediment area: formed by the reliefs of Bellunese, Carnia and the Alpine and hill zones which border the northern and northeastern parts of Veneto and Friuli. With the exception of the northernmost part of Carnia and upper part of the Brenta river, occupied by metamorphic rocks with limited groundwater circulation, the extensive calcareous and dolomitic formations are the site of considerable groundwater which provides a substantial input to the watercourses. In this area the drainage pattern has been subjected to numerous defence works, in the forms of channels, dams, and canals for hydroelectric purposes, the regime of watercourses is conditioned by these works. In terms of both water capacity and transport of solid materials;
- the upper plain consisting of extensive alluvial fans deposited by the watercourses flowing from the mountain watersheds; this area is characterized by watercourses extending over wide, virtually dry gravel beds, particularly during the summer months. Aquifer recharge also takes place at the surface of these fans as a result of both the direct input of precipitations and the input of water from the Alps and Pre-Alps. The large volumes of water from the mountain pediment deposits feed major blowouts along the edges of the fans;
- the lower plain formed of the land which, from the belt of blowouts emerging at the end of the fans along the mountain pediment, declines towards the coast line; the water in this area is collected by a dense network of mostly artificial reclamation ditches and drain which partly converge into marshy and lake areas.

Below is a profile of several characteristics of in the individual watersheds:

- the Isonzo rises in the inhabited area of Trento (sic!), has five tributaries and flows in the Adriatic after a total of 140 km. The severe water shortages in the drier seasons are linked to the presence of upstream reservoirs;
- the Tagliamento originates from the eastern slopes of the Niaron mountains. It initially flows parallel to the Carniche Alps, to then cross the Pre-Alps and after 158 km flows out into the Adriatic Sea between the lagoons of Caorle and Marano. Extensive exploitation for hydroelectricity in the upper part of the watershed causes widespread hydrogeological instability;
- the Livenza rises near Polcenigo from sources fed by infiltrations into the karst formations of the Cansiglio tableland, a morphological zone which is part of the Piave watershed. Excessive withdrawal by the reservoirs upstream leads to water emergencies which adversely affect the irrigation of the land downstream.

- the Piave, which is about 222 km in length, rises in the far north of the region of Veneto in the southern side of Mount Peralba. Mora than any of the other rivers in Veneto its regime is affected by intensive water exploitation for irrigation, particularly in the upper plain areas.
- the Brenta originates in Lake Caldonazzo and it is fed mainly by the tributaries on its left which flow down from the granite range of Cima d'Asta and the volcanic and metamorphic reliefs. The tributaries on its right which flow in from the karst tableland of the Sette Comuni are shallow;
- the Bacchiglione rises north of Vicenza frm a series of blowouts; the Brenta and Bacchiglione watersheds are linked artificially in the Chioggia area. The extremely uneven use of water from the two rivers causes marked imbalances which are naturally accentuated during the drier seasons.

The mountain and hill declivities are characterized both by individual situations of landslides of significant dimensions and by widespread instability.

The precariousness of the drainage pattern is the result of:

- difficulties in regulating the flows of mountain streams, which moreover are influenced by the input deriving from the waste water of the densely populated areas along the pediment belt;
- the hydraulic risk present in the pediment areas where there are embankments, as a result of continuous accumulation of solid material transported there;
- high flood stages in all the rivers of the watershed;
- hydraulic failure of land subjected to mechanical drainage;
- subsidence of vast areas to altitudes below sea level, and coastal erosion;

high rate of dune erosion, accompanied by salt water infiltration into the groundwater at the mouth of Tagliamento; risk of sea floods in the coastal area at the mouth of the Piave, with possible damage to cropland in the area.

From the point of view of water quality:

- the water of the Isonzo presents bacterial pollution and significant concentrations af ammoniacal nitrogen, which make it difficult to use for drinking supply;
- the Tagliamento water is of good quality, although there are sporadic cases of chemical pollution confined to the stretch downstream of Tolmezzo;
- water quality is generally good in the Livenza in the middle-upper portion of the watershed; its end stretch presents significant concentrations of nitrogen, phosphorous and heavy metals;
- a high pollutant load is observed in the water in the initial stretch of the Piave which is affected by inputs from the tributaries on the right which cross several inhabited centres and industrial areas. Water quality improves downstream as far as the Ponte di Piave area, to then deteriorated again because of the massive input of urban and industrial waste, as well as large amounts of nutrients from the reclamation networks, which contribute to localize water eutrophication;
- water quality in the upper part of the Brenta-Bacchiglione watershed is relatively good, but declines notably in the middle-lower parts, especially compared with the other watercourses in the Upper Adriatic; deterioration begins in the middle stretch as a result of the increasing input of urban and industrial waste, becomes significant downstream of the city of Padua and is at a maximum around the outlet.

RIVER ARNO WATERSHED

This watershed covers about 8,000 square kilometres in Tuscany and Umbria and is divided into six sub-watersheds: Casentino, Val di Chiana, Sieve and Upper, Middle and Lower Valdarno.
The main watercourse is the River Arno, which is about 241 km in length, follows a rectilinear route in the upper parts of the watershed and has numerous meandering between the Era and Pesa tributaries, particularly in its end stretch.
Some 2 million inhabitants live in a polycentric type of settlement formed of 142 municipalities, in which there site of major historical importance together with small and medium centres and more recent settlements deriving from intensive industrial development.
The upper part of the Arno watershed is formed by the Apennine mountains and the middle-lower part and by the pre-Apennine reliefs. Only 17% of the total area is flat land.
The Apennine range is mainly sandstone which develops into mary and clay. Permeability is generally low and mainly due to fissures. Ground water circulation, which is widespread but limited, feeds small springs and results in seasonally varied river regime.
The secondary watersheds of the pre-Apennine range are formed of lutaceous, sandy and conglomerate rocks; the latter two are characterized by discontinuous groundwater circulation. The permeability of the lutaceous rocks is very low and the streams are fed almost exclusively during the rain season. The lowlands in the Arno watershed are the site of vast marshy areas, now almost entirely reclaimed, in which the groundwater lies at surface level.

There are phenomena of widespread hydrogeological instability and numerous landslides which affect inhabited centres and settlements of historical and environmental value. In general, the causes of instability can be linked to the nature of the land, the poor surface water-regime, the shortage of preventive studies able to highlight the risk connected with the recent development of settlements in geologically unsuitable situations.
Hydraulic risk affects much of the valley in different ways. The severe crisis faced by the Val di Chiana hydraulic systems is the result of drastic alterations in the flow regime caused by the urbanization that has replaced farming activities. Adverse effects have also become apparent in the runoff capacity of the drainage pattern and the sewer network.
Qarrying activities in the river beds have caused widespread environmental damage due to the presence of disused quarrie which have not yet been reclaimed; a particular situation of environmental risk has developed in the case of water resources in fan belts such as those around Florence where the river meets the Bisenzio, the Val d'Era and the upper Valdarno. The regional administration of Tuscany has enacted its own laws on quarrying activities for the reclamation of disused quarries.
The coastal stretch influenced by the Arno extends from the port of Livorno as far as the port of Viareggio. The central part, between the mouth of the River Serchio and the far north of the inhabited centre of Tirrenia, is affected by intensive erosion mainly due to human inervention, such as the building of piers at river mouth and the extraction of inert materials, which has enormously reduced the transport of solids to the sea.

As a result of the reduction in areas receiving runoff, extensive zones around Pisa, Livorno and Collesalvetti are affected by frequent floods. The stretch of the River Arno between Arezzo and Florence is affected by heavy withdrawals for drinking water supply, placed for this purpose in quality class A3.
The aqueducts using this water are the Buon Riposo (Aretino stretch), the Figline (Valdarno stretch), Anconella and Mantignano (Florence stretch). The water of the River Elsa, the ombrone and various tributaries in the Pistoia plains (Bure di Lano, Bure di Baggio, Fosso del Castagno) is also used for the same purpose and has been assigned to class A3 by the regional administrations.

The water supply, derived mainly from the river of the lateral groundwater linked to it, is substantially affected by the flow levels connected with the seasonal meteoclimatic cycles and the quality of surface water, itself severely harmed by urban, industrial and agricultural effluents. A risk factor for the groundwater is represented by the inadeguacy or the inefficiency of the sewer network in much of the watershed.

The most heavily polluted situations are manifested downstream of Florence, the waste water of which remains untreated owing to long delays in building the district plant; the end stretch, on the other hand, is the site of the major treatment works in the textile, leather and paper industry areas, which have led to considerable improvements in the middle-lower part of the watershed. Of particular importance is the pollution from livestock farming in Val di Chiana and in the Arno, from the ENEL artificial reservoirs as far as Florence where most of the water for potable use in the region is drawn. The high pollutant load discharged into the sea by the river has negative effects on long stretches of the coast, which is environmentally important and the site of tourist resorts. Local contributions to this load derive from the Pisa area where the failure to complete the sewer network prevents the full use of existing treatment plants.

TIBER WATERSHED

The River Tiber watershed extends over some 17,000 square kilometres divided between the regions of Emilia Romagna, Tuscany, Marche, Umbria, Lazio and Abruzzo, with an overall population of 4.5 million distributed unevenly: In addition to the metropolitan area of Rome, it comprises other important urbanized areas such as those of Narni, Terni, Spoleto, Foligno, Assisi and Perugia, and the area along the eastern section of the watershed near the border with Marche and Abruzzo, which separate the metropolitan area of Rome from the Umbrian valley.

The watershed has divided into eight sub-watersheds: the Tiber as far as Corbara, the Tiber from Corbara to its confluence with the Nera, the Tiber between the Nera and Aniene, the Tiber from its confluence with the Aniene to its mouth, the watersheds of Chiasco and Topino, paglia and Chiani, Nera and Velino, and the Aniene wateshed.

The following tributaries flow into the main water course which is 405 km in length: Nestore, Chiani, Paglia and Trela on the right of the watershed and Chiasco, Nera, Farfa and Aniene on the left.
The hydrogeological system of the Tiber is formed of very different lithomorphological complexes.

The whole eastern sector in Marche, Abruzzo and Lazio is formed of massive calcareous rocks. Major water reservoirs, among the most substantial in Italy, are to be found in these rocks, which give rise to the numerous Karst springs used to supply water to Rome and other urban settlements.
Next in order of importance are the sandstone rocks of the Apennine mountains in Tuscany and Umbria, which are permeable due to fissures and therefore a site of moderate circulation. The volcanic rocks in Lazio occupy the lower (?) are left of the Tiber and are characterized by goog groundwater infiltration and active circulation inside the lava, due to fisseres, and the tuffs, characterized by interstitial permeability. There are frequent perched water tables of limited size and capacity, which feed quite substantial springs. In the alluvial sandy deposits of the middle Tiber Valley groundwater circulation is limited.

Numerous artificial watersheds and embankments interrupt the continuity of the Tiber channel.
The initial stretch of the Tiber watershed, as far as Corbara, is characterized by steep slopes and highly vulnerable to erosion (which is also to be attributed to scarce forest cover), with resultant landslides. In the next stretch, up to the point where it meets the Nera, the Tiber cuts into volcanic-sedimental table of Lazio to form steep slopes where erosion is intensive. In the subsequent atretch as far as the Aniene, the river initially crosses calcareous rocks and then tufaceous and sedimentary rocks.
In the Paglia sub-watershed where there is a predominance of tufaceous-marl rocks, most of the land is bare and frequently flooded, which in the past has destroyed dams and bridges, as well as disrupted the Autostrada del Sole and the Rome-Florence railway line.
The River Velino sub-watershed is characterized (?) the marked instability of its calcareous slopes; its torrential nature causes significant quantities of solid materials to be transported, which form barriers and stem water runoff. The River Nera has a very deep-set channel as a result of the chemical dissolution of its calcareous slopes.
The mountain part of the River Aniene is characterized by very steep slopes and scarce vegetation. Erosion has deepened its bed to form wide and high gorges. Although solid transport is moderate, it still tends to significantly fill the bed, particularly in the flat stretches.

The stretch of coast which can be identified as physiographic unit dynamically linked to the River Tiber is bordered to the north by the Linaro headland and in the south by the Anzio headland; it extends for about 95 km and untila about a century ago had been progressively advancing due to the considerable amount of solids transported by the Tiber. In the last twenty years the reverse has occurred, with the coastline notably retreating as a result of both the drastic reduction in the input of solids from the river and widespread anthropization along the coast.
One of the main cause of the reduced sedimentation is the Corbara dam which intercepts the large volumes of solids, consisting mainly of sandstone, transported from the upper part of the watershed.
Tha Alviano, Nazzano, Ponte Felice and Castel Giubileo dams tend to intercept almost all the remaining solids transported before the outlet into the sea. Sedimentation is further decreased by the intensive extraction of inert materials and erosion is pronpounced along the coastline.

The watershed is characterized by substantial hydrogeological instability. The areas most affected are around the Nera and the Tiber near Montedoglio. In the subsequent stretch as far as the coast, the areas where the instability is most evident are those at mountain pediments in the Viterbo and Rieti lowlands. More or less widespread instability, particularly notable in Tivoli area, is to be ascribed to the inadequate flow regime regulation of both surface water and groundwater.
The containment capacity of the River Aniene, limited to a flow of only 150-200 cubic metres per second, reached with anannual frequency, exposes the part of the river inm the valley to overflow wihen floods occur, with maximum flows calculated at being up to three times greater.

A significant volume of surface water is used for irrigation; major withdrawals are made in the upper Tiber Valley (Montedoglio and Chiasco reservoirs) to serve areas in the Arno watershed as well, and in the end stretch of the river for the areas destined for accretion at Ostia and Maccarese.
In the Tiber watershed there are 25 hydroelectric power stations. The largest reservoir, at Corbara, dams the main course of the river about 100 km upstream of Rome. Other large reservoirs are at Slato, Turano and Piediluco.

In the main, the productive settlements are located in the middle section of the river valley and in the industrial area of the Aniene, which includes the paper mills of Tivoli and Subiaco. In the areas where the rate of industrial and urban development is high and often incontrolled, the inadequacy of the centralized sewage and water treatment plants and the lack of industrial waste water collection networks have raised pollution levels. Most of the effluents from the city of Rome are discharged immediately downstream of the urbanized area, at about 15 km from the mouth: the tretment plant serving the inhabited area along the coast disposes slightly upstream of the mouth in an area of major importance to tourism and the economy.
From the point of view of chemical pollution, conditions in the initial stretch of the river present no specific problem problems; the situation worsens decidedly as the river enters the Rome area, particularly after if meets the Aniene, the watershed of which is characterized by extreme environmental degradation; pollution levels in the water remain high as far as the mouth.
Intensive agricultural development and swine breeding mainly in the upper part of the watershed have given rise to widespread pollution which is difficult to control and adds to the pollution of urban and industrial origin. The major water sources, connected to the vast carbonatic rocks, are highly vulnerable, for the most part without protective soil cover and have no capability to filter any pollution which percolates through.

WATERSHEDS OF THE RIVERS VOLTURNO AND LIRI - GARIGLIANO

The watersheds of these rivers cover an overall area of about 10,500 square kilometres (5,500 sqare kilometres for the Volturno and 5,000 square kilometres for the Liri-Garigliano) in Campania, Lazio; Abruzzo and Molise.

The Volturno watershed is bordered by the southern ramification of the Apennines in Molise and Lazio to the north, the Matese, Sannio and Daunia mountains to east, the Piacentini mountains to the south-east, the Tifatini mountains and the Maggiore mountains to the west.
The River Volturno is about 170 km in length and rises in the Mentuccia hills level with the ofshoots of the Mainarde range, crosses the Vanafro plain, runs through the Matese and Maggiore clusters. After receiving the water from its main tributary the River Calore, it flows down toward south-west, crossing the vast coastal plain and flowing into sea level with Castel Valturno.

Three main morphological units can be identified in the watershed: the mountains and upper hill reliefs, the hill belt, the flat valley floor and the coastal plain area, following the sructural layout of the main geological outcrops. The morphological ridges correspond mainly to the zones of calcareous-dolomitic outcrops; in the hill areas the outcrops are predominantly of lutaceous deposits; in the tableland areas are uqaternary alluvial sediments and volcano-sedimentary deposits.ùThe upper watershed of the Liri-Garigliano is formed by the Roveto valley, which is extremely elongated in shape and lies between the watersheds of the Marsica range to the east and the Simbruni mountains to the southwest; the plain stretch begins downstream of Isola Liri. The Liri is about 160 kim in length, rises near the inhabited centre of Cappadocia from a group of springs fed by Simbruni massif, after joining the Rapido-Gari, the watercourse is known as the River Gariglino and flows into the Tyrrenian sea just sout of Minturno.
The channel net is divided into numerous small watersheds, which, with the exception of those of River Sacco (covering 25% of the whole area) and the River Fucino, are morphologically separate from the Liri, but connested to it by means of an artificial effluent.

In the end portion of the watershed the watercourse is characterized from a morphological point of view by numerous broad meandering sreams.
Mention should be made of the particulrly severe coastline retreat level with the river mouth, due to the low input of solid material by the river resulting from substantial and often unauthorized excavation in the areas upstream. Numerous reservoirs for water flow regulation also tend to reduce sedimentary input to the coast.

The widespread calcareos rocks, particularly in the Garigliano watershed, are the main reason for the abundance of water resources in the area; the numerous major karst-like formation are evidence of this abundance.
Other formations such as the sandstone and volcanic rocks are of lesser importance in terms of local water resources, both because they are not as widwspread and because their permeability is limited.
The major instability phenomena in the Volturno watershed can be observed in the north-west sector and in the River Calore sub-watershed. For the Liri-Garigliano, conurbations and the diversion of land originally destined for agricultural activities and reforestation have given rise to areas of potential instability in 62% of the entire watershed.
The type of instability varies from zone to zone. In relation to the lithogeological and morphological characteristics, the vegetation cover and land use.

In the past there have been numerous devastating floods of the Liri-Garigliano, which have been further aggravated by extensive anthropization; the flood flow rate is also destined to rise due the presence of numerous canals for irrigation.
For both rivers quarry activities have affected the landscape and the functioning of the channel; in particula, the quarries on the slopes have produced a risk of instability which may evolve into landslides.

The two watersheds, in which there are some 600,000 inhabitants, have severe land-use problems which undermines their resources and development; over-populated and over-exploited areas in which there is a widespread heavy pollution (Capua, Caserta, Benevento, Avellino, etc.) exist alongside areas, particularly in several zones of the Liri-Garigliano, which are abandoned and highly vulnerable.

The water quality data for this watershed are so inadequate that the Ministry of the Environment considers the setting up of a water quality monitoring network an absolute priority, which must be dealt with under the agreements with the regional administrations of Campania and Lazio for the national environmental information and monitoring system.

The quality of both surface water and groundwater is most at risk in areas with denser industrial and urban settlements. Damage is most pronounced in the River Sacco, which receives waste from the major urban settlements (Frosinone, Ceccano) and from an important industrial agglomerate where there are also many small craft industries. It is interesting to consider the strategic role performed by the development and extension of irrigation in the evolution and progress of the agricultural sector in reclaimed areas of the coastal zone and other zones in the Volturno watershed. Other areas where environmental degradation is notable are the river Fucino watershed, around the conversion industrial paper mills, and the Rapido-Gari watershed due to the presence of large urban (Cassino) and industrial centres.