HYDROGEOLOGICAL INVESTIGATION METHODS AND CRITERIA FOR THE LOCATION OF NEW INDUSTRIAL PLANTS: APPLICATIONS IN A CENTRAL APENNINE TEST AREA

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SUMMARY: This study was directed towards defining criteria as well as illustrating the hydrogeological research methods capable of identifying, within a large region, the most suitable areas for the installation of new industrial plants.
A test-study was conducted in the Tenna and Aso River basins, covering an area of approximately 1000 km^2, in Marche Region.

1. INTRODUCTION

This work summarises the results of research performed in 1993 by the Department of Earth Sciences at "La Sapienza" University in Rome, under contract to the "Istituto Superiore per la Prevenzione e la Sicurezza sul Lavoro" (ISPESL).

This study was directed towards defining criteria as well as illustrating the hydrogeological research methods capable of identifying, within a large region, the most suitable areas for the installation of new industrial plants.

A test-study was conducted in the Tenna and Aso River basins, covering an area of approximately 1000 km^2, in Marche Region.

A pollution prevention criteria was adopted for the selection process, where the most suitable area was considered that where there is minor risk of ground water contamination. The primary objective of this study is to avoid the risk of polluting groundwater resources, although it was also necessary to consider surface water protection. This two goals must be examined in tandem because, as shown in the test research, these two water resources are linked through many processes.

The research methods were based on an up to date literature review, integrated with intense field work which was indispensable to determine:

- the geological, hydrogeological and geomorphological characteristics of the region;
- the size, distribution and present use of the available groundwater resource;
- the chemical - physical characteristics of both local surface and ground water.

This research produced a series of 1:25,000 scale maps which illustrate the characteristics of the region, particularly the aerial distribution of the major aquifers. The combination of these maps results in a single map (Figure 1) which divides the region into areas of different levels of contamination risk, indispensable for the safe placement of new industrial plants.

It is important to note that the greater part of existing plants in the sample area are located in high risk zones.

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2. CRITERIA FOR LOCATING NEW INDUSTRIAL PLANTS

The criteria for site definition is based on the evaluation of pollution risk.
To evaluate this risk one must take into account the following elements, which are briefly described below:

- the type of industrial plant;
- the existing set of laws;
- the site and water characteristics.

2.1 Plant Type

One can consider any industrial activity which produces or requires the use of substances capable of contaminating either surface or ground waters as a potential pollution source. Polluting substances can be discharged, into the surface or subsurface environment, either during normal industrial activities or as the result of accidental spills that compromise the use or integrity of the plant.

2.2 Laws

This study intends to guarantee the protection of surface and ground waters even in the case of insufficient or disregarded laws, and above all in the case of damage or accidents which alter the normal functioning of the plants and / or security systems.

2.3 Region Characteristics

This section has two objectives:

- to evaluate the risk of groundwater pollution due to industrial activities;
- to evaluate the risk of incidents which alter normal industrial activity, such as geomorphological instability, volcanism, seismicity or floods, etc.

The study of the region addressed the following points:

2.3.1 The presence of vulnerable aquifers

Where there are no significant aquifers the risk of groundwater contamination is minimal. In contrast the risk is at a maximum when important aquifers exist, particularly if these are sources for human consumption. It is therefore necessary to construct detailed aquifer maps and to define their characteristics.

2.3.2 Terrain stability

Highly stable regions reduce the risk of geological related incidents, thus also reducing the possibility of contaminant release and dispersion. Stability maps, created by using applied geomorphology methods, are therefore also required.

2.3.3 Region security

It is important to avoid the risk that the industrial plant could be subjected to flooding and the consequent release and dispersion of polluting substances. As a result maps are needed which define the regions of high flood risk. In particular situations, other causes of geological risk, such as seismicity or volcanism, can be taken into consideration.

2.3.4 Water quality and use

Water can be used for various purposes (hydroelectric, industrial, agricultural, human consumption etc.) based on its quality and quantity. All aquifers used for human consumption must be rigorously protected, whereas waters designated for other uses can have lower standards; because of this, water quality and use maps are needed.

3. CRITERIA FOR CONTAMINATION RISK ASSESSMENT

By combining the results obtained by the studies described above it is possible to identify areas which have different pollution risk levels, as characterised below:

Very Low Risk
- absence of significant aquifers
- absence of aquifers used for human consumption
- absence of periodic flooding events
- highly stable geomorphology

Low Risk
- absence of significant aquifers
- absence of aquifers used for human consumption
- absence of flooding events
- presence of widespread instability phenomena

Moderate Risk
- presence of significant aquifers
- presence of widespread instability phenomena

High Risk
- presence of significant aquifers
- presence of aquifers used for human consumption
- area subject to periodic flooding
- presence of clear geomorphological instability phenomena

4. HYDROGEOLOGICAL RESEARCH METHODS

This section contains a synthesis of the "type research program" used to analyse the Tenna and Aso River basins, an area covering approximately 1000 km^2, where all the research methods were tested.
The hydrogeological research is subdivided into two principle phases:
- definition of the hydrogeologic and geomorphological characteristics of the region;
- selection of the area relative to the risk of pollution.

4.1 Definition of the hydrogeological and geomorphological characteristics of the region

4.1.1 1st Objective.

To identify the most significant aquifers and define their principle characteristics

Methods
Use of traditional regional hydrogeological techniques that usually involve the following investigations:

a) Climatology
   - Calculate precipitation, evapotranspiration and average effective precipitation

   Products: related climatic maps

b) Geology
   - traditional regional geological techniques;
   - critically examine the literature and geological maps of the considered area;
   - in areas that consist predominantly of sedimentary rocks, define the stratigraphy and structural setting;
   - field verification, using a wide grid, of available maps;
   - identification of lithological complexes;

creation of a 1:25,000 scale geological map, to be used for the preparation of the hydrogeological map.

Product: 25,000 scale geological map

Hydrogeological Complexes
- identification of hydrogeological complexes

Structural Hydrogeology
- define the regional hydrogeological setting and identify the hydrogeological structures and principle aquifers. In this phase must also be identified structures, which consist predominantly of ancient detrital and terraced alluvial deposits and recent alluvial deposits, which can feed or be fed by running surface waters.

Product: aquifer identification and delimitation

Surface hydrology
- Collection and processing of all available hydometric data used for the definition of average observable surface flow rate, as well as the flow regime. Furthermore, direct measurements are made in the field to control the acquired data.

Products hydrograph analysis and calculation of run off and base-flow (fed by groundwater); comprehensive evaluation of the surface flow rate due to the aquifers existing in the region.

f) Quantitative Hydrogeology
- Identification of the perennial hydrographic flow net using specific field controls;
- Identification of the natural springs that feed the perennial hydrographic net (linear and point sources);
- Evaluation of spring flow rates and the flow regimes (see also surface hydrology);
- Identification of the exchange relationship between alluvial aquifers and surface waterways;
- calculation of the water balance for a single aquifer (if possible) and determine its potential in terms of effective flow rate.

Products: Hydrogeolgical map, at a scale of 1:25,000, showing outcropping hydrogeological complexes and related characteristics, as well as point or linear springs subdivided on the basis of flow-rate. Documentation relative to the flow rate of all indicated springs and evaluation of each identified aquifer's potential as deduced from the surface flow rate.

4.1.2 2nd Objective

Define the present use of the aquifers and identify, in particular, those destined for human consumption.

Methods
a) Investigation of deviated spring waters, for both municipal and industrial use;
b) Investigation of groundwater supplies for municipal, agricultural and industrial use
c) Investigation of surface water supplies for agricultural and hydroelectric use;

Products: Identification of the aquifers used as water supply sources for human consumption
Determination of the size of the surface and subsurface supply for different purposes.

4.1.3 3rd Objective

Define the natural geochemical facies for each aquifer and identify pollution indexes

Methods
Traditional geochemical techniques are used which are generally based on the collection and elaboration of chemical analyses available predominantly through the Local Health Unit (USL).
a) Characterisation, through applied geochemical methods, of the natural groundwater geochemical facies;
b) Determination of water quality for those natural sources available throughout the region;
c) Determination of the compatibility between natural-water geochemical characteristics and the drinking water standards for human consumption;
d) Identification of agricultural and industrial activity pollution indexes.

Products: Graphical documentation showing regional water quality. Identification of the resources that, because of their quality, may be destined for human consumption. Determination of the level of groundwater quality compromise and the identification of the cause of this degradation.

4.1.4 4th Objective

Define the general geomorphological stability of the region

Methods
Study the region using standard applied geomorphology techniques
a) Identification of the lithological characteristics of the outcropping units as well as their distribution in the area;
b) Analysis of the structural setting;
c) Airphoto interpretation and direct control in the field of present conditions and potential instabilities;
d) Identification of the most obvious instability indexes;
e) Evaluation of the state of geomorphological slope equilibrium;
f) Identification of the areas subject to high erosion.

Product: Geomorphological map at a scale of 1:25,000

4.1.5 5th Objective

Identification of the areas prone to periodic flooding

Methods
a) Historical analysis and study of the literature to define areas subject to periodic flooding;
b) Field work to control high flood risk areas.

Product: Hydrological map at a scale of 1:25,000 of the areas prone to periodic flooding

4.2. Selection of areas relative to pollution risk

Objective:
Classification of areas relative to pollution risk due to the installation of new industries

Area Selection Method
Selection is based on the results acquired during the first phase of the study, and include the identification of:
1) the recharge areas of aquifers used (or useable) for human consumption;
2) the areas subject to accelerated erosion;
3) the areas prone to periodic flooding;
4) the areas subject to obvious geomorphological instability but without significant aquifers;

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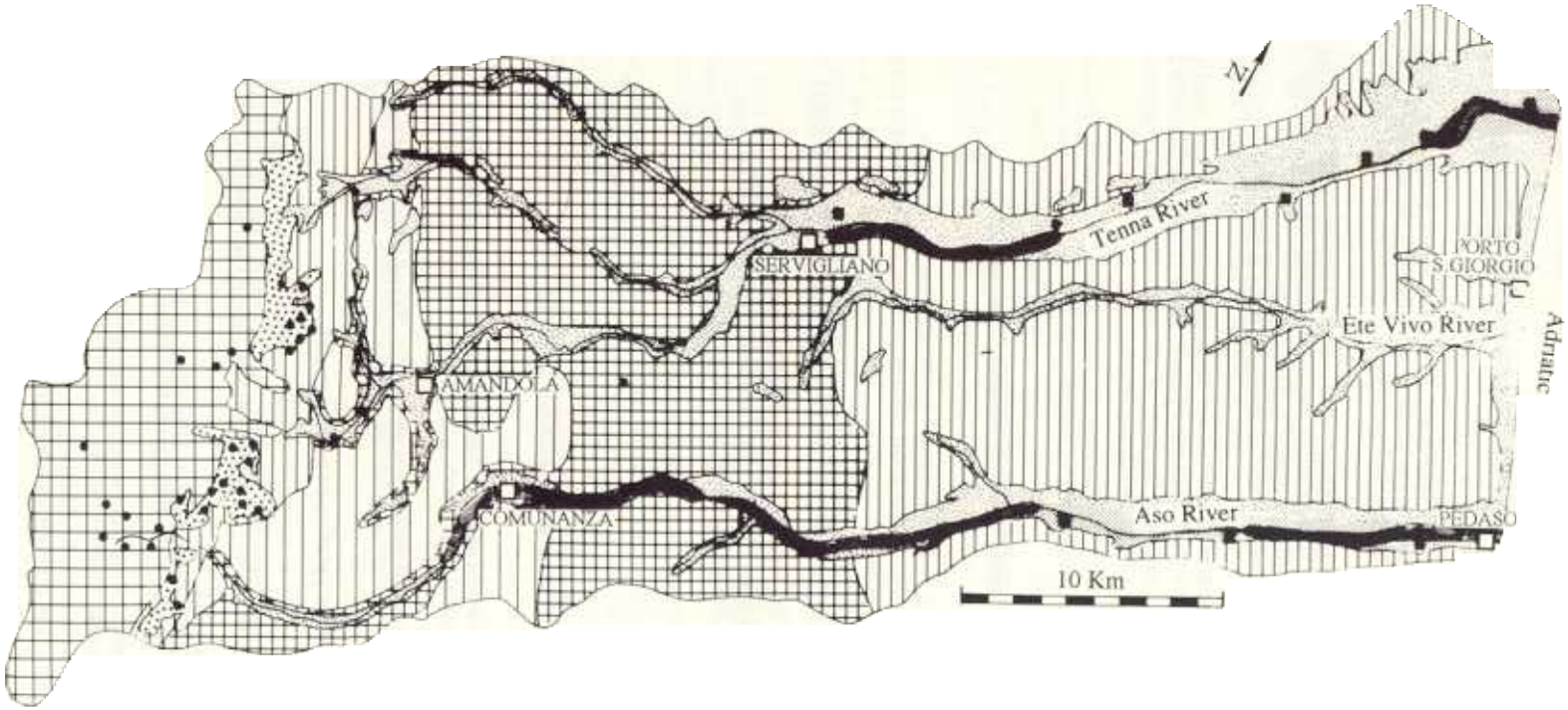

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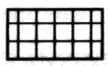
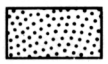
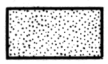
Very high risk areas



Carbonate formations (Jurassic-Cretaceous)
Recharge areas of aquifer used (or useable) for human consumption

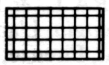


Detrital cones and fans (Pleistocene-Olocene)
Recharge areas of aquifer used (or useable) for human consumption



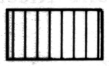
Alluvial deposits (Pleistocene-Olocene)
Recharge areas of aquifer used (or useable) for human consumption. Areas prone to periodic flooding and areas subjected to obvious geomophological instability

Moderate risk areas



Marine clay deposits with sands and conglomerates (Upper Miocene-Pleistocene)
Areas subjected to obvious geomorphological instability phenomena but without significant aquifers

Low risk areas



Marls and shales (Upper Cretaceous-Miocene)
Transgressive marine deposits consisting of clays, sands and conglomerates (Miocene-Pleistocene)
Areas where there are widespread instability phenomena and small local aquifers

Very low risk areas

Turbidites sequences consisting of sandstones and clays (Upper Miocene)
Areas lacking significant aquifers and having geomorphological stability

Areas subjected to accelerated erosion

Areas prone to periodic flooding

Springs (a) and water wells (b) used as water supply sources for human consumption

5) the areas where there are widespread instability phenomena and small local aquifers;
6) the areas lacking significant aquifers and having geomorphological stability .

Evaluation of Risk
- High risk areas can be considered those which correspond to one or more of points 1), 2), 3);
- Moderate risk areas can be considered those which correspond to point 4);
- Low risk areas can be considered those which correspond to point 5);
- Very low risk areas, would be those that match point 6).

Results
The results of the hydrogeological investigations carried out in the test-area are summerised in Figure .1.

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